

**MULTIVARIATE MORPHOMETRIC ANALYSIS AND BEHAVIOUR OF
HONEYBEES (*APIS MELLIFERA* L.) IN THE SOUTHERN REGIONS OF
ETHIOPIA**

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Abstract

Morphometric and behavioural characteristics of honeybees, *Apis mellifera* were analysed using multivariate and bivariate statistical methods to characterise honeybees of southern Ethiopian region. A total of 33800 morphometric character measurements were taken from 2600 individual worker honeybees of 130 honeybee colonies collected at 26 sampling localities with an average inter-locality distance of 89km to determine the occurrence of morphoclusters. 117 experienced farmer beekeepers and beekeeping experts were interviewed on pre-tested questionnaire to investigate the behavioural characteristics of these honeybees in their respective areas.

Morphometric characters associated with pigmentation and body size exhibited a higher discriminant power while forewing venation angles (B4, N23 and O26) lack discriminatory power to segregate honeybees in the southern Ethiopian region.

Principal components and discriminant analyses using the most discriminatory morphological characters delineated four statistically distinct morphoclusters in the southern Ethiopian region: the smallest and yellow honeybees, *A. m. woyi-gambella* which are different from all African honeybees, occur in the western and southern lowlands; the small and yellowiest honeybees, *Apis mellifera jemenitica* in the eastern escarpment; the largest and darkest honeybees, *Apis mellifera bandasii* in the central and eastern highlands; and dark honeybees, *Apis mellifera scutellata* in the wet tropical forests. High intracolony and intercolony variances within and between the boundaries of the honeybee groups were detected. The former suggests areas of ecological instability, while the latter areas of transitional or natural hybridisation zones. These areas

are characterised by transitional ecological zones having intermediate climate and physiography.

Even though honeybees of the southern Ethiopian region are generally dark and small, they show a high tendency to reproductive swarming, migration and aggressiveness, great variation in pigmentation, size and behaviour were observed both within and between the groups. *A. m. jemenitica* honeybees have a high propensity to migration and less a tendency for reproductive swarming. *A. m. bandasii* and *A. m. scutellata* have a high inclination to reproductive swarming and the former has a lesser and the later intermediate propensity to migration. *A. m. woyi-gambella* honeybees have intermediate swarming and migration tendencies. These results revealed that reproductive swarming and migration are higher in resource-rich and resource-poor areas respectively.

Honey plants of the central highlands of Ethiopia are predominantly herbaceous in nature and mainly grow on open and cultivated lands. The bulk of pollen collected came comparatively from few genera. Strong correlation was observed between the intensities of flowering and rainfall. Reproductive swarming and migration occur during high and low intensity of flowering respectively.

TABLES OF CONTENTS

Abstracts	IV
Table of Contents	VI
List of Tables	XII
List of Figures	XX
Acknowledgements	XXIV
Chapter 1: General background	1
1.1 Introduction	1
1.2 Research objectives	3
1.2.1 General objective	3
1.2.2 Specific objectives	3
1.3 The significance of the study	4
1.4 The study area	5
1.4.1 Location	5
1.4.2 Topography and altitude	6
1.4.3 Climate	6
1.4.4 Soils	7
1.4.5 Vegetation	7
1.4.6 Production system	8
1.4.7 Beekeeping potential and practise	9
1.4.8 Honey harvesting	11

Chapter 2: Literature Review	12
2.1 Development of geographical honeybee races	12
2.2 History of honeybee taxonomy	13
2.3 Morphometric characters	14
2.4 Statistical analysis	21
2.5 African honeybee races	22
2.5.1 Northwestern African honeybees	24
2.5.1.1 <i>Apis mellifera intermissa</i> Buttel-Reepen (1906)	25
2.5.1.2 <i>Apis mellifera sahariensis</i> Baldensperger (1922)	26
2.5.2 Honeybees of northeastern Africa	26
2.5.2.1 The Nile Valley honeybees	27
2.5.2.1.1 <i>Apis mellifera lamarkii</i> Cockerell (1906)	27
2.5.2.2 Honeybees of Horn of Africa	28
2.5.2.2.1 <i>Apis mellifera jemenitica</i> Ruttner (1975)	30
2.5.2.2.2 <i>Apis mellifera scutellata</i> Lepletier (1836)	32
2.5.2.2.3 <i>Apis mellifera litorea</i> Smith (1961)	33
2.5.2.2.4 <i>Apis mellifera monticola</i> Smith (1961)	33
2.5.3 Southern African honeybees	34
2.5.3.1 The southernmost African honeybee	34
2.5.3.1.1 <i>Apis mellifera capensis</i> Eschscholtz(1822)	34
2.5.3.2 The southern African island honeybee	35
2.5.3.2.1 <i>Apis mellifera unicolor</i> Latreille (1804)	35

2.5.4 Western African honeybees	36
2.5.4.1 <i>Apis mellifera adansonii</i> Latreille (1804)	36
2.5.5 Ethiopian honeybees	40
chapter 3: Research Methodologies	43
3.1 Sampling sites	43
3.2 Climatological and physical environmental data collection	44
3.3 Sample collection	48
3.4 Morphometric characters	48
3.5 Survey work	53
3.6 Multivariate analysis	57
3.7 Analysis of the survey data	58
Chapter 4: Results	60
4.1 Morphometric characteristics of southern Ethiopian honeybees	60
4.2 Correlations amongst morphometric characters	63
4.3 Correlation of morphometric characters with the physical environment and climate of the southern Ethiopian region	65
4.4 Analysis of variance	69
4.5 Multivariate results	71
4.6 Morphometric characteristics of the groups	84
4.6.1 Morphometric characteristics of Group 1 honeybees	85
4.6.2 Morphometric characteristics of Group 2 honeybees	86
4.6.3 Morphometric characteristics of Group 3 honeybees	87
4.6.4 Morphometric characteristics of Group 4 honeybees	88

4.7	Agro-ecology of the honeybee groups	95
4.7.1	General	95
4.7.2	Honeybee groups of the region	97
4.7.2.1	Group 1 honeybee agro-ecological areas	97
4.7.2.2	Group 2 honeybee agro-ecological areas	98
4.7.2.3	Group 3 honeybee agro-ecological areas	98
4.7.2.4	Group 4 honeybee agro-ecological areas	102
4.7.3	Honeybee pests and predators in the southern Ethiopian region	105
4.8	Behaviour of southern Ethiopian honeybees	109
4.8.1	Reproductive swarming	109
4.8.1.1	Reproductive swarming tendency	109
4.8.1.2	Multiple reproductive swarming	112
4.8.1.3	Reproductive swarming tendency by colour and aggressive behaviour	116
4.8.1.4	Swarm catching rate	118
4.8.1.5	Swarm phenology	120
4.8.2	Migration	125
4.8.2.1	Migration tendency	125
4.8.2.2	Migration phenology	129
4.8.2.3	Causes of migration	132
4.8.3	Aggressive behaviour	140
4.8.3.1	Conditions aggravating the aggressiveness of honeybees	145
4.8.4	Correlations of honeybee behaviour with climate and	152

physical environmental factors

4.9	Honey	154
4.9.1	Honey production	154
4.9.2	Honey flow period	157
Chapter 5: Discussion		160
5.1	General	160
5.2	Correlation of morphometric characters with each other and environmental factors	162
5.3	Morphometric characters for the discrimination of honeybees of southern Ethiopia	165
5.4	Morphoclusters	167
5.5	Transitional zones	177
5.6	Behaviour of honeybee groups of southern Ethiopia	179
5.6.1	Reproductive swarming	179
5.6.2	Migration	186
5.6.3	Aggressiveness	192
5.7	Honey yield	195
Chapter 6: Summary and conclusion		199
6.	Summary and conclusion	199
6.1	General	199
6.2	Morphoclusters/honeybee groups of the region	202
6.2.1	<i>Apis mellifera woyi-gambella</i>	203

6.2.2	<i>Apis mellifera jemenitica</i>	205
6.2.3	<i>Apis mellifera bandasii</i>	207
6.2.4	<i>Apis mellifera scutellata</i>	209
6.3	conclusion	215
Chapter 7: Seasonality and intensity of flowering, distribution and nature of honey plants and resource partitioning in honeybee foraging in the central highlands		218
7.1	Summery	218
7.2	Introduction	219
7.3	Materials and methods	219
7.4	Results	221
7.5	Discussion	225
Chapter 8:References		243
Chapter 9 Appendices		272
9.1	Traditional beekeeping practise in the southern Ethiopia	272
9.1.1	General	272
9.1.2	Traditional beekeeping practise in the area of <i>A. m. scutellata</i>	272
9.1.3	Traditional beekeeping practise in the area of <i>A. m. bandasii</i>	274
9.1.4	Traditional beekeeping practise in the area of <i>A. m. woyi-gambella</i>	276
9.1.5	Traditional beekeeping practise in the area of <i>A. m. jemenitica</i>	277
9.2	Questionnaire	279
9.3	Tables and figures	294

LIST OF TABLES

Table 1: List of characters for standard morphometry.	19
Table 2: Characters used for discrimination of African honeybees.	20
Table 3: Discriminant characters of eight sub-Saharan races of <i>Apis mellifera</i> (means and standard deviations of <i>n</i> samples, measurements in <i>mm</i>).	37
Table 4: Mean and standard deviation of the morphometric characters of the African morphoclusters measurements in <i>mm</i> , angles in degrees.	38
Table 5: Locality, altitude, co-ordinate, region, zone, woreda, between distance and sample size of sampling localities.	46
Table 6: Number of farmer beekeepers and honeybee experts, experience and the number of honeybee colonies owned by the farmers at each locality sampled.	55
Table 7: Sampling sites and colony sample sizes by major and sub-agro-ecological zones.	56
Table 8: The means, ranges and standard deviations of morphometric characters of honeybee samples from southern Ethiopia.	62
Table 9: The correlation matrix amongst morphometric characters used to discriminate southern Ethiopian honeybees.	65
Table 10: Correlations of morphometric characters with physical environment and climate of the study area.	67
Table 11: Analysis of variance of morphometric characters along the sampling localities in southern Ethiopia.	70
Table 12: Factors extracted and total variances caused by each factors	73

in the southern Ethiopian honeybee population.

Table 13: Factor loadings of each character extracted in the principal components analysis.	74
Table 14: Classification matrix obtained by discriminant analysis.	79
Table 15: Morphometric characters entered into the discriminant function ranked according to their discriminatory power.	79
Table 16: Squared Mahalanobis distances (D^2) between the four groups of honeybees.	80
Table 17: Intercolonial and intracolonial variances of factor scores of morphometric characters for each locality.	83
Table 18: Means and standard deviations of morphometric characters of each group of honeybees.	84
Table 19: Agro-climate (%), land use patterns (%), geographical co-ordinates (degrees), elevation (metres) and climate: temperature ($^{\circ}C$) and rainfall (mm) of the region studied.	96
Table 20: Major honey plants growing in the central and eastern highlands. (determined during survey work).	100
Table 21: Major honey plants growing in the wet tropical forest areas (determined during survey work).	103
Table 22: Pests and predators, incidence time and damage caused in the region.	106
Table 23: P-values for multiple comparisons (Tukey HSD test) for mean reproductive swarming among the four southern Ethiopian honeybee groups.	112
Table 24: P-values for the multiple comparisons (Tukey HSD test) of mean	114

minimum successive reproductive swarms among the four southern Ethiopian honeybee groups.	
Table 25: P-values for the multiple comparisons (Tukey HSD test) of mean maximum successive reproductive swarms among the four southern Ethiopian honeybee groups.	115
Table 26: Reproductive swarming tendencies of honeybee groups by colour.	117
Table 27: Reproductive swarming tendencies of honeybee groups by defensive behaviour.	117
Table 28: P-values for the multiple comparisons (Tukey post hoc, HSD test) of mean swarm catching rate among the areas of the four southern Ethiopian honeybee groups.	120
Table 29: The onset of major swarming for the four groups of the southern Ethiopian honeybees.	121
Table 30: Ending times of major swarming for the four groups of the southern Ethiopian honeybees.	122
Table 31: Onset and ending times for minor swarming for the four groups of southern Ethiopian honeybees.	124
Table 32: P-values for the multiple comparisons (Tukey <i>post hoc</i> HSD test) of mean migration rates among the four southern Ethiopian honeybee groups.	127
Table 33: P-values for the multiple comparisons (Tukey <i>post hoc</i> HSD test) of mean unoccupied beehives among the areas of the four southern Ethiopian honeybee groups.	129
Table 34: Onset of migration of the four groups of southern	130

Ethiopian honeybees.	
Table 35: Ending time of migration of the four groups of southern Ethiopian honeybees.	131
Table 36: The percentage responses of beekeepers for rating aggressive behaviour of southern Ethiopian honeybee groups.	141
Table 37: Aggressiveness rated by colour in the honeybee groups of Southern Ethiopia	143
Table 38: The seasons in which honeybee groups of southern Ethiopia become more aggressive.	144
Table 39: The correlations among some honeybee behaviours and climate and physical environment of the region.	154
Table 40: P-values multiple comparisons (Tukey <i>post hoc</i> , HSD test) for mean honey yield (1999/2000) among the four honeybee groups of southern Ethiopia.	157
Table 41: The major honey flow period for the four southern Ethiopian honeybee groups.	158
Table 42: Minor honey flow periods for the four southern Ethiopian honeybee groups.	159
Table 43: Morphometric comparisons of <i>A. m. litorea</i> and group 1 honeybees.	171
Table 44: Comparison of morphometric measurements of group 2 honeybees with those of <i>A. m. jemenitica</i> honeybees.	173
Table 45: Morphometric measurements comparison of group 3	175

with those of <i>A. m. bandasii</i> honeybees.	
Table 46: Average altitude, temperature, rainfall, swarming and migration periods of areas of morphoclusters and transitional zones.	197
Table 47: Locality, rainy season, reproductive swarming and migration periods.	198
Table 48: Proportion of colour in the honeybee populations of southern Ethiopia region.	217
Table 49: Botanical name, family, nature, food source, flowering time and habitat distribution of honey plants in the central highlands of Ethiopia.	231
Table 50: Plant nature and flowering period (numbers in brackets reflect percentages, while others represent the number of species).	236
Table 51: The mean amount of pollen and the number of days pollen was collected during each season.	237
Table 52: Family, nature and habitat distribution of honey plant species in the central highlands of Ethiopia.	239
Table 53: The standardised temperature, rainfall, flowering intensity and reproductive swarming and migration periods of honeybees in the central highlands of Ethiopia.	241
Table 54: Posterior probability for classification of colonies into the four groups of southern Ethiopian region.	294
Table 55: Mean comparisons of morphometric characters over sampling localities.	297
Table 55.1: Pigmentation of Scutellum.	297
Table 55.2: Pigmentation of plate.	298

Table 55.3: Hair length.	299
Table 55.4: Pigmentation of tergite 2.	300
Table 55.5: Pigmentation of tergite 3.	301
Table 55.6: Pigmentation of tergite 4.	302
Table 55.7: Width of tergite 3.	303
Table 55.8: Width of tergite 4	304
Table 55.9: Sternite 3 longitudinal.	305
Table 55.10: Sternite 3 transversal	306
Table 55.11: Forewing angle B4	307
Table 55.12: Forewing angle N23	308
Table 55.13: Forewing angle O26	309
Table 56: Mean morphometric characters of honeybee colonies of the southern Ethiopian region.	311
Table 57: Climatic data of honeybee colony sampling localities (1920 – 1980yrs).	316
Table 57.1: Monthly temperatures and rainfall for Colony sampling locality, Gechi (S1).	316
Table 57.2: Monthly temperatures and rainfall for colony sampling locality, Itang (S2).	316
Table 57.3: Monthly temperatures and rainfall for colony sampling locality, Masha (S3).	317
Table 57.4: Monthly temperatures and rainfall for colony sampling locality, Woshi (S4).	317

Table 57.5: Monthly temperatures and rainfall for colony sampling locality, Waka (S5).	318
Table 57.6: Monthly temperatures and rainfall for colony sampling locality, Sodo (S6).	318
Table 57.7: Monthly temperatures and rainfall for colony sampling locality, Woyito (S7).	319
Table 57.8: Monthly temperatures and rainfall for colony sampling locality, Konso (S8).	319
Table 57.9: Monthly temperatures and rainfall for colony sampling locality, Arero (S9).	320
Table 57.10: Monthly temperatures and rainfall for colony sampling locality, Harkalo (S10).	320
Table 57.11: Monthly temperatures and rainfall for colony sampling locality, Eshedo Aliyo (S11).	321
Table 57.12: Monthly temperatures and rainfall for colony sampling locality, Serofta (S12).	321
Table 57.13: Monthly temperatures and rainfall for colony sampling locality, Mararo (S13).	322
Table 57.14: Monthly temperatures and rainfall for colony sampling locality, Wolta'e Atote (S14).	322
Table 57.15: Monthly temperatures and rainfall for colony sampling locality, Karre Tule (S15).	323
Table 57.16: Monthly temperatures and rainfall for colony	323

sampling locality, Dudi Affi (S16).	
Table 57.17: Monthly temperatures and rainfall for colony	324
sampling locality, Deriri Arba (S17).	
Table 57.18: Monthly temperatures and rainfall for colony	324
sampling locality, Boke Tiko (S18).	
Table 57.19: Monthly temperatures and rainfall for colony	325
sampling locality, Nazrieth (S19).	
Table 57.20: Monthly temperatures and rainfall for colony	325
sampling locality, Alage (S20).	
Table 57.21: Monthly temperatures and rainfall for colony	326
sampling locality, Hosaina (S21).	
Table 57.22: Monthly temperatures and rainfall for colony	326
sampling locality, Sawla (S22).	
Table 57.23: Monthly temperatures and rainfall for colony	327
sampling locality, Effe Yachi (S23).	
Table 57.24: Monthly temperatures and rainfall for colony	327
sampling locality, Boter Bacho (S24).	
Table 57.25: Monthly temperatures and rainfall for colony	328
sampling locality, Roge (S25).	
Table 57.26: Monthly temperatures and rainfall for colony	328
sampling locality, Gado Lama (S26)	

LIST OF FIGURES

Figure 1: Geographical distribution of African honeybees.	39
Figure 2: Southern Ethiopian honeybee sampling localities.	47
Figure 3: Morphometric characters used to discriminate honeybees of southern Ethiopia region	51
Figure 4: Factor plot using the most discriminant factor scores Factor 1 (pigmentation) and Factor 2 (related to body size).	75
Figure 5: Factor score plot using morphometric characters excluding those of pigmentation.	76
Figure 6: Factor score plot using pigmentation only.	77
Figure 7: Discriminant plot using the most discriminatory functions (root 1 and root 2) and the formation of four clear groups.	82
Figure 8: Range and comparison of scutellum pigmentation by group.	89
Figure 9: Range and comparison of scutellar plate pigmentation by group.	90
Figure 10: Range and comparison of length of cover hair by group.	90
Figure 11: Range and comparison of tergite 2 pigmentation by group.	91
Figure 12: Range and comparison of tergite 3 pigmentation by group.	91
Figure 13: Range and comparison of tergite 4 pigmentation by group.	92
Figure 14: Range and comparison of width of tergite 3 by group.	92
Figure 15: Range and comparison of width of tergite 4 by group.	93
Figure 16: Range and comparison of longitudinal sternite 3 by group.	93
Figure 17: Range and comparison of transversal wax plate on sternite 3 by group.	94
Figure 18: Annual mean rainfall for the four honeybee group areas.	107

Figure 19: Annual mean minimum temperatures for the four honeybee group areas.	107
Figure 20: Annual mean maximum temperatures of the four honeybee group areas.	108
Figure 21: Mean altitudes of the four honeybee group areas.	108
Figure 22: Proportion of forest in the four honeybee group areas.	109
Figure 23: Mean reproductive swarming rates of the southern honeybee groups	111
Figure 24: The mean minimum number of successive swarms per colony per year in the four groups of southern Ethiopian honeybees.	114
Figure 25: The mean maximum number of successive swarms per colony per year in the four groups of southern Ethiopian honeybees.	115
Figure 26: The mean swarm catching rate of the four honeybee group areas of southern Ethiopian honeybees	119
Figure 27: The mean migration rate of honeybee groups of southern Ethiopia.	126
Figure 28: The mean unoccupied honeybee hives in the areas of the four honeybee groups of southern Ethiopia.	128
Figure 29: Direction of migration of the southern Ethiopian groups of honeybees.	132
Figure 30: Response of farmer beekeepers: a shortage of forage is one of the causes for the migration of their honeybee colonies.	133
Figure 31: Response of farmer beekeepers: a shortage of water is one of causes for the migration of their honeybee colonies.	135

Figure 32: Response of farmer beekeepers: high temperature is a cause for migration of honeybee colonies in their respective areas.	136
Figure 33: Response of farmer beekeepers: attack of pests and predators is one of the causes for the migration of honeybee colonies in the area.	137
Figure 34: Response of farmer beekeepers: drought is one of the factors that causes honeybee colony migration.	138
Figure 35: Response of farmer beekeepers: high rainfall is a cause for the migration of honeybee colonies.	139
Figure 36: Response of farmer beekeepers: very cold temperature is a cause for the migration of honeybee colonies in the area.	140
Figure 37: Response of farmer beekeepers: honeybees are more aggressive during honey harvest.	147
Figure 38: Response of farmer beekeepers: honeybees are more aggressive during honey flow time.	148
Figure 39: Response of farmer beekeepers: honeybees are more aggressive when honeybee colonies are attacked by pests and predators.	149
Figure 40: Response of farmer beekeepers: honeybees are more aggressive during brood rearing time.	150
Figure 41: Response of farmer beekeepers: honeybees are more aggressive during midday (11.05 am – 2.00pm).	151
Figure 42: Mean honey yield of the four southern Ethiopian honeybee groups (units in kg)in the year 1999/2000.	156

Figure 43: Physiography, sampling localities and distribution of the four morphoclusters of honeybees in the southern Ethiopian region.	212
Figure 44: Physiography, sampling localities, distribution of the four morphoclusters (broken lines) and reproductive swarming phenology (solid lines) of honeybees of southern Ethiopia.	213
Figure 45: Physiography, sampling localities, distribution of the four morphoclusters (broken lines) and migration phenology (solid lines) of honeybees of southern Ethiopia.	214
Figure 46: The effect of rainfall on reproductive swarming of honeybees of southern Ethiopia.	310
Figure 47: Annual rainfall distribution in Ethiopia.	329
Figure 48: Physiography, localities and geographical distribution of the 5 honeybee clusters in Ethiopian region.	330
Figure 49: Reproductive swarming phenology of honeybee in Ethiopia.	331
Figure 50: Migration phenology of honeybees in Ethiopia.	332

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Chapter One

1 General background

1.1 Introduction

Ethiopia, which is located in the eastern part of Africa between 32⁰ and 48⁰ East longitude and 3⁰ and 15⁰ North latitude, has an area of 1.1 million square kilometres. It borders on Somalia to the southeast, Djibouti to the northeast, Kenya to the south, Eritrea to the north, and Sudan to the west. It is a highly diversified agro-ecological country having 18 major and 48 sub-agro-ecological zones.

Ethiopia has a population of 60 million of which more than 80 percent live in rural areas (CSA, 1996). The economy of the country is mainly dependent on agriculture. Agriculture accounts for 55% of the GDP, generates 60% earnings, provides materials for 70% of agro-industries of the country and employs 80% of the labour force (World Bank, 1995).

Beekeeping is one of the oldest agricultural sectors in Ethiopia. Even though when and where beekeeping started in the country is not clearly known, it was suggested that traditional beekeeping began 5000-5500 BP in the northern part of the country (Kassaye, 1984). Beekeeping plays an important role in the economy of the country in general and for farmer beekeepers in particular. Ethiopia is the leading honey and beeswax producer in the African continent. It produces 23000 tonnes of crude honey and 3000 tonnes of beeswax annually. Farmer beekeepers of the country earn about US \$ 45-60 million and US \$ 12.25 million annually from honey and beeswax respectively. The sector also supports the national economy through foreign export. Beeswax is one of the

12 exportable agricultural products of the country. Ethiopia produces 23.58% and 2.13% of African and world honey production respectively (Geremew *et al.*, 1998).

Ethiopia, with diversified geographical features, has different climatic conditions and variable natural and cultivated vegetation which are suitable for the existence of honeybees. The population of honeybee colonies in Ethiopia is estimated to be about 10 million. This ranks the country first in Africa (Geremew *et al.*, 1998).

Despite the fact that the country has high potential resources for beekeeping, a tremendous honeybee colony population and longstanding beekeeping practice, knowledge about the honeybee races, their behaviour (swarming, migration and defensiveness) and ecological distribution is very limited. Of course there are a few works on the identification of Ethiopian honeybee races (Smith, 1961; Ruttner, 1975; Kassaye, 1990; Radloff and Hepburn, 1997a; Hepburn and Radloff, 1998). Even though these studies indicated the presence of some African bee races (see section 2.5.5), the results were inconsistent, contradictory, did not address the behaviour and distribution of these honeybee groups. Moreover the studies were concentrated in certain areas and small sample size. Therefore it is of paramount importance to resolve and establish a clear understanding and knowledge of Ethiopian honeybee races that lacks clarity at present.

The present study was conducted in the south, southwest, central and eastern parts of Ethiopia. The region is ecologically diverse and comprises 17 of 18 major agro-ecological zones. It is the major potential area for beekeeping and comprises about 75% of honeybee colony populations of the country. Moreover beekeeping is one of the important cash generating agricultural activity in the region.

1.2 Research objectives.

1.2.1 General objective

The main objectives of this study are to bridge the information gap and resolve the ambiguity of information about Ethiopian honeybee races, in particular the regions of central and south, southwest and eastern parts of the country. Also to generate base line data on Ethiopian honeybee races in the country: the behaviour and distribution which constitutes a starting base for all research and development activities of the apicultural sector in Ethiopia.

1.2.2 Specific objectives

1. To determine and confirm the presence of honeybee races in the central, south, southwest and eastern parts of the country.
2. To determine the geographical distribution of these honeybees.
3. To characterise the geographical distribution features under which these honeybees exist.
4. To investigate the important behaviour of the races (swarming, migration and aggressiveness) and to determine the effect of climate and physical environment on these behaviours; and
5. To extend the study to include parts of the region not yet surveyed.

1.3 The significance of the study

In spite of the country's potential for beekeeping and diverse use of apiculture, the types of honeybees in the country are not clearly known because of the controversial and contradictory reports on Ethiopian honeybees. All farmer beekeepers, hobby beekeepers and development workers differentiate honeybee colonies with a traditional system by size (big and small) and colour (black, red or yellow, and grey). This traditional system lacks consistency and varies from region to region. Furthermore, sometimes it is difficult to find uniform colour within the colony. This lack of knowledge of honeybee races in the country prevents understanding of the biology, behaviour, distribution and productivity of the existing honeybees in the country.

To maximise the output of beekeeping, improved management techniques for each type of honeybee in a particular ecology is of paramount importance. However to generate such basic, necessary technologies, knowledge about the types of honeybees of a particular ecology is a prerequisite. Moreover, different honeybees have different potentials for honey, beeswax, other honeybee products and pollination of cultivated crops. To select and make use of these honeybee types according to the potential they have is not possible without knowing basic morphometric information about these honeybees. Hence to generate the basic necessary information and technologies that cater for the problems of farmer beekeepers of different agro-ecological zones, identification and characterisation of honeybee races are crucial.

Characterisation of Ethiopian honeybees must be the first priority in the sector of apiculture to (i) address the basic problems of farmer beekeepers of different agro-ecological zones, (ii) generate appropriate honeybee management systems that best suite

the types of honeybees and specified agro-ecology, (iii) select the best performing and productive honeybee races, multiply and disseminate to end-user, (iv) develop coherent policies for conservation of local races, (v) correctly identify intrusion of unwanted genotypes and improve the genotypes of these unwanted traits.

1.4 Study area

1.4.1 Location

The study area is located in the southern part of Ethiopia between 3⁰ N and 9⁰ N latitude and 32⁰ E and 48⁰ E longitude. It is located south of Addis Ababa, the capital city of Ethiopia, including the south, southwest and southeast parts of the country that border on Somalia to the east and southeast, Kenya to the south and Sudan to the west and southwest. The area includes the regional estates of Oromia, South Nation Nationality and People (SNNP), Somali and Gambella. It falls under 17 of the 18 major agro-ecological zones (AEZ) of the whole country. However the dominant agro-ecological zones of the region are: hot to warm sub-humid lowlands (SH1); tepid to cool sub-humid mid-highlands (SH2); tepid to cool humid mid-highlands (H2); hot to warm moist lowlands (M1); tepid to cool moist mid to highlands (M2); hot to warm sub-moist lowlands (SM1); hot to warm lowland plains (A1); hot to warm semi-arid lowlands (SA1) and hot to warm humid lowlands (H1).

This study area accounts for over 60% of the country and comprises about 75% of the country's honeybee population and almost all the major forests of the country. The mixed high forest of mostly broad-leafed species is found in the more humid part of the country in the southwest, where the mean annual rainfall is above 1500mm. Most of the

potential beekeeping areas are located within this region. Furthermore, both improved and traditional beekeeping are practiced in this region. Besides keeping bees at the homestead and in the forest, classical honey-hunting tradition continues in the region.

1.4.2 Topography and altitude

The topography of the region ranges from extreme lowlands to very high altitudes. Altitude varies from less than 1000 metres above sea level in the eastern escarpment to as high as 4300 metres above sea level in the high mountains of Bale, Arsi of Oromia National Regional State (ONRS) and in the southern and the southeastern parts of the South Ethiopian Nations, Nationalities and People Regional State (SENNPRS). The region is characterised by differences in physiography, the main sections being: flat to gentle slopping; plains; mountains; lakes and rift valleys; plateau valleys; escarpment and river gorges (Ethiopian Mapping Authority, 1988).

1.4.3 Climate

This zone receives overhead sun twice a year. However as most of the places are highlands, tropical temperature conditions are not experienced except in the lowlands on the peripheries. The mean annual temperature varies from over 30⁰C in tropical lowlands to less than 10⁰C at very high altitudes. These places have their highest temperatures in autumn and spring when the sun is directly overhead. During summer, the main rainy season, the temperature is reduced considerably in the southern and southeastern areas, with high humidity and frequent cloud cover.

The southwestern area is the region which receives the heaviest rainfall. It is the wettest part of the country with only two to four dry months a year. It has bimodal rainfall and gets 40 % of its rain during summer (June-September). The mean annual rainfall for this region is 1500mm ranging from less than 1000mm to over 2800mm.

The southeastern region has a mean annual rainfall of 700mm, but ranges from less than 400mm to over 2000mm (Ethiopian Mapping Authority, 1988). The southeastern highlands and associated lowlands receive most of its rainfall during spring (March-May) and the remainder in autumn (September-November). The eastern escarpment of the southeastern region is arid (Ethiopian Mapping Authority, 1988).

1.4.4 Soils

Soils of the zone vary from poor in drier parts to very fertile. It can be characterised by different soil types, however, the important soils in the zone include the following: Bendezina, vertic Andosols, orthic Acrisols, eurtic Nitosols, Vertisols, Nitosols, Leptisols, Luvisols, Regosols, Leptosols, eutric Regosols, humic cambisols, eutric Fluvisols, cambic Arenosols, chromic Vertisols, calcie Cambisols, vertic Cambisols, chromic Luvisols, eutric Cambisols, Lithosols, gleyic Salochak, dystic Nitosols, pellic Vertisols, dystic Cambisols and haplic Phaeozems (MOA, 1998)

1.4.5 Vegetation

Vegetation of the south, southeast, southwest and west part of the country varies from almost desert to tropical high forest. The most common type of vegetation in this region includes Afro alpine, sub-Afro alpine, high forest (dense, dense mixed high forest,

dense coniferous high forest, and disturbed high forest), woodland (dense and open wood land), dense bush land (dense bush land and lowland bamboo bush land), shrub land (open shrub land), and grassland (open grassland, bush shrubbed grassland and wooded grassland).

Due to its favourable climatic condition and edaphic factors a wide range of species of uncultivated plants from the smallest herbaceous ones to giant trees grow in this region: *Acacia spp.*, *Terminalia spp.*, *Erythrina spp.*, *Ficus spp.*, *Balanites spp.*, *Cordia africana*, *Zizyphus spp.*, *Croton machrostachys*, *Milletia spp.*, *Albizia spp.*, *Juniperus spp.*, *Schefflera abyssinica*, *Arudinaria alpine*, *Fagarosis spp.*, *Phonix*, *Allophylus*, *Podocarpus gracilior*, *Pygeum africanum*, *Euphoribia candelubrum*, *Ekebergia capensis*, *Syzygium guineense*, *Dracaena spp.*, *Celtis*, *Olea africana*, *Maytenus arbitufolia*, *Erica arborea*, *Hypericum spp.*, *Hygenia abyssinica*, *Albizia spp.*, *Anigeria altissima*, *Polyscia spp.*, and *Anigeria adolf* are few among the dominant plants of the region (MOA,1998).

1.4.6 Production system

The production system of the zone is a mixed one comprising crops (cereal and enset) and livestock. In some areas a nomadic pastoral system is still practiced. Crop cultivation in the region varies from subsistent crop production, which is undertaken by subsistent farmers, to intensive crop production by state farms. Both annual and perennial crops are grown. Maize, sorghum, teff, barley, wheat, pulses, tubers, oilseeds and various types of vegetables are the major annual crops while coffee, enset, chat, and a variety of

fruits such as bananas, mangos, papaya, citrus, and sugar cane are the main perennial crops grown in the region.

The region is one of the major livestock producing areas in the country. Almost all livestock rearing takes place in this region including that of cattle, sheep, goats, horses, donkeys, mules, poultry, honeybees and camels. Besides provision of protein in diets and as a source of cash for subsistent farmers, livestock is used as a means of transportation and for ploughing. The region is also known for its wild life resources. The main national wildlife parks are located in this region and hence it is one of the main tourist attraction areas of the country.

1.4.7 Beekeeping potential and practise

The region has favourable climatic conditions, immense variable natural vegetation and other potential apicultural resource bases. These conditions make the region the most suitable to honeybees. About 75% of the country's honeybee population exists in this region and the holding size of honeybee colonies ranges from 1 to 400 per farmer. As indicated in section 2.5.5 all identified honeybee races in the country are found in the region (Smith, 1961; Ruttner, 1975; Kassaye, 1990; Radloff and Hepburn, 1997a).

Three types of apicultural production systems are practiced in the region: traditional beekeeping, intermediate (Kenya top bar and mud hives) and improved (movable frame hives). However, the apicultural production system of the region is largely traditional, using local hives and skill. Traditional bee keeping practice is ancient and is an inherited part of the culture of farmer beekeepers as the knowledge passes down

from generation to generation. It is also considered as inherited wealth the same as that of movable and fixed assets or properties.

Farmer beekeepers in the south and southwest part of the region keep their honeybee colonies either in the forest or the farmyard hanging on tall trees. Those in the central highlands place their colonies either in the backyard or under the roof of their houses. The local beehives used in the region vary from place to place depending on local materials available: log beehives and bark beehives (made up of stem and bark from trees like *Cordia africana*, *Acacia spp.*, *Croton machrostachys*, etc.), bamboo beehives (made out of split bamboo stems), wicker beehives (made from twigs of trees and shrubs), straw beehives (made from various straw and grasses) and pot beehives (made of clay). All these beehives, except the pot beehive, are cylindrical in shape. To protect honeybee colonies from excessive heat, rain and cold, the beehives are covered on the exterior either by enset, bamboo leaves, and straw or long grass.

In the south and southwest honeybee colonies are hung on tall trees either with ropes or wooden hooks in an inclined position with the entrance facing the ground, to safeguard the colony from predators, such as bee-eating birds, ants and other pests. It is common to find more than 20 honeybee colonies hanging in the branches of one tree. Farmer beekeepers keeping their honeybee colonies in the forests practice little or no beekeeping management. They visit their colonies during the honey flow period for honey harvesting. Those beekeepers that keep their honeybee colonies in either the backyard or under the roof of their houses (central highlanders) pay careful attention to their honeybee colonies: provide their bees with supplementary forage (flour made from toasted barley, peas, chickpeas, beans) and water during a dearth period. They also

provide protection from pests and predators (spiders, ants, honey badgers etc.). Besides keeping honeybee colonies, classical honey-hunting tradition still continues in the southwest, west and southern parts of the region.

1.4.8 Honey harvesting

Due to the aggressive defence behaviour of Ethiopian honeybees the harvesting of honey is done only during the evening once the sun has set. In the south and southwest of the region, where honeybee colonies are kept in the forests, hives are brought to the ground either by slowly lowering with a rope tied around the middle of the hive or they are thrown down. In the first method, honeybees are driven out from the beehive by smoke while in later the honeybees evacuate when thrown. All combs containing pollen, brood, nectar and honey are cut off and put together in a common container called a 'Gabatee' or 'okolee' or 'okotee' or 'karbata' or 'chilgee' which are made up of wood, straw, clay, skin and hides, respectively. These local honey containers vary from place to place. After the removal of the entire hive contents the beehives are re-hung on the same tree, thrown away or taken home for the next season's use after repair. While in the central highland part of the region, farmer beekeepers are more conscientious about their honeybee colonies and leave some honey, pollen and brood to ensure the colony stays after honey harvesting.

Since the collected honey is crude it is mainly used for making local beer called 'teji.' Only a small amount is supplied to the market for table use. The local people also use honey for traditional medicine to cure different ailments.

Chapter Two

2 Literature Review

2.1 Development of geographical honeybee races

Honeybees belong to the order Hymenoptera, superfamily Apoidea and family Apidae consisting of about 20000 species of bees. The majority of these bees are solitary; they have no co-ordinated division of labour. Those which produce honey belong to two subfamilies of the family Apidae: Apinae (honeybees) and Meliponinae (stingless bees). Bees which are used mainly for honey production and other hive products are known as honeybees. Honeybees are the basis of the world's beekeeping industry (Crane, 1990).

There are four well-recognised honeybee species in the world, namely *Apis mellifera*, *Apis dorsata*, *Apis florea* and *Apis cerana* but several other new species have recently been discovered. *Apis mellifera* is native to Europe and Africa whilst the rest are native to the Asian continent. *Apis dorsata* and *Apis florea* live on a single honeycomb in open sites while *Apis cerana* and *Apis mellifera* construct multiple honeycombs in protected sites. Asian honeybees generally yield less honey than the European honeybee *Apis mellifera*. Due to its higher honey yields and easy adaptability to new environments, *Apis mellifera* has been widely distributed to different parts of the world. It occurs in all of Europe and Africa except for the desert regions. It also extends as far north as southern Scandinavia and the forests of Russia, as far east as the Urals and farther south to Iran (Ruttner, 1988). *Apis mellifera* is widely and extensively used in the beekeeping industry worldwide.

As it moved from its original homeland to different parts of the world, *Apis mellifera* faced new environments with different flora, climates and other factors that affected its existence. To cope with these new changes in environment in which they were to live, *Apis mellifera* underwent rapid changes in morphology, behaviour and biochemical processes (Ruttner, 1988; Cornuet and Garnery, 1991a). This has given rise to many geographically adjusted groups, called geographical honeybee races. At present about 25 honeybee races of *Apis mellifera* are recognised in the world corresponding to geographically distinct regions of which ten (10) are recognised as African honeybee races. Climate is a major isolating factor for honeybee races in Africa (Ruttner, 1975, 1985; Fletcher, 1978a; Hepburn and Radloff, 1998).

2.2 History of honeybee taxonomy

Because of their importance in human culture and economical value, honeybees are present in almost all regions where man lives (Ruttner, 1988). The benefits honeybees render to humans have long captivated the attention of scientists. Since the 17th century species of honeybees were identified but with insufficient diagnostic characterisation. Linnaeus was the first person to describe *Apis mellifera* in the middle of 1700's.

P. Andanson first started segregating *Apis mellifera* into races using honeybees from Senegal (Ruttner, 1988). Since then efforts to update and improve the systematic classifications of honeybees have continued (Buttel-Reepen, 1906; Ashmead, 1904; Skorikov, 1929b; Maa, 1953). The search for long-tongued honeybees for the pollination of red clover in Russia in the early 1900's resulted in the development of morphometric studies (Daly, 1992). Work on the identification of honeybees by Koshevnikov in the

early 1900's resulted in the first morphometric measurements being done. Since then many scientists have followed similar morphometric studies: Martynov (1901), Kulagin (1906), Alpatov (1929).

However the main drawback of these early morphometric studies was the limited numbers of observations and sample sizes used which are statistically unacceptable today. As time passed the importance of using adequate sample sizes has been recognised by scientists. Chochlov (1916) was the first person to use adequate numbers of honeybees for morphometric studies, followed by Michalov (1924, 1926) and Alpatov (1925, 1929). In the course of their work these scientists were able to recognise the effect environment played on the geographical variation of honeybees.

The purpose of the first morphometric analysis of African honeybees was not to achieve complete separation and draw geographical borderlines among the existing geographical races of African honeybees, but to collect and establish a database (Ruttner, 1975; Ruttner and Kauhausen, 1985). Based on past studies and trials undertaken today however, morphometric characters and statistical tools for identification of honeybee races were well selected and standardised.

2.3 Morphometric characters

Variability among honeybee species is described by the use of qualitative differences such as male copulatory organs, while on a subspecific level the variability is mainly quantitative, focusing on various parts of the body (Ruttner, 1988).

Aristotle and Columella were among the first of the ancients to note visible differences in colour amongst honeybee colonies (Fraser, 1951). Since then colour has

became a dominant character in the systematics of honeybee races. Colour may be an important characteristic to easily distinguish honeybee races in the field. However colour alone is frequently inadequate for the classification of honeybee races, as its variation is not normally distributed and is bimodal in distribution (Ruttner, 1987). Morphometric analysis of Mediterranean honeybee races using six morphological characters (colour being one of the six characters used) divided all races into two groups: yellow and black. On removing the colour component from the analysis, the remaining five characters easily separated the honeybees into the expected number of geographical populations (Cornuet *et al.*, 1975).

Since size differences are commonly observed among honeybee races this is used as one of the characters in their classification. Measuring different parts of the honeybee's body is used to assess differences between honeybee races. Besides the tongue, Alpatov (1929) introduced a number of morphometric measurements related to size: three segments of the hind leg (femur, tibia and metatarsus), length and width of forewing and size of the wax mirror. Recognising the difficulty encountered while measuring the overall size of honeybees, he also introduced the measurement of sternites and tergites to overall body size. Morphological differences among honeybee populations are easily detected by measuring the isolated body parts. Size variations between the smallest and the largest *Apis mellifera* populations were found to range from 25% to 31% of the smallest value, except for the variation in tongue length. Morphometric characters associated with body size are positively correlated to each other to varying degrees, thus it is very important to include reasonable numbers of morphometric characters of different body parts to attain better results in the discrimination of honeybee populations

(Ruttner, 1988). However when the most important morphological characters associated with body size were selected, many races of *Apis mellifera* could be completely separated by a few characters of size alone. Using only forewing length and tergite 3 and 4, Ruttner (1975) successfully separated honeybee populations of *Apis mellifera jemenitica*, *Apis mellifera meda* and *Apis mellifera mellifera*. As a result, size remains one of the major characters in morphometric analyses of honeybees.

A number of indices of wing venation were used for discrimination between *Apis mellifera* races: precubital index (length and width of cubital cell 2), dumb-bell index (B-A: I-E), radial index (E`-X: E`-Y) and discoidal index (relative position of point D to the prolongation of line E`-E) (Goetze, 1964; Louis, 1963) are the main ones. Goetze (1930, 1964) introduced the cubital index (relation between venation segments) to the category of morphometric characters. Later on DuPraw (1964, 1965a, b) added wing venation angles (angles formed by connection lines between crossing veins). This introduction of wing venation angles to the category of morphometric characters brought advancement in morphometric analysis. The intraspecific morphological variations among *A. mellifera* honeybee populations can be detected using wing venation alone or combining them with other morphometric characters associated with wing size. Moreover wing venation angles are not correlated to each other and with morphometric characters related to body size and are normally distributed (DuPraw, 1965b). Thus wing venation angles remain important morphometric characters used to discriminate honeybee populations. As a result, all indices mentioned above, except for cubital index (CI), became outdated after the introduction of wing venation angles (Ruttner, 1988).

Hair cover of worker bees (length of cover hair and width of tomenta) is another of the characters used in the morphometric analysis of honeybees. Even though it is often difficult to accurately measure the hair on the abdomen they have great geographical variability. Therefore, using the length of hair on the abdomen of the worker bee helps to easily differentiate between different geographically distinct groups. Morphometric analysis using the length of abdominal cover hair alone successfully discriminated *Apis mellifera mellifera* from *Apis mellifera carnica*. "When combined with cubital index even a slight degree of hybridisation can be detected" (Ruttner, 1983).

In addition to the above mentioned morphometric characters a number of other morphological measurements were used for honeybee morphometric analysis: the size of brood cells, the number of hamuli, width of head and thorax (Goetze, 1930), density of spines on wing surfaces (Woyke, 1976b) and length of venom and rectal glands (Firsow, 1976), inter-ocellar and oculo-ocellar distances, length of antenna or its segments, distance and diameter of eyes (Stort, 1979; Rashad and El-Sarrag, 1980), length and width of the hindwing (Daly *et al.*, 1982). Alpatov (1929), Goetze (1964), DuPraw (1964) and Ruttner *et al.* (1978) were the principal scientists in the development of basic morphometric characters used today (Table 1).

Even though utilising several characters in honeybee morphometric analysis is extremely important to obtain consistent results. After much consideration, forty (40) characters were selected from several characters used in earlier times for morphometric analysis (Ruttner, 1988). These were further reduced to a standard set of thirty-six (36) morphometric characters (Table 1) through careful screening and selection (Ruttner, 1988). Ruttner also indicated the possibility of reducing the number of characters

according to the region under investigation when combined with stepwise discrimination. It has been reported that as few as a third of the standard set of characters may be adequate to discriminate African honeybee races (Crewe *et al.*, 1994; Ruttner *et al.*, 1978; Daly and Balling, 1978). Using only nine (9) characters of the standard set (Table 2), African honeybee races were successfully discriminated (Crewe *et al.*, 1994; Hepburn and Radloff, 1996a; Radloff *et al.*, 1996; Radloff and Hepburn, 1997a; Hepburn and Radloff, 1998).

Instead of using many unnecessary characters it is therefore important to carefully select the most important characters that fit the region under investigation. The selected characters however should have the quality of variability among honeybee races of different geographical regions and be easy to measure to attain precise values within reasonable time and labour constraints (Ruttner, 1988).

Sometimes, due to close morphological similarities among different honeybee races it is very difficult to separate one from the other using morphometric characters alone. In such cases, therefore, inclusion of special characters: behaviour, reproductive system, size of brood cells and drone size are very important (Ruttner, 1988). Furthermore, analyses of pheromones, allozyme, microsatellite and mitochondria DNA techniques were developed and have become vital tools in support of morphometric analysis in honeybee race discrimination (Hepburn and Radloff, 1998).

Table 1. List of characters for standard morphometry.

Category	Ruttner No.	Characters	Author	
Hair	1	Length of cover hair on tergite 5	Goetze 1964	
	2	Width of tomentum on tergite 4	Goetze 1964	
	3	Width of stripe posterior of tomentum	Goetze 1964	
Size	4	Proboscis	Alpatov 1929	
	5	Femur	Alpatov 1929	
	6	Tibia	Alpatov 1929	
	7	Metatarsus length	Alpatov 1929	
	8	Metatarsus width	Alpatov 1929	
	9	Tergite 3 longitudinal	Alpatov 1929	
	10	Tergite 4 longitudinal	Alpatov 1929	
	11	Sternite 3 longitudinal	Alpatov 1929	
	12	Wax plate of sternite 3 longitudinal	Alpatov 1929	
	13	Wax plate of sternite 3 transversal	Alpatov 1929	
	14	Distance between wax plates, st.3	Ruttner et al.1978	
	15	Sternite 6 longitudinal	Ruttner et al.1978	
	16	Sternite 6 transverse	Ruttner et al.1978	
	Forewing	17	Forewing longitudinal	Alpatov 1928
		18	Forewing transversal	Alpatov 1928
19		Cubital vein, distance a	Goetze 1964	
20		Cubital index, distance b	Goetze 1964	
21		Angle of wing venation A4	DuPraw 1964	
22		Angle of wing venation B4	DuPraw 1964	
23		Angle of wing venation D7	DuPraw 1964	
24		Angle of wing venation E9	DuPraw 1964	
25		Angle of wing venation G18	DuPraw 1964	
26		Angle of wing venation I10	DuPraw 1964	
27		Angle of wing venation I16	DuPraw 1964	
28		Angle of wing venation K19	DuPraw 1964	
29		Angle of wing venation L13	DuPraw 1964	
30		Angle of wing venation N23	DuPraw 1964	
31		Angle of wing venation O26	DuPraw 1964	
Colour	32	Pigmentation of tergite 2	Goetze 1964	
	33	Pigmentation of tergite 3	Goetze 1964	
	34	Pigmentation of tergite4	Goetze 1964	
	35	Pigmentation of scutellum (Sc)	Ruttner et al. 1978	
	36	Pigmentation of scutellum (Bk)	Ruttner et al. 1978	

Source: Ruttner (1988).

Table 2. Characters used for discrimination of African honeybees.

No.	Characters	Ruttner No.	Author
1	Length of cover hair on tergite 5	1	Goetze 1964
2	Sternite 3 longitudinal	11	Alpatov 1929
3	The transversal length of wax plate on sternite 3	13	Alpatov 1929
4	Pigmentation of scutellum (Sc)	35	Ruttner et al. 1978
5	Pigmentation of scutellum plate (Bk)	36	Ruttner et al. 1978
6	Pigmentation of tergite 2	32	Goetze 1964
7	Wing angle B4	22	DuPraw 1964
8	Wing angle N23	30	DuPraw 1964
9	Wing angle O26	31	DuPraw 1964

Source: Compiled from Hepburn and Radloff (1998).

2.4 Statistical Analysis

Morphometric character analysis is a powerful tool used to describe differences amongst different geographical honeybee races when it is combined with multivariate analyses. Multivariate analysis is the main tool in morphometric studies to analyse the geographical variability among honeybee species and races. In the early 1900's statistical analysis such as the mean, standard deviation, coefficient of variation and correlation were used to assess differences amongst honeybee populations (Merrill, 1922; Phillips, 1929; Alpatov, 1929; Michailov, 1924, 1926). Further improvement was made when Goetze (1930, 1940; 1964) introduced univariate statistics in morphometric analysis. This method is still used by some apiculturists to classify European honeybee races (Ruttner, 1988).

Later, in the 1960's DuPraw (1964, 1965a) introduced multivariate analyses in the area of honeybee classification. Multivariate analysis is a statistical tool that helps to visualise the differences among the values of characters measured during morphometric analysis of honeybees. This method of analysis has the power to discriminate between ecotypes within races and between genetic lines (Louis and Lefebvre, 1968; Tomassone and Fresnaye, 1971; Louis *et al.*, 1968).

Multivariate analysis consists of several techniques: factor analysis and principal components analysis, which are used to detect clusters of colonies within populations (Ruttner *et al.*, 1978; Ruttner, 1988); stepwise discriminant analysis, which confirms separation of clusters, determines discriminatory variables and calculates the percentage of correctly classified colonies (Ruttner, 1988; Daly, 1992); confidence ellipses (75-95%) which are used to test significance of discrimination (Cornuet, 1982) and phenograms or

dendrograms, used to depict distances (Mahalanobis distance) between clusters (Tomassone and Fresnaye, 1971; Cornuet *et al.*, 1975; Cornuet and Garnery, 1991a, b; Daly, 1992). It is also used to test significant multivariate mean difference between clusters (Rinderer *et al.*, 1990).

2.5 African honeybee races

Africa with its large and diversified ecology has a larger honeybee population than Europe. Africa is thought to be the origin of *Apis mellifera* (Ruttner *et al.*, 1978). The presence of all lineages: A, M, C, O and Y in Africa has been confirmed (Ruttner *et al.*, 1978; Garnery *et al.*, 1992; Smith and Brown, 1988; Franck *et al.*, 2001; Arial and Sheppard, 1966). The taxonomy and behaviour of African honeybees have not been as thoroughly studied as those of European honeybees. Hence knowledge about African honeybees is very limited. However some important studies have been done to classify African honeybee races of which the most important are those of Alpatov (1935a, b), Anderson (1963), Baldensperger (1922, 1924, 1932), Br. Adam (1983, 1987), Cockerell (1906), Cornuet *et al.* (1988), Cornuet and Fresnaye (1989), Cornuet and Garnery (1991a, b), Crewe *et al.* (1994), Douhet (1965a, b, 1980), DuPraw (1964, 1965a, b), El-Banby (1977), Eschscholtz (1822), Franck *et al.* (1998), Goetze (1964), Hepburn (1989), Hepburn and Crewe (1990, 1991a, b), Hepburn (1988), Hepburn and Radloff (1998), Kassaye (1990), Kerr (1992), Kerr and Portugal-Araujo (1958), Latreille (1804), Lepeletier (1836), Maa (1953), Meixner *et al.* (1989, 1994), Mogga (1988), Mohamed (1982), N'Diaye (1974, 1976), Radloff *et al.* (1998), Radloff and Hepburn (1997a, b), Rashad and El-Sarrag (1978, 1980), Ruttner (1975, 1976 a, b, c, 1978, 1980, 1981, 1985,

1988, 1992), Saeed (1981), Smith (1961), Smith and Glenn (1994), Smith *et al.* (1991) and Vlatcovic (1969).

Collectively these studies indicated that out of approximately twenty-five (25) *Apis mellifera* races found in the world about twelve (12) geographically distinct races occur on the African continent: *Apis mellifera intermissa* (Buttel-Reepen, 1906); *Apis mellifera sahariensis* (Baldensperger, 1932) and *Apis mellifera major* (Ruttner, 1975) in the Mahgreb; *Apis mellifera lamarckii* (Cockerell, 1906), *Apis mellifera jemenitica* (Ruttner, 1975) and *Apis mellifera nubica* (Ruttner, 1975) in northeast Africa; *Apis mellifera monticola* (Smith, 1961) and *Apis mellifera litorea* (Smith, 1961) in southeast Africa; *Apis mellifera unicolor* (Latrielle, 1804), *Apis mellifera scutellata* (Lepeletier, 1836) and *Apis mellifera capensis* (Eschscholtz, 1822) in southern Africa and *Apis mellifera adansonii* (Latreille, 1804) in west Africa.

A recent review of intra-specific nomenclature of *Apis mellifera* has reported the presence of twenty-two (22) honeybee races and ten (10) valid geographical races in Africa in particular (Engel, 1999). *Apis mellifera nubica* and *Apis mellifera major*, which were considered geographical races of Africa in earlier times, have been withdrawn from the list of subspecies due to lack of clear morphometric demarcations from other honeybee races of their region. Hence they are considered as micro-geographical races of *Apis mellifera jemenitica* and Mahgreb honeybees respectively (Ruttner, 1988; Hepburn and Radloff, 1998).

African honeybees are quite different from European honeybees in morphometric characteristics and behaviour. They are smaller, very defensive and highly mobile. African honeybees have a high tendency for swarming. Many swarms can be issued

successively from a single colony. This repeated swarming from the same colony results in the reduced size of the mother colony. However it quickly recovers within a short period because they produce more rapidly than European honeybees. African honeybees are able to raise 50% more brood given identical volume and period than European bees. An African queen may lay over 2500 eggs per day during the honey flow period (Fletcher, 1978a). Their developmental period is also somewhat shorter than that of European honeybees. The size of the brood cell is smaller, however, and the number of brood cells per unit area is greater in African honeybees compared to the European ones. Migration and absconding are also highly characteristic of African honeybees. During dearth periods and unfavourable conditions they leave their nests and move to a more suitable locality. Some return to their original nesting sites when adverse conditions improve (Ruttner, 1988).

Even though some studies were conducted on the identification of African honeybee races, they were not adequate to generate enough information on a continental level. The behaviour, biology and distribution of African honeybees were not well studied and documented. Furthermore most of the studies were based on small sample sizes and whole parts of the African continent were not addressed (Hepburn and Radloff, 1998).

2.5.1 Northwestern African honeybees

This region is located in northwest Africa including the Sahara desert and north of the Sahara extending to the Mediterranean Sea and Atlantic Ocean. The region is

characterised by extremely hot temperatures during the day and low temperatures at night, low rainfall varying from year-to-year and scarce vegetation (Walter, 1958).

The predominant honeybee races of this region are: the black honeybees found along the Mediterranean Sea, *Apis mellifera intermissa*; mainly yellow but variable in colour found south of the mountains bordering the Sahara desert, *Apis mellifera sahariensis*; and the black Rif mountain honeybees, *Apis mellifera major* (Ruttner, 1975, 1988; Cornuet *et al.*, 1988; Baldensperger, 1922, 1924, 1932; Haccour, 1960a; Alber, 1952).

A recent morphometric analysis of the region, however, has shown only the presence of *Apis mellifera intermissa* and *Apis mellifera sahariensis*. No indication of *Apis mellifera major* was found. Thus it is considered as an ecotype of the region (Hepburn and Radloff, 1996a). The honeybees of the region are known for their ability to withstand harsh climatic conditions and scarce forage (pollen and nectar) (Ruttner, 1988).

2.5.1.1 *Apis mellifera intermissa* Buttel-Reepen (1906)

Apis mellifera intermissa, known as the Tellian bee of the Mahgreb is found along the Mediterranean and Atlantic coasts. It is black in colour and large in size: it has the longest hair (0.30mm), largest longitudinal sternite 3 (11) (2.80mm) and transversal wax plate on sternite 3 (13) (2.38mm) (Hepburn and Radloff, 1998). It shows several similarities to the southwestern European honeybees (Paradeau, 1951; Hicheri and Bouderbala, 1969). However, mitochondrial DNA and alarm pheromone analyses indicate that it has a greater affinity to African honeybees than to European honeybees

(Hepburn and Radloff, 1996a, b; Garnery *et al.*, 1992). It has a high tendency to swarm and uses propolis extensively, has an aggressive defensive behaviour and is extremely excitable (Ruttner, 1988).

2.5.1.2 *Apis mellifera sahariensis* Baldensperger (1922)

It is found in fertile lands of the Sahara desert and along the south edge of the mountains Morocco and Algeria. It lives within extreme temperature ranges -8°C to 50°C and drought conditions. *Apis mellifera sahariensis* has a more slender abdomen and higher cubital index than *Apis mellifera intermissa* and is smaller in size (Ruttner 1988). It has hair length of 0.25mm, sternite 3 longitudinal 2.69mm and transversal wax plate on sternite 3(13) 2.25mm (Hepburn and Radloff, 1998). Though it is mainly yellowish tan, its colour is variable: bees in oases and along the north edge of Sahara in Morocco are yellowish while to the east in Algeria it is blackish (Baldensperger, 1932; Haccour, 1960a, b).

Apis mellifera sahariensis is quite different in behaviour from *Apis mellifera intermissa*. It has little inclination to use propolis, a moderate tendency to swarm, produces a restricted number of queen cells and is more docile. Due to the fact that it is less aggressive, it is not effective at defending its nest. However it becomes nervous when disturbed (Ruttner, 1988).

2.5.2 Honeybees of northeastern Africa

The region is considered as the probable centre of origin for *Apis mellifera* due to the co-existence of three mitochondrial lineages (A, O and Y) (Franck *et al.*, 2001;

Ruttner, 1988; Hepburn and Radloff, 1998). Honeybee groups occupying two different geographical areas: the Nile Valley and the Horn of Africa are found in this region.

2.5.2.1 The Nile Valley honeybees

The Nile Valley is located in the northern part of Egypt and separated from southern Africa and the Mahgreb by the Sahara desert. The Egyptian honeybee race, *Apis mellifera lamarckii* is the predominant honeybee of the region (Hepburn and Radloff, 1998).

2.5.2.1.1 *Apis mellifera lamarckii* Cockerell (1906)

Apis mellifera lamarckii was first identified by Latreille in 1804 and was named “fasciata”. Later in 1906 it was renamed *Apis mellifera lamarckii* by Cockerell. It is found in the lower Nile Valley at the eastern extremity of north Africa. The race has a beautiful colour pattern of bright orange bands with shining black margins on its abdomen (Rotter, 1920, 1921; El-Banby, 1965; Ruttner, 1988). Due to its attractive colour it was shipped to Germany, England and North America in early 1865-1867 (Buttel-Reepen, 1906). Its tergite 2 has a narrow yellow stripe while its tergites 3 and 4 have only yellow spots (Ruttner, 1988).

Apis mellifera lamarckii resembles the Mediterranean honeybee races more than the tropical African honeybee races in behaviour. Unlike tropical African honeybee races, it does not excessively migrate, abscond and swarm (Ruttner, 1988). Even though *Apis mellifera lamarckii* resembles the Mediterranean honeybees in behaviour, morphometrically it is closer to tropical African honeybees. The factor and discriminant analysis results indicate a lack of affinity between *Apis mellifera lamarckii* and *Apis mellifera intermissa*, rather it is a discrete morphocluster close to northeastern African

honeybee races (Hepburn and Radloff, 1998). No population variability was recorded among *Apis mellifera lamarckii* within 600km distance along the Nile (Hassanein and El-Banby, 1956c; Kashcef, 1959a; Wafa *et al.*, 1965; El-Banby, 1968; Br. Adam, 1983, 1987).

Apis mellifera lamarckii is small in size, has short legs, wings and tongue. The length and width of its hindwing are 10.46mm and 3.31mm respectively. The length of its hind leg is 8.32mm (Ruttner, 1988) and has hair length of 0.22mm, longitudinal sternite 3 (11) 2.49mm and transversal wax plate on sternite 3 (13) 2.04mm (Hepburn and Radloff, 1998).

Apis mellifera lamarckii has a high tendency for brood production. It rears brood throughout the year. It constructs as many as 50-260 queen cells during the reproduction period (Rotter, 1920; El-Banby, 1963a). However, it has a low tendency to swarm. Surprisingly enough, many virgin queens live together within a colony and swarm only when one of the young queens is mated. Indeed 36 living virgin queens have been collected from a single swarm and in another observation 12 queens were found alive after being kept in a cage for 24 hours (Buttel-Reepen, 1921).

Compared to the development time of the European honeybee races, *Apis mellifera lamarckii* has a shorter developmental period. Worker honeybees emerge within 19.4 days while queens emerge in 15.4 days (El-Banby, 1963b).

2.5.2.2 Honeybees of the Horn of Africa

This region includes all countries located at the northeastern part of the African continent: Sudan, Somalia, Kenya, Ethiopia, etc. The region has a high potential for

honeybee populations and beekeeping activities and has a complex and diversified ecology.

Despite the region's potential, research has not been adequately addressed and present knowledge about honeybees of the region is minimal. Moreover there is much inconsistency in the work done so far. Of the present 10 recognised African honeybee races half of them were found here: *Apis mellifera monticola*, *Apis mellifera litorea*, *Apis mellifera jemenetica*, *Apis mellifera scutellata* and *Apis mellifera adansonii* were regarded as honeybees of the region (Smith, 1961; Ruttner, 1975).

However later studies on honeybees of this region indicate the presence of only three honeybee races: the small honeybees of semi-desert, *Apis mellifera jemenetica*, the medium-sized honeybees of forest and Savannah, *Apis mellifera sudanensis*, and the large honeybee along the border of Ethiopia and Sudan, *Apis mellifera bandasii* (Mogga, 1988). The study conducted in early 1990's even further reduced the number of honeybee races of the region to two: *A. m. sudanensis*, distributed throughout Sudan, south of the Nubian desert, and *A. m. nubica*, along the Sudan and Ethiopia border (El-Sarrag *et al.*, 1992). A more recent morphometric analysis of honeybees from Sudan, Somalia, Kenya and Ethiopia revealed the presence of three morphoclusters in this region: *Apis mellifera jemenetica*, *Apis mellifera sudanensis* and *Apis mellifera bandasii* (Radloff and Hepburn, 1997a). This result was consistent with the results of Mogga (1988) and created the necessity for further research on the honeybees of the area. Furthermore it regarded honeybees of Sudan, Somalia, and north Ethiopia as *Apis mellifera jementica*, with some variant (*sudanensis* and *bandasii*) honeybees of south Ethiopia and Kenyan highlands

(excluding Mt Elgon) as *Apis mellifera scutellata*, and honeybees of central Ethiopia as *Apis mellifera monticola* (Hepburn and Radloff, 1998).

2.5.2.2.1 *Apis mellifera jemenitica* Ruttner (1975)

Apis mellifera jemenitica is the smallest subspecies of *Apis mellifera* of the sub-Saharan region (Ruttner, 1975). It is considered as a honeybee of the hot arid zone of northeastern Africa and Arabia. Its territory covers the north of the east African highlands and plains, the belt of desert east of the Sahara, across the Nile valley to the Arabian Peninsula. It is found in Oman, Sudan, Chad, Somalia, Saudi Arabia, Ethiopia, Mauritania, Senegal, Mali, Niger and Burkina Faso (Ruttner, 1988; Hepburn and Radloff, 1998). It is commonly known as the eastern and Arabian honeybee, but is also found in west African zones (Ruttner, 1988; Radloff, 1996; Hepburn and Radloff, 1998). *Apis mellifera jemenitica* exists in the zone with high temperatures ranging from 27⁰C - 31⁰C with very low rainfall 30-300mm (Fletcher, 1978a). Its natural habitat is the dry thorn bush (*Acacia*) of Africa.

Morphometrically, *Apis mellifera jemenitica* is the smallest of all African honeybees. It has short hair cover (0.195mm), a short proboscis (5.48mm), wings (8.13mm) and legs (7.12mm) (Ruttner, 1988) (Table 3).

Even though the behavioural characteristics of these honeybees are not well documented, they exhibit high variation in behaviour. They commonly migrate during the dry period. No absconding problems were reported from Oman and Yemen, yet in Sudan, absconding occurs during the dry season (Rashad and El-Sarrag, 1980). Moreover honeybees of Oman frequently swarm and to issue 10-12 swarms per colony is common

in a favourable season. *Apis mellifera jemenitica* found in north Oman, Sallalah and north Yemen are reported as being docile (Dutton *et al.*, 1981; Field, 1980); while those in Sudan react aggressively and quickly (Rashad and El-Sarrag, 1980; Wille, 1979).

Like behavioural variability, morphometric variability was recorded among *Apis mellifera jemenitica* populations from different geographical areas. Even though the Saudi Arabian honeybees show high variability, generally they are the smallest and yellow honeybees, having short body hair and slender abdomen. These are the smallest *Apis mellifera* honeybees, and have a 5.02mm long proboscis, 7.66mm forewing, and 6.78mm leg (Ruttner, 1988).

Omani honeybees exhibit a high variation in pigmentation. Tergite 2 pigmentation of these honeybees varies from completely black to largely yellow. Morphometrically these honeybees occupy an intermediate position between Chad and Saudi honeybees and they are larger than Yemeni honeybees (Ruttner, 1988).

Sudanese honeybees are larger than Arabian honeybees and have slender and lighter abdomens than other populations of *A. m. jemenitica* honeybees. They are similar to Somalian honeybees except they have a slightly shorter proboscis and lighter slender abdomen. Unlike the others, the honeybees of Chad show a lesser degree of variability in morphological characters (Ruttner, 1988).

Generally *Apis mellifera jemenitica* is subdivided into two major groups based on morphometrical variability as west African and northeast African *Apis mellifera jemenitica* (Hepburn and Radloff, 1998). The former have hair length of 0.20mm, width of sternite 3 (11) 2.43mm and transversal length of wax plate on sternite 3 (13) 1.98mm,

while the later have hair length of 0.21mm, width of sternite 3 (11) 2.48mm and transversal wax plate on sternite 3 (13) 2.07mm (Table 4) (Hepburn and Radloff, 1998).

2.5.2.2.2 *Apis mellifera scutellata* Lepletier (1836)

Apis mellifera scutellata are considered as eastern and southern African thorn woodland and tall grass savannah honeybees (Ruttner 1988). The area where it is found extends from Ethiopia to South Africa including Kenya, Uganda, Tanzania, Rwanda, Burundi, Malawi, Zambia, Namibia, Botswana and Zimbabwe (Hepburn and Radloff, 1998). It is generally called the African or highland honeybee. Ecologically *Apis mellifera scutellata* is found between altitudes of 500-2400m above sea level, mean annual temperatures of 16 °C to 23 °C, between the areas of *Apis mellifera litorea* and *Apis mellifera monticola* (Smith, 1961). Morphometrically, *Apis mellifera scutellata* is relatively large compared to other honeybees of its region, *Apis mellifera litorea*. Its body size is medium; the length of its proboscis is 5.86mm, forewing 8.66mm, and hindleg 7.58mm and has a cubital index of 2.55 (Table 3) (Ruttner, 1988).

Its tergite and sternite size are similar but somewhat smaller compared to *Apis mellifera monticola*, but its proboscis, forewing, and hindlegs are shorter (Ruttner, 1988). *Apis mellifera scutellata* can be subgrouped as south African and east African honeybees due to morphometric variability. The former group is characterised by having 2.56mm width of sternite 3, 2.14mm transversal length of wax plate on sternite 3 and pigmentation of tergite 2 is 7.98 while the second group have measurements of 2.49mm, 2.05mm, and 7.30mm respectively (Table 4) (Hepburn and Radloff, 1998). *Apis mellifera scutellata* has pronounced defensive behaviour and a high tendency to swarm and abscond (Ruttner, 1988).

2.5.2.2.3 *Apis mellifera litorea* Smith (1961)

Apis mellifera litorea is a small yellow honeybee found along the east African coast from Kenya to Mozambique, where the climate is warm and there is some forage throughout the year (Ruttner, 1988). It has also been reported from Ethiopia (Kassaye, 1990) and Somalia (Hepburn and Radloff, 1998). With regard to morphometric characters associated with body size and hair, it exhibits an intermediate position between *Apis mellifera jemenitica* and *Apis mellifera adansonii* (Ruttner, 1988).

The unique feature of *Apis mellifera litorea* is that it has a long proboscis compared to its body size and leg length. The length of its proboscis is 5.81mm, forewing 8.4mm, hind leg 7.26mm and cubital index of 2.25 (Table 3) (Ruttner, 1988) longitudinal of sternite 3 is 2.46mm and transversal of wax plate 2.07mm (Hepburn and Radloff, 1998). *Apis mellifera litorea* is inseparable from honeybees of sub-Saharan Africa in morphometric characters associated with pigmentation (Ruttner, 1988).

The worker cell size and comb space are relatively small and measure 4.62mm 28-30mm respectively (Smith, 1961). Absconding is common among the populations of *Apis mellifera litorea* colonies during dearth periods and when attacked by pests and predators (Ruttner, 1988).

2.5.2.2.4 *Apis mellifera monticola* Smith (1961)

Apis mellifera monticola is a black honeybee with small yellow spots and stripes on its abdomen and exhibits high variation in pigmentation. Based on colour it is grouped as *black monticola* and *yellow monticola* (Hepburn and Radloff, 1998). It is the honeybee of the rain forests in the eastern mountains of Africa at altitudes between 2000-3000m

above sea level in Ethiopia, Tanzania, Kenya, and Burundi (Smith, 1961) and Northern Malawi and Cameroon (Radloff *et al.*, 1997b), Zambia and Uganda (Hepburn and Radloff, 1998) (Fig. 1).

Morphometrically there is high variability in size (tongue, wing and leg) among the populations of *Apis mellifera monticola*. They are medium-sized honeybees, but larger and with longer hair cover than all other honeybee races of tropical Africa. The *monticola black* has body hair of 0.26mm long, the sternite 3 width of 2.53mm, transverse length of wax plate on sternite 3 measures 2.15mm while the *monticola yellow* has cover hair of 0.25mm, width of sternite 3 (11) is 2.55mm, and transverse length of wax plate on sternite 3 (13) is 2.14mm (Table 4) (Hepburn and Radloff, 1998). Behaviourally, *Apis mellifera monticola* is described as relatively gentle and manageable compared to other African honeybee races (Ruttner, 1988).

2.5.3 Southern African honeybees

2.5.3.1 The southernmost African honeybees

2.5.3.1.1 *Apis mellifera capensis* Eschscholtz (1822)

Apis mellifera capensis is a dark honeybee found in South Africa, endemic to the fynbos region. It has a small body size with a slender abdomen. Its abdomen and wings are slightly larger than *Apis mellifera litorea* and *Apis mellifera adansonii*. Like *Apis mellifera litorea* its proboscis is long compared to its body size. The proboscis length is 5.8mm, forewing 8.95mm, hindleg 7.82mm and cubital index of 2.33 (Ruttner, 1988) (Table 3) and longitudinal of sternite 3 and transversal of wax plate on sternite 3 measure 2.60mm and 2.14mm respectively (Hepburn and Radloff, 1998) (Table 4).

The most remarkable feature of this race is the ability workers have to lay eggs, which develop into females (workers or queens), when a colony loses its queen. The laying workers start laying eggs 3-4 days after the queen disappears and are treated as queens by other workers. The laying workers produce queen substance (pheromones) and have better-developed ovaries and spermathecae than workers of other honeybee races. The developmental period of these honeybees is short: the adult worker emerges only 9.6 days after the cells are sealed. The swarming of a colony may occur without a queen. The swarm will rear a queen from thelytokously-produced eggs (Gough, 1928; Onions, 1912, 1914).

2.5.3.2 The southern African island honeybees

2.5.3.2.1 *Apis mellifera unicolor* Latreille (1804)

A. m. unicolor is a uniformly black island honeybee, found in Madagascar. Ecologically it occurs between altitudes of 1000m and 2000m with a mean annual rainfall of 1500mm. Its ecology is similar to the savannah ecology of *A. m. scutellata*. However, morphologically these two honeybees are different. *A. m. unicolor* is smaller than *A. m. scutellata*. Hair length measures 0.26mm, proboscis 5.67mm, forewing 8.77mm, hindleg 7.46mm (Ruttner, 1988), longitudinal sternite 3 and transversal wax plate on sternite 3 are 2.62mm and 2.17mm (Hepburn and Radloff, 1998).

The unique feature of this honeybee is that it has a short proboscis and very long forewings compared to its body size. Moreover it exhibits variability in behavioural characteristics: coastal honeybees of Madagascar have a high propensity to absconding while honeybees found in the highlands are less mobile and very gentle (Ruttner, 1988).

2.5.4 Western African honeybees

2.5.4.1 *Apis mellifera adansonii* Latreille (1804)

This is a small yellow honeybee, exhibiting a high degree of variation in pigmentation. It is larger than *Apis mellifera litorea* (Ruttner, 1988) and has the largest area of distribution extending from Senegal in the west through Sierra Leone, Liberia, Ivory Coast, Ghana, Togo, Benin, Nigeria, southern Cameroon and southward into the Congo basin, Zaire, Angola, Zambia (Hepburn and Radloff, 1998). It was also reported from Ethiopia (Kassaye, 1990). These localities occur in different ecological zones: west coast, tropical rain forest and sahel; however they mainly occur in the wet tropics and equatorial zones (Hepburn and Radloff, 1998).

Morphometrically it is intermediate between *Apis mellifera litorea* and *Apis mellifera scutellata* and has similarities with both of these honeybee groups in certain morphometrical characters. The average measurement for proboscis was 5.68mm, forewing 8.45mm, hindleg 7.49mm and cubital index of 2.39 (Table 3) (Ruttner, 1988), hair length 0.23mm, sternite 3 (11) 2.50mm, wax plate on sternite 3 (11) 2.09mm (Hupburn and Radloff, 1998) (Table 4).

Variability in defensive characteristics among populations of *Apis mellifera adansonii* has been reported. Honeybees in Lusaka, Zambia are highly aggressive and prone to sting while honeybees in the Guinea-Bissau are less aggressive (Ruttner, 1988).

Table 3. Discriminant characters of eight sub-Saharan races of *Apis mellifera* (means and standard deviations in brackets of *n* samples, measurements in *mm*).

Character	<i>lamarckii</i> n=16	<i>jemenitica</i> n=30	<i>litorea</i> n=11	<i>scutellata</i> n=19	<i>adansonii</i> n=23	<i>monticola</i> n=9	<i>capensis</i> n=10	<i>unicolor</i> n=8
L.of hair	0.23 (0.04)	0.195 (0.02)	0.23 (0.02)	0.22 (0.04)	0.24 (0.02)	0.26 (0.04)	0.21 (0.03)	0.26 (0.04)
Proboscis	5.81 (0.23)	5.48 (0.12)	5.81 (0.20)	5.86 (0.17)	5.68 (0.18)	6.06 (0.13)	5.80 (0.12)	5.67 (0.13)
Forewing length	8.38 (0.25)	8.13 0.19	8.40 0.10	8.66 0.16	8.45 0.16	8.85 0.23	8.95 0.37	8.77 0.32
Hind leg	7.47 (0.27)	7.12 0.22	7.26 0.12	7.58 0.20	7.49 0.15	7.68 0.22	7.82 0.37	7.46 0.14
Terg.3+4	4.24 (0.17)	3.94 0.14	3.92 0.10	4.17 0.14	4.02 0.10	4.17 0.17	4.25 0.21	4.03 0.12
Stern 6 ind	87.39 (4.80)	82.86 (3.38)	85.08 (2.99)	85.05 (4.05)	84.47 (4.44)	86.05 (5.58)	86.07 (3.95)	85.8 (2.35)
Cub Ind	2.37 (0.37)	2.20 (0.40)	2.25 (0.41)	2.52 (0.46)	2.39 (0.41)	2.35 (0.41)	2.33 (0.34)	2.79 (0.42)
Angle I16	96.76 (3.60)	91.09 (4.89)	91.31 (4.33)	92.40 (4.19)	94.95 (3.82)	86.44 (8.37)	92.66 (3.81)	92.46 (3.24)
Colour terg 4	6.37 (2.32)	7.49 (1.27)	7.30 (0.80)	7.31 (1.32)	7.44 (1.26)	3.5 (1.92)	4.68 (0.59)	3.73 (1.11)
Colour scutell	5.58 (2.17)	6.26 (1.02)	6.77 (0.96)	5.61 (1.46)	6.13 (1.40)	0.97 (1.81)	1.93 (2.02)	0.35 (0.73)

Source: Ruttner (1988).

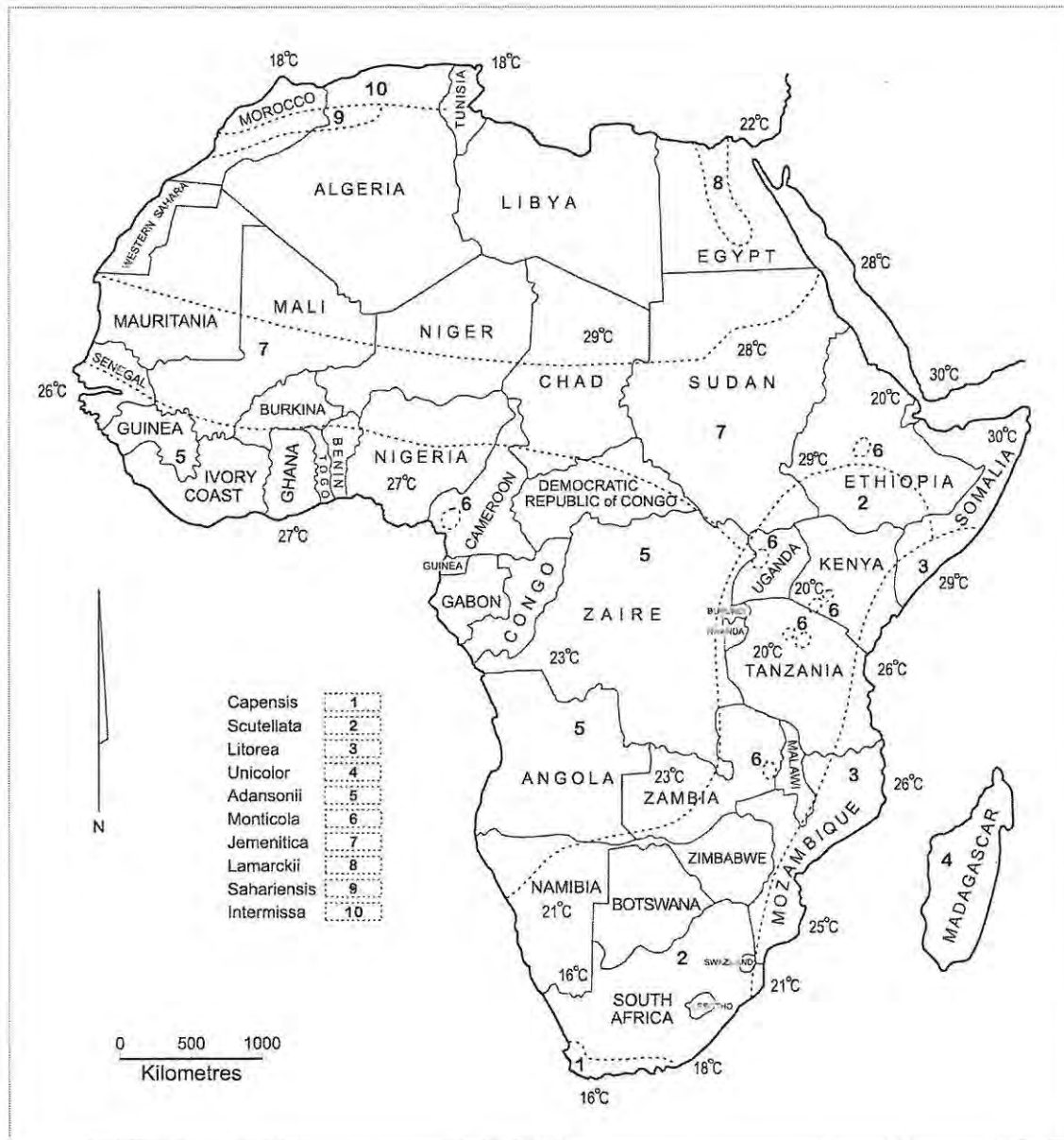
Table 4. Mean and standard deviation in brackets of the morphometric characters of the African morphoclusters measurements in *mm*, angles in degrees).

Morphocluster	Characters: Ruttner numbers								
	1	11	13	22	30	31	32	35	36
<i>A. m. adansonii</i>	0.23 (0.02)	2.50 (0.05)	2.09 (0.05)	103.71 (2.75)	89.51 (3.60)	38.23 (2.19)	8.23 (0.98)	6.25 (0.93)	2.62 (1.56)
<i>A. m. capensis</i>	0.18 (0.02)	2.60 (0.06)	2.14 (0.06)	101.61 (2.34)	87.20 (2.22)	38.21 (1.69)	5.12 (1.18)	2.08 (1.44)	1.79 (1.38)
<i>A. m. intermissa</i>	0.30 (0.06)	2.80 (0.09)	2.38 (0.09)	105.34 (3.49)	87.02 (5.84)	38.55 (2.94)	1.53 (0.46)	0.27 (0.34)	0.67 (0.62)
<i>A. m. jemenitica 1</i>	0.20 (0.02)	2.43 (0.07)	1.98 (0.06)	101.88 (4.16)	89.78 (2.24)	37.55 (2.49)	8.72 (0.63)	6.75 (0.94)	2.97 (1.76)
<i>A. m. jemenitica 2</i>	0.21 (0.02)	2.48 (0.07)	2.07 (0.06)	106.45 (6.61)	89.85 (3.32)	39.07 (2.44)	8.83 (0.24)	5.87 (1.96)	2.42 (1.19)
<i>A. m. lamarckii</i>	0.22 (0.03)	2.49 (0.10)	2.04 (0.09)	101.08 (4.30)	92.69 (2.05)	39.93 (2.24)	7.52 (2.13)	5.40 (1.77)	3.77 (1.33)
<i>A. m. litorea</i>	0.22 (0.02)	2.46 (0.06)	2.07 (0.04)	104.34 (3.10)	85.12 (4.36)	39.08 (3.01)	7.67 (0.69)	6.36 (0.47)	2.90 (2.02)
<i>A. m. monticola</i> black	0.26 (0.02)	2.53 (0.06)	2.15 (0.08)	103.39 (2.79)	89.04 (4.25)	38.26 (2.18)	2.95 (1.80)	1.87 (1.50)	1.18 (1.04)
<i>A. m. monticola</i> yellow	0.25 (0.02)	2.55 (0.06)	2.14 (0.08)	106.19 (2.00)	90.86 (2.72)	37.70 (1.68)	7.74 (0.99)	5.81 (0.81)	3.00 (1.47)
<i>A. m. sahariensis</i>	0.25 (0.05)	2.69 (0.08)	2.25 (0.08)	102.17 (3.74)	87.81 (5.24)	35.80 (1.51)	7.67 (1.42)	5.55 (1.83)	3.21 (1.00)
<i>A. m. scutellata 1</i>	0.22 (0.02)	2.56 (0.07)	2.14 (0.05)	102.40 (2.47)	86.24 (2.64)	37.68 (1.40)	7.98 (0.70)	4.79 (1.43)	2.09 (1.36)
<i>A. m. scutellata 2</i>	0.22 (0.02)	2.49 (0.06)	2.05 (0.09)	103.80 (2.81)	88.25 (3.29)	38.22 (2.23)	7.30 (1.42)	5.24 (1.37)	1.66 (1.16)
<i>A. m. unicolor</i>	0.26 (0.02)	2.62 (0.02)	2.17 (0.02)	97.46 (1.27)	88.62 (1.46)	35.88 (0.96)	0.99 (0.46)	0.37 (0.21)	1.26 (0.74)

Apis mellifera jemenitica 1 refers to west and *A. m. jemenitica 2* to northeast Africa. *A. m. scutellata 1* refers to southern Africa and *A. m. scutellata 2* to eastern Africa.

Source: Hepburn and Radloff (1998).

Fig. 1. Geographical distribution of African honeybees.



Source: Adapted from Hepburn and Radloff (1998).

2.5.5 Ethiopian honeybees

Despite the fact that apiculture is one of the oldest agricultural practises and cash-generating activities, research on beekeeping in general and the characterization of Ethiopian honeybees in particular is at an infant stage. Clear and sufficient knowledge on the characterisation of Ethiopian honeybees is minimal. No detailed morphometric analyses have been conducted apart from that of Smith (1961), Ruttner (1975), Kassaye (1990) and Radloff and Hepburn (1997a).

Even though these studies indicate the presence of different African races: *Apis mellifera monticola*, *Apis mellifera jemenitica*, *Apis mellifera scutellata*, *Apis mellifera litorea*, *Apis mellifera adansonii*, *Apis mellifera sudanensis* and *Apis mellifera bandasii*, the results are not in accord. *Apis mellifera monticola* was the first African honeybee race reported occurring in the central plateaus of Ethiopia (Smith, 1961). Smith came to this conclusion as a result of a single sample he obtained from the central highlands of the country. However this result was supported by the findings of Ruttner (1975) and Meixner *et al.* (1989). The existence of *Apis mellifera jemenitica* and *Apis mellifera scutellata* in Ethiopia were also reported (Ruttner, 1975) 14 years after the discovery of the *Apis mellifera monticola* in the country.

Kassaye (1990) was the first Ethiopian who attempted to classify Ethiopian honeybee races. His results suggested the presence of five distinctly separate groups of honeybees representing different agro-ecological areas of the country: the extreme western lowlands (samples from Gambella) *Apis mellifera litorea*; the southeastern highlands (samples from Dinsho) *Apis mellifera monticola*; the eastern honeybees (sample from Ataye) *Apis mellifera jemenitica*; and tropical forest honeybees (samples

from Asela, Nekemte, Anger Gutine, Bebeke, Arbamich, Negele and Agarfa), which according to him differed from all African honeybee races, and which he named *Apis mellifera abyssinica* and *Apis mellifera adansonii*. All reports are inconsistent except for *Apis mellifera monticola* and *Apis mellifera jemenitica*. *Apis mellifera litorea* was considered a coastal honeybee by Ruttner (1975, 1988) and Smith (1961) but was reported to occur in the western mainland of the country (Kassaye, 1990).

Seven years later after the work of Kassaye (1990) quite different results on Ethiopian honeybee races were published which contradicted all previous reports. This report indicated the presence of only three geographically distinct honeybee races in the country: small bees of mixed colour, black and yellow, in the north (honeybees of Adi Arkay, Bahirdar) *Apis mellifera jemenitica*, the larger and darker honeybees in central parts of the country (Debremarkos, Holetta, and Shashmene) *Apis mellifera bandasii*, and medium-sized bees in the southern parts of the country (Mega and Ageremariam) *Apis mellifera sudanensis* (Radloff and Hepburn, 1997a). This was consistent with the works of Mogga (1988).

Shortly after the study on Ethiopian honeybees was published, the databases of Ruttner and Hepburn-Radloff were combined for the multivariate analysis of honeybees of the Horn of Africa. The result of this multivariate analysis was also inconsistent with results of all previously published studies on morphometric studies of the region. It indicated that the original honeybee populations designated as *Apis mellifera jemenitica*, *Apis mellifera sudanensis* and *Apis mellifera bandasii* by both Mogga (1988) and Radloff and Hepburn (1997a) did not form separate clusters (Hepburn and Radloff, 1998). Hence extensive studies on honeybees of the Horn of Africa and Ethiopia in particular were

strongly recommended to clearly define the honeybee races of the region. It was suggested that until the Horn could be more extensively studied, that the northern honeybees of the country be regarded as *Apis mellifera jemenitica* with local population variants (*sudanensis* and *bandasii*), honeybees of the southern most Ethiopia as *Apis mellifera scutellata*, and honeybees of the central mountains, as a dark form of *Apis mellifera monticola* (Hepburn and Radloff, 1998).

Moreover, the microsatellite and mitochondrial analyses of African honeybees have shown that the origin of Ethiopian honeybees is quite different to other African honeybee races. The origin of northeastern honeybees and that of Ethiopia in particular has a greater affinity to Asian honeybees (Franck *et al.*, 2001). Besides these contradictory conclusions, none of the results indicated the distribution, behaviour and biology of these honeybees for the whole of Ethiopia. Some of the studies did not use adequate sample sizes during the analysis.

This unclear and complicated information contributed to the lack of appropriate and sufficient knowledge on the honeybees of Ethiopia. Researchers, farmer beekeepers and hobbyist beekeepers of the country are not aware which honeybees they are working with. These conditions prevent the evaluation of the potential of each existing honeybee race and to select, multiply and use the best performing and promising ones to generate improved management technologies that help to maximise honey and other honeybee products for respective honeybee types and regions.

Chapter Three

3 Research methodologies.

3.1 Sampling Sites

The sampling sites are located in the south, southwest and southeastern parts of the country between 4° 49' 54.3" N to 9° 7' 98" N latitude and 34° 16' 07" E to 42° 57' 57" E longitude. This includes the prominent regional states in apiculture: Oromia, South Nation, Nationality and People (SNNP), Gambella and Somali. These sites lie within 10 major agro-ecological (MAEZ) and 15 sub-agro-ecological (SAEZ) zones. Hot to warm sub-humid lowlands (SH1); tepid to cool sub-humid midlands (SH2); hot to warm humid lowlands (H1); tepid to cool humid highlands (H2); cold to very cold humid sub-Afro to Afro Alpine (H3); hot to warm semi-arid lowlands (SA1); tepid to cool arid mid highlands (A2); tepid to cool moist midlands (M2); hot to warm sub-moist lowlands (SM1) and tepid to cool sub-moist midlands (SM2) are the major agro-ecological zones.

The sub-agro-ecological zones include: hot to warm sub-humid plains (SH1-1); hot to warm sub-moist mountains (SH1-7); tepid to cool sub-humid plateaus (SH2-6); tepid to cool sub-humid mountains (SH2-7); hot to warm humid mountains (H1-7); tepid to cool humid mountains (H2-7); cold to very cold humid mountains (H3-7); hot to warm semi-arid mountains and plateaus (SA1-5); tepid to cool arid plains (A2-1); tepid to cool moist plains (M2-1); tepid to cool moist mountains and plateaus (M2-5); hot to warm sub-moist plains (SM1-1); hot to warm sub-moist mountains (SM1-7); tepid to cool sub-moist lakes and rift valley (SM2-2) and tepid to cool sub-moist mountains (SM2-7).

As indicated in Table 7, honeybee samples were collected from all 10 major agro-ecological zones; where sampling sites ranged from between 1-5 and colony sample

size between 5-25. Twenty-six (26) localities, not covered by previous morphometric studies were systematically selected from each regional state (Fig. 2) at an average, inter locality distance of about 89km (Table 5).

In previous studies of African honeybee races a sampling distance of approximately 1000km was used (Ruttner, 1988, 1992; Kerr, 1992). However, due to morphometric variation within honeybee races over a short distance, sampling resolution of approximately 160km was used in the most recent study of African honeybee races (Radloff and Hepburn, 1997a). To obtain information on the distribution and to define the territories of each group of honeybees wherever possible, an average sampling distance of 89km was used in this study.

3.2 Climatical and physical environmental data collection

The positions of localities where samples were obtained were recorded using a Garmin 4.57 hand-held Global Positioning System. Climatic data were extracted from the Centre for Resource and Environmental Studies (CRES) database (Hutchinson *et al.*, 1996) for each of the sampled localities using IDRISI32 GIS software. This database consists of grid values of elevation (DEM) and monthly mean climate for the African continent at a spatial resolution of 0.05 degrees of longitude and latitude.

The climate data consist of interpolated monthly mean and annual mean values of rainfall (from 6051 stations), daily minimum temperature (1504 stations) and daily maximum temperature (1499 stations). Most of the temperature and rainfall data were recorded over the period 1920-1980. The standard errors in temperature are about 0.5 degrees centigrade. The standard errors in the rainfall grids range from between about 5

to 15 per cent depending on data density and the spatial variability of the actual monthly mean rainfall. The digital elevation model was based on elevations obtained from 1: 1 000000 scale air navigation charts. The standard errors for elevation values in the DEM range between 20 and 150 m (Hutchinson *et al.*, 1996).

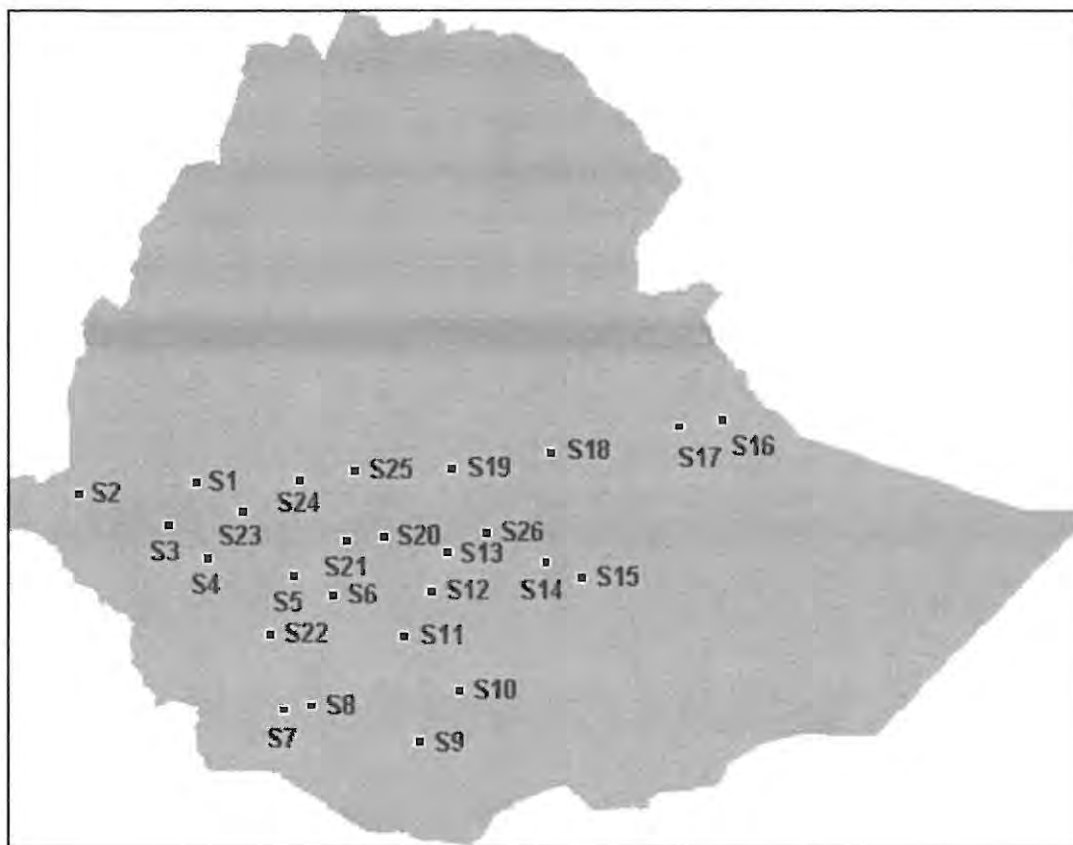
Table 5. Locality, altitude, co-ordinates, region, zone, woreda, between distance and sample size of sampling localities.

	Locality	Altitude (metres)	Geo.coordinates (Degrees)	Region	Zone	Woreda	Distance* Between Localities (km)	Sample size (number)	
								Colony	Bees
1	Gechi (S1)	1515.7	8°21'2"N 35°51'44"E	Oromia	Iluababor	Yayo	70	5	100
2	Itang (S2)	455.9	8°11'30.1"N 34°16'07"E	Gambella	Itang	Itang	120	5	100
3	Masha (S3)	2110.1	7°46'4.5"N 35°28'13.3"E	SNNP	Kafa Shaka	Masha	120	5	100
4	Woshi (S4)	1750.7	7°19'16.6"N 36°1'24.4"E	SNNP	Kafa Shaka	Chana	110	5	100
5	Waka (S5)	1719	7°44'7"N 37°11'12"E	SNNP	North Omo	Merka Gena	70	5	100
6	Sodo (S6)	1758.5	6°49'22.6"N 37°43'26.2"E	SNNP	North Omo	Sodo Zuria	80	5	100
7	Woyito (S7)	921.2	5°16'40.4"N 37°3'33.4"E	SNNP	North Omo	Konso	60	5	100
8	Konso (S8)	1436.1	5°20'17.7"N 37°25'34.8"E	SNNP	North Omo	Konso	70	5	100
9	Arero (S9)	1483.2	4°49'54.3"N 38°52'49.6"E	Oromia	Borena	Arero	100	5	100
10	Har Kalo (S10)	1427.3	5°33'7.1"N 39°23'30.5"E	Oromia	Borena	Liben	100	5	100
11	Eshido Aliyo (S11)	2157.8	6°17'5.2"N 38°39'41.8"E	Oromia	Borena	Bore	80	5	100
12	Serofta (S12)	2377.4	6°51'58.2"N 39°1'5.1"E	Oromia	Bale	Dodola	80	5	100
13	Mararo (S13)	2868.5	7°24'37.5"N 39°14'30.1"E	Oromia	Arisi	Limuna Bilbilo	60	5	100
14	Woltae Atote (S14)	2050.5	7°15'55.4"N 40°34'25.1"E	Oromia	Bale	Ginir	120	5	100
15	Karre Tule (S15)	1194.3	7°3'49.0"N 41°04'4.5"E	Oromia	Bale	Raitu	80	5	100
16	Dudi Affi (S16)	1559.3	9°12'21.6"N 42°57'57.1"E	Somali	Jijiga	Jijiga	70	5	100
17	Deriri Arba (S17)	1449.5	9°7'9.8"N 42°23'15"E	Oromia/ Somali	East Hararghe	Babile	70	5	100
18	Boke Tiko (S18)	1574.8	8°43'40.5"N 40°38'33.4"E	Oromia	West Hararghe	Boke	160	5	100
19	Nazrieth (S19)	1699.3	8°32'7.5"N 39°17'37.7"E	Oromia	East Showa	Adama	120	5	100
20	Alage (S20)	1830.5	7°36'14"N 38°24'27.4"E	Oromia	East Showa	Adamtulu Gido K.	70	5	100
21	Hosaina (S21)	2276.2	7°33'8"N 37°53'27.3"E	SNNP	Hadia	Lemmo	60	5	100
22	Sawla (S22)	2087.2	6°18'4.1"N 36°52'54.5"E	SNNP	North Omo	Gofa	120	5	100
23	Effo Yachi (S23)	1876.8	7°57'40.0"N 36°30'23"E	Oromia	Jimma	Gomma	80	5	100
24	Boter Bacho (S24)	2957.9	8°21'57.3"N 37°16'24.2"E	Oromia	Jimma	Limu Kosa	70	5	100
25	Roge (S25)	2194.2	8°30'37.8"N 37°59'56.34"E	Oromia	West Showa	Woliso	80	5	100
26	Gado Lama (S26)	2121.1	7°40'34.2"N 39°46'20.7"E	Oromia	Arisi	Robe	80	5	100

* Map distances from the nearest sampling locality.

mean = 88.5km

Fig. 2. Southern Ethiopian honeybee sampling localities



Key:

S1 Gechi	S8 Konso	S15 Karre Tule	S22 Sawla
S2 Itang	S9 Arero	S16 Dudi Affi	S23 Effo Yachi
S3 Masha	S10 Har Kalo	S17 Deriri Arba	S24 Boter Bacho
S4 Woshi	S11 Eshido Aliyo	S18 Boke Tiko	S25 Roge
S5 Waka	S12 Serofta	S19 Nazrieth	S26 Gado Lama
S6 Sodo	S13 Mararo	S20 Alage	
S7 Woyito	S14 Woltae Atote	S21 Hosaina	

3.3 Sample collection

130 honeybee colony samples, each containing about 50 worker honeybees, were sampled from 26 localities: five colony samples from each locality (Fig. 2 and Table 5). These honeybee samples were collected from the entrance of 70 basket and 60 movable frame hives. The honeybees were killed and preserved in 70% ethanol and transported to the honeybee laboratory at Rhodes University for morphometric measurements. The samples were collected during July and August 2000.

10-20 worker honeybees were recommended as the standard sample size for honeybee morphometric analysis (Ruttner, 1988). Prior morphometric analyses of African honeybees were conducted using a 20 honeybee sample size (Radloff, 1996; Radloff *et al.*, 1996; Radloff and Hepburn, 1997a, b; Hepburn and Radloff, 1998) and it was decided on this basis that 20 worker honeybees, representing each colony of each of the study sites, were to be used for morphometric measurements in this study.

3.4 Morphometric characters

The morphometric measurements were conducted in the honeybee laboratory, Department of Zoology and Entomology at Rhodes University Grahamstown, South Africa.

As mentioned in Section 2.3 above, as few as one third of the standard set of characters are adequate to discriminate between African honeybee races (Ruttner, 1988). Nine to ten characters were used in previous morphometric analyses of African honeybee races (Radloff, 1996; Crewe *et al.*, 1994; Radloff and Hepburn, 1997a, b; Hepburn and Radloff, 1998). Proboscis length was originally included as one of the discriminant

characters, however, since it is very difficult to fully stretch a folded proboscis for morphometric measurement this would introduce discrepancies in the data, and was therefore excluded. Hepburn and Radloff, (1998) and Radloff *et al.*, (1998) successfully classified African honeybees using only 9 morphometric characters.

However, due to higher variation in pigmentation and body size in the population of honeybees of Ethiopia (Radloff and Hepburn, 1997a) in the present study four more (2 related to pigmentation and 2 to body size, that is pigmentation and size of abdominal tergite 3 and 4) morphological characters were included. Thus 13 morphometric characters were used to morphometrically characterise the honeybee races of the south, southwestern and southeastern parts of Ethiopia: length of cover hair on tergite 5 (1), transversal length of wax plate on sternite 3 (13), width of sternite 3 (11), pigmentation of scutellum (sc) (35), pigmentation of scutellar plate (bk) (36), pigmentation of tergite 2 (32), tergite 3 (33), tergite 4 (34), wing venation angle B4 (22), angle N23 (30) and angle O26 (31), tergite 3(9) and tergite 4 (10) longitudinal. Numbers in brackets indicate Ruttner numbers (1988) (Fig. 3).

Characters associated with size: transversal length of wax plates, longitude of sternite 3, width of tergite 3 and tergite 4 were measured with a Wild M5A binocular dissecting microscope fitted with an ocular micrometer at a magnification power of 25x while the length of cover hair was measured at a magnification power of 50x. The left forewing of worker honeybees from each sample were mounted on projector slides and projected onto Summasketch III digitizer using a slide projector. Wing venation angles were measured using a digitised computer. Characters associated with pigmentation (pigmentation of tergite 2, tergite 3, tergite 4, pigmentation of scutellum (sc) and

scutellum plate (K, B)) were given a value ranging from 0 (completely black) to 9 (bright yellow) based on the Goetze (1940, 1964) and Ruttner (1978) colour code.

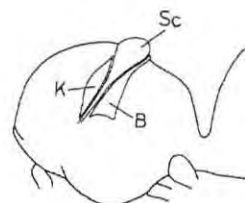
A total of 33800 character measurements from 2600 individual honeybees of 130 honeybee colonies from 26 sampling sites were taken during the course of this study.

Fig. 3. Morphometric characters used to discriminate honeybees of southern Ethiopia region and magnification used to measure each character (X)

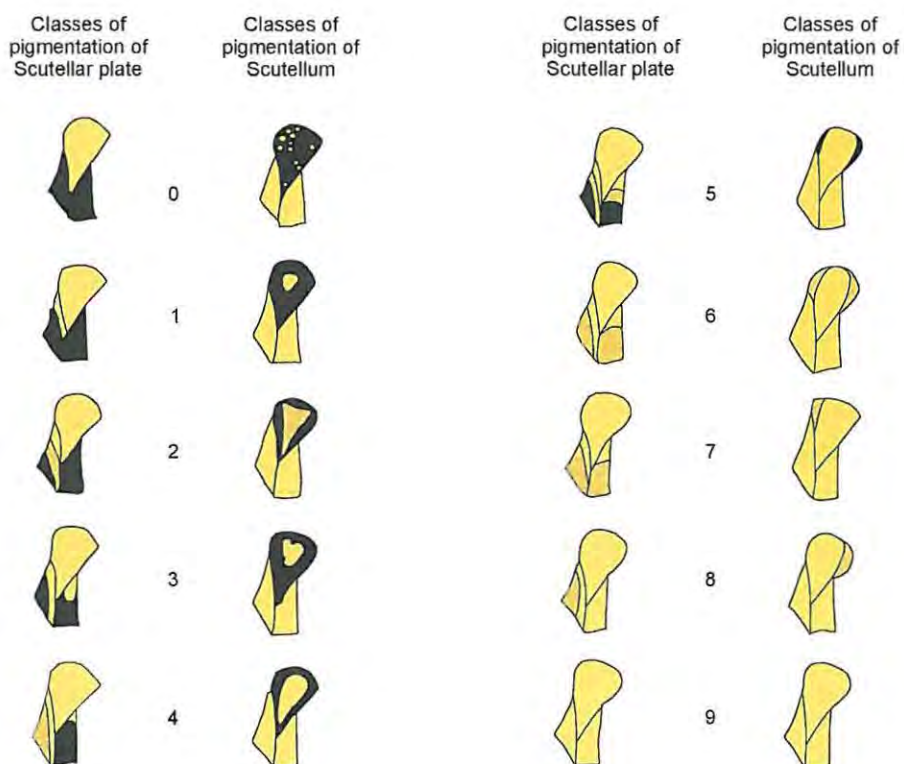
A) Hair length on the fifth abdominal segment (x 50)



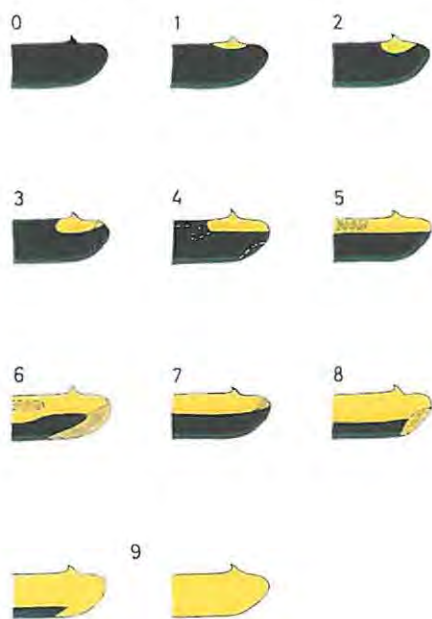
B) Scutellum of honeybees



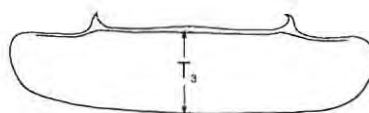
B1) Classes of pigmentation of scutellum(Sc) (35) and scutellar plate (Kb) (36)



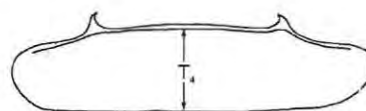
C) Classes of pigmentation of tergite 2-4 (32-35)



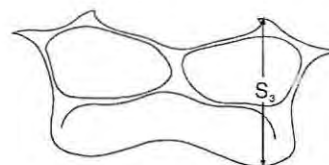
D) Tergite 3 longitudinal (9) X 25



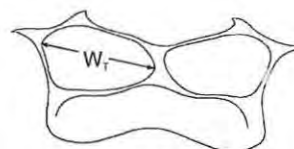
E) Tergite 4 longitudinal (10) X 25



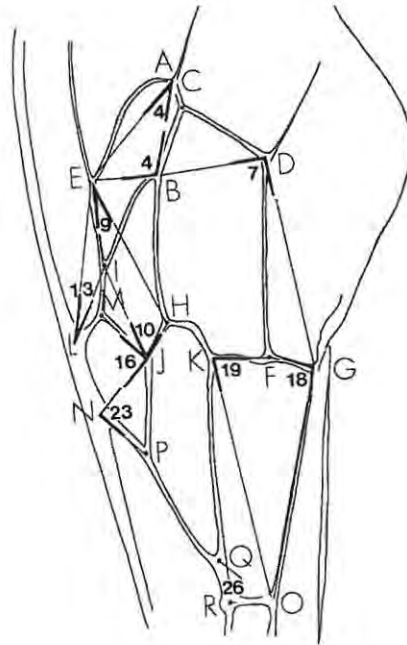
F) Sternite 3 longitudinal (11) X 25



G) Transversal of wax plate on sternite 3 (13) X 25



H) Forewing angles (B4, N23 and O26 (22), (33) and (31) respectively



3.5 Survey work

Along with honeybee sample collection, survey work was also conducted. The main objectives of this survey were to characterise the environmental conditions (climate, honeybee plants, etc.) under which these honeybee populations exist and to determine the behaviour of these honeybees.

A pre-tested questionnaire was structured and designed to collect all necessary data from farmer beekeepers and beekeeping experts (Appendix 9.2). 117 farmer beekeepers from 25 honeybee sampling localities (3-8 farmers from each locality Table 6) were selected on the basis of their skills and extensive beekeeping experience and interviewed on a locality-based questionnaire. An experienced farmer beekeeper in Itang could not be found, as farmers at this particular site do not practice backyard beekeeping, only honey hunting.

The selection of the sample units was conducted after consultation with the District Agricultural Development Department at each respective locality. Selected farmer beekeepers from each locality had between 7-39 years of beekeeping experience and the number of colonies ranged between 3-130 (Table 6). Besides farmer beekeepers, 35 beekeeping experts and technicians working for District or Zone Agricultural Development Departments were interviewed on a pre-structured questionnaire with regard to general information about the woreda (district) and regional beekeeping potential and/or locality. Most of the questionnaires were filled in during group discussion.

In addition to the questionnaire, information was also collected through group discussions with experienced farmer beekeepers and beekeeping developmental workers and from the researchers' personal observations. Relevant data were also collected from Regional Agricultural Development Offices and various other sources.

Table 6. Number of farmer beekeepers and honeybee experts, experience and the number of honeybee colonies owned by the farmers at each locality sampled.

No.	Localities	Number of farmers/ experts interviewed		Beekeeping experience (years)		Number of colonies owned	
		Farmers	Experts	Range	Average	Range	Average
1	Gechi (S1)	3	1	2 - 20	13.3	5 - 90	36.3
2	Itang (S2)	0	2	0	0	0	0
3	Masha (S3)	4	1	10 - 40	21.0	10 - 50	30.0
4	Woshi (S4)	3	1	3 - 20	11.0	5 - 56	25.3
5	Waka (S5)	3	1	3 - 20	9.0	7 - 15	10.0
6	Sodo (S6)	4	1	4 - 11	8.8	5 - 11	8.8
7	Woyito (S7)	4	1	7 - 21	14.8	10 - 20	15.0
8	Konso (S8)	3	1	22 - 30	26.7	10 - 16	13.7
9	Arero (S9)	4	2	3 - 58	17.8	7 - 15	11.8
10	Har Kalo (S10)	6	2	15 - 30	23.3	5 - 20	12.5
11	Eshido Aliyo (S11)	3	2	10 - 50	23.0	15 - 300	130
12	Serofta (S12)	3	1	3 - 17	8.0	2 - 9	4.3
13	Mararo (S13)	3	1	5 - 50	21.7	4 - 8	6.7
14	Woltae Atote (S14)	8	2	2 - 20	9.2	1 - 9	3.1
15	Karre Tule (S15)	6	1	18 - 65	39.8	20 - 59	30.8
16	Dudi Affi (S16)	3	1	6 - 8	7.0	2 - 8	6.0
17	Deriri Arba (S17)	3	1	2 - 25	10.3	6 - 15	9.0
18	Boke Tiko (S18)	4	2	3 - 35	15.4	5 - 19	10.0
19	Nazrieth (S19)	4	1	5 - 20	13.6	2 - 7	5.3
20	Alage (S20)	6	2	10 - 35	23.9	5 - 16	9.5
21	Hosaina (S21)	7	2	5 - 57	28.1	2 - 35	11.0
22	Sawla (S22)	4	1	5 - 45	29.0	64 - 105	66.0
23	Effo Yachi (S23)	5	2	7 - 35	18.8	2 - 50	21.2
24	Boter Bacho (S24)	7	1	3 - 35	12.2	8 - 45	20.4
25	Roge (S25)	5	1	3 - 20	14.0	3 - 15	7.0
26	Gado Lama (S26)	3	1	10 - 40	30.0	4 - 10	7.0
Total		117	35				

NB The traditional beehives used at each locality was indicated by region in appendix 9.1

Table 7. Sampling sites and colony sample sizes by major and sub agro-ecological zones.

No.	MAEZs*	SAEZs**	Sampling sites	No. of sites	Sample size (number)
1	SH1	SH1-7	Gechi (S1), Waka (S5) and Sawla (S22)	3	15
		SH1-1	Itang (Gambella) (S2)	1	5
2	SH2	SH2-6	Roge (S25)	1	5
		SH2-7	Sodo (S6), Serofta (S12), Effen Yachi (S23), Hosaina (S21) and Boter Bacho (S24)	5	25
3	H1	H1-7	Konso (S8)	1	5
4	H2	H2-7	Masha (S3), Woshi (S4), Eshido Aliyo (S11), Gado Lama (S26) and Woltae Atote (S14)	5	25
5	H3	H3-7	Mararo (S13)	1	5
6	SA1	SA1-5	Woyito (S7)	1	5
7	A2	A2-1	Dudi Affi (S16)	1	5
8	M2	M2-1	Har Kalo (S10)	1	5
		M2-5	Arero (S9)	1	5
9	SM1	SM1-1	Karre Tule (S15)	2	10
		SM1-7	Deriri Arba (S17)	1	5
10	SM2	SM2-2	Nazrieth (S19) and Alage (S20)	2	10
		SM2-7	Boke Tiko (S18)	1	5
Total				26	130

* Major agro-ecological zones.

** Sub-agro-ecological zones

3.6 Multivariate analysis

The mean and variances from 20 honeybee workers of each colony were calculated and analysed using multivariate statistical methods. To detect the presence of possible clusters of colonies among the scatter plot of scores on the plane, the principal components analysis method was employed. A stepwise linear discriminant analysis was conducted to verify the separation of clusters, to determine the discriminant function that was used to classify colonies, to determine the most discriminatory variables that entered the linear discriminant function and to determine the percentage of correctly classified colonies.

The significant difference cluster vectors of means of the characters entered into the discriminant function were determined using Wilks' lambda statistic while the likelihood ratio test was employed to envisage the homogeneity of within group covariance matrices. The distribution of the lambda (Λ) statistic was approximated by the F distribution. Quadratic discriminant functions were applied wherever homogeneity tests were found significant. Mahalanobis distances among cluster groups were calculated.

The first unrotated factor score of each morphometric cluster from each honeybee and colony were determined by factor analysis using each character of honeybee and colony means of each character respectively. The intra and intercolonial variances of these factors for each locality were calculated and variance homogeneity was tested using Levene's F statistics. This F-test procedure is based on analysis of variance using the absolute deviation of each case from its locally mean (Brown and Forsythe, 1974).

Correlation analysis was used to determine the relationship within morphometric characters and between morphometrical variations of honeybee populations and

environmental variables: altitude, rainfall, temperature, latitude and longitude. The significance of each correlation variable was tested by Bartlett's statistic. The distribution of this statistic is approximated by the Chi-square distribution. To ensure that the overall level of significance was no larger than 0.05 the sequential Bonferroni method of multiple correlation tests was applied.

3.7 Analysis of the survey data

Non-parametric Kruskal-Wallis ANOVA and parametric ANOVA procedures were used to analyse the survey data. From the survey data collected, the reproductive swarming, swarm-catching and migration rates, the proportion of highly aggressive honeybee colonies and intensity of stings received by a beekeeper during honey harvest were calculated and statistically analysed using Kruskal-Wallis ANOVA as the variances of these data were significantly different and not normally distributed. To detect where the statistically significant difference occur in these data pair-wise Mann-whitney U test was employed. Other data: unoccupied beehive rate, multiple swarming and honey yield were analysed using parametric ANOVA as the data fitted all ANOVA assumptions. The *post hoc* Tukey mean comparison test (HDS) was employed to detect significant mean differences in the data. When necessary transformations (arc sine square root for proportions and square root for counting data) were employed. For other categorical data (to determine swarming, migration, honey periods, aggressive behaviour, cause of migration and factors aggravating aggressive behaviour of honeybees) Pearson chi-square tests were conducted to determine the statistically significant differences among the

results. The Yates chi-square test was used to correct the errors that might occur in Pearson chi-square analysis because it is affected by low frequencies.

Correlation analyses were conducted to determine the relation between honeybee behaviour and climate (rainfall and temperature) and physical environmental variables (altitude, latitude and longitude). To ensure that the overall level of significance was less than 0.05, the sequential Bonferroni method of multiple correlation tests was applied. The homogeneity and normality of the data were tested using Levene's and Shapiro Wilk's W tests respectively.

Chapter Four

4 Results

4.1 Morphometric characteristics of southern Ethiopian honeybees

To morphometrically discriminate southern Ethiopian honeybees 13 morphometric characters used to successfully discriminate African honeybees were measured (Crewe *et al.*, 1994; Radloff *et al.*, 1996; Hepburn and Radloff, 1996). These characters can be grouped into three main categories (with their Ruttner, 1988 numbers in brackets): pigment, including pigmentation of scutellum (35), scutellar plate (36), tergite 2 (32), tergite 3 (33), tergite 4 (34); size, comprising tergite 3 longitudinal (9), tergite 4 longitudinal (10), sternite 3 longitudinal (11), width of wax plate on sternite 3 (13) length of hair on 5th abdominal segment (1); and wing venation angles including angle B4 (22), angle N23 (30) and angle O26 (31).

The measurements of these characters were made on 2600 worker honeybees, collected from 26 different localities in the southern parts of Ethiopia. The means, range and standard deviation of each morphometric character of the honeybees from southern Ethiopia are indicated in Table 8. The statistical results show that the pigmentation values of the scutellum and scutellar plate varied from 0 to 8.05 and 0 to 2.5 with an average of 1.6 ± 2.24 and 0.5 ± 0.59 respectively. While the pigmentation values of abdominal tergite 2 and tergite 3 ranged from 0 to 8.95 with an average of 2.38 ± 2.96 and 2.63 ± 2.82 respectively. The pigmentation of tergite 4 varied from 0 to 8.90 with an average of 2.18 ± 2.41 .

The length of hair on the 5th abdomen segment was short and varied from 0.12mm to 0.23mm with an average length of 0.17 ± 0.02 mm. The width of abdominal tergite 3 and tergite 4 ranged from 1.82mm to 2.18 mm and 1.74mm to 2.11mm with an average of 2.03 ± 0.07 mm and 1.97 ± 0.07 mm in that order. The width of sternite 3 varied from 2.3mm to 2.64mm with an average width of 2.48 ± 0.08 mm while the transversal length of wax plate on sternite 3 ranged from 1.83 to 2.21mm with an average of 2.04 ± 0.07 mm. The angles of the forewing venation of B4, N23 and O26 of the samples from southern Ethiopia varied from 96.00 to 114.90, 83.97 to 92.59 and 32.43 to 43.38 with an average of 104.60 ± 3.14 , 87.53 ± 1.79 and 37.22 ± 1.78 respectively.

Table 8. The means, ranges and standard deviations of morphometric characters of honeybee samples from southern Ethiopia.

NO.	CHARACTERS	MEANS	MINIMUM	MAXIMUM	STD. DEV.
1	SCUTLUM	1.60	0.00	8.05	2.24
2	PLATE	0.50	0.00	2.50	0.59
3	HAIR	0.17	0.12	0.23	0.02
4	TERG 2 PIG	2.38	0.00	8.95	2.96
5	TERG 3 PIG	2.63	0.00	8.95	2.82
6	TERG 4 PIG	2.18	0.00	8.90	2.41
7	TERG 3 LOG	2.03	1.82	2.18	0.07
8	TERG 4 LOG	1.97	1.74	2.11	0.07
9	STR 3 LOG	2.48	2.30	2.64	0.08
10	STR 3 TRS	2.04	1.83	2.21	0.07
11	ANGLE B4	104.60	96.00	114.90	3.14
12	ANGLE N23	87.53	83.97	92.59	1.79
13	ANGLE O26	37.22	32.43	42.38	1.78

SCUTLUM: Pigmentation of scutellum

PLATE: Pigmentation of scutellar plate

HAIR: Length of hair on fifth abdominal segment

TERG2 PIG: Pigmentation of tergite 2

TERG3 PIG: Pigmentation of tergite 3

TERG4 PIG: Pigmentation of tergite 4

TER3 LOG: Width of tergite 3

TER4 LOG: Width of tergite 4

SRT3 LOG: Length of sternite 3

SRT3 TRS: Width of wax plate on sternite 3

ANGLE B4: Wing venation angle B4

ANGLE N23: Wing venation angle N23

ANGLE O26: Wing venation angle O26

4.2 Correlations amongst morphometric characters

Table 9 indicates the correlation matrix of all 13 morphometric characters used to discriminate honeybee colonies of the southern Ethiopian region. Inter-relationships amongst morphometric characters were noted. Significant correlation coefficients varied from -0.26 to 0.99.

A strong positive correlation was observed between colour of the scutellum and the abdominal pigmentation: pigmentation of tergite 2 ($r = 0.97$), tergite 3 ($r = 0.95$), and tergite 4 ($r = 0.94$). These correlations are highly significant ($p < 0.001$) and pigmentation of the scutellum was also weakly negatively correlated with characters associated with body size (width of tergite 3, length of sternite 3, width of wax plate on sternite 3 and length of hair). However, pigmentation of the scutellar plate showed no significant correlation ($p > 0.05$) to all other pigmentation characters (scutellum, tergite 2, tergite 3 and tergite 4), body size (width of tergite 3 and tergite 4, sternite 3 longitudinal (13) and width of wax plate on sternite 3 (11) and forewing venation angles (B4, N23 and O26). These results indicate that, with the exception of the scutellar plate, all pigmentation characters were positively correlated with one another and negatively correlated to all morphometric characters related to body size (except for correlation between scutellum and width of tergite 4). Change of pigmentation in one pigmentation character will also be manifested in other pigmentation characters. It was also found that smaller honeybees are lighter in colour.

The length of hair on the 5th abdominal segment was positively correlated with the body size morphometric characters: width of the 3rd ($r = 0.65$) and 4th ($r = 0.63$) abdominal tergites, longitudinal of the 3rd abdominal sternite ($r = 0.66$), width of wax

plate on sternite 3 ($r = 0.59$), and negatively correlated with all pigmentation characters (except for scutellar plate) and the forewing venation angle O26. Except for angle O26 ($p = 0.003$) in all cases the correlations with pigmentation and body size morphometric characters were highly significant ($p < 0.001$). An increase in the length of hair on the 5th abdominal segment indicates an increase in body size and a darker pigmentation.

Moreover, there were strong positive correlations among the body size morphometric characters (width of tergite 3, tergite 4, longitudinal of sternite 3 and width of wax plate on the sternite 3), used in the discrimination of honeybee colonies of the region. Increase in one of the body size morphometric characters may indicate an increase in other body size characters.

Forewing venation angles (B4, N23 and O26) showed no significant correlations with each other and morphometric characters related to pigmentation. Angle O26 had significant correlation with length of body hair, width of tergite 3 (9) and 4 (10), sternite 3 (13), $p < 0.0038$, but not stronger ($-0.26 < r < -0.35$) while the other two angles (B4 and N23) showed no significant correlation with morphometric characters associated to body size.

Table 9. The correlation matrix amongst morphometric characters used to discriminate southern Ethiopian honeybees (absolute value of $r \geq 0.26$ is significant at $p < 0.0038$).

Ruttner No.	35	36	1	32	33	34	9	10	13	11	22	30	31
35	1												
36	-.24	1											
1	.40	0.03	1										
32	.97	-.24	-.41	1									
33	.95	-.18	-.41	.99	1								
34	.94	-.19	-.37	.98	.99	1							
9	-.30	-.19	.65	-.34	-.38	-.36	1						
10	-.25	-.2	.63	-.3	-.34	-.3	.97	1					
13	-.46	-.06	.66	-.47	-.48	-.47	.83	.80	1				
11	-.35	-.13	.59	-.36	-.38	-.34	.75	.73	.87	1			
22	-.07	.19	.06	-.07	-.07	-.06	.10	.09	.11	.17	1		
30	.02	.08	-.15	-.01	.00	.00	-.15	-.13	-.01	-.07	-.12	1	
31	-.09	.14	-.26	-.07	-.06	-.08	-.34	-.34	-.27	-.15	-.04	.20	1

Level of significance adjusted using Bonferroni procedure, that is significant if $p < 0.0038$.

4.3 Correlation of morphometric characters with the physical environment and climate of the southern Ethiopian region

Table 10 below indicates the correlations of the morphometric characters used to discriminate the southern Ethiopian honeybee colonies with physical environmental factors (latitude, longitude and altitude) and climate (maximum and minimum temperature and rainfall).

The pigmentation of the scutellum was negatively correlated with altitude and rainfall, but positively correlated with minimum and maximum temperatures and longitude. However a smaller correlation was observed with maximum temperature ($r = 0.46$) compared to minimum temperature ($r = 0.51$) (Table 10). Increase in altitude and

rainfall are associated with changes of pigmentation on the scutellum to black. In other words, honeybees at higher altitudes and in high rainfall areas have a darker scutellum. Accordingly with an increase in temperature and decrease in altitude and rainfall this would result in a change of pigmentation on the scutellum to light or yellow. The higher the temperature and the lower the altitude the lighter the pigmentation of the scutellum, which could explain why the lowland southern Ethiopian honeybees have a lighter or yellow scutellum.

Unlike the scutellum, the scutellar plate showed no significant correlation at all with physical environment, altitude and climate of the region (temperature and rainfall). Hence it seems that the pigmentation of the scutellar plate is not dependent on latitude, longitude, altitude, temperature or rainfall.

Like the scutellum, abdominal pigmentation characters (pigmentation of tergite 2, tergite 3, and tergite 4) were also positively correlated with minimum and maximum temperature and negatively correlated with altitude and rainfall. In all cases the correlations were highly significant ($p < 0.001$), showing that these environmental factors have a large effect on the abdominal pigmentation. Honeybees of higher altitudes and rainfall areas would have darker abdominal pigmentation while those honeybees in places with higher temperatures would have lighter or yellow abdominal pigmentation. Pigmentation on tergite 2, tergite 3 and tergite 4 showed a highly positive significant correlation with longitude. This result confirms the above findings, that increases in longitude in the southeastern or eastern parts of the country, which are arid and/or semi-arid lowland, having warm and/or hot temperature result in honeybees that are lighter in colour than those of central parts, which are in relatively cooler areas.

Table 10. Correlations of morphometric characters with physical environment and climate of the study area with corresponding p-values (levels of significance were adjusted using Bonferroni procedure, i.e. significant correlation if p-value < 0.0083).

Ruttner No.	Latitude	Longitude	Altitude	Maximum Temperature	Minimum Temperature	Rainfall
35	.17 (p=.060)	.41 (p=.000)	-.51 (p=.00)	.46 (p=.000)	.51 (p=.000)	-.54 (p=.000)
36	-.17(p=.049)	-.21(p=.018)	.08 (p=.396)	-.07 (p=.397)	-.03 (p=.713)	.21 (p=.017)
1	.27 (p=.002)	.13 (p=.127)	.65 (p=.000)	-.59 (p=.000)	-.66 (p=.000)	.23 (p=.009)
32	.16 (p=.068)	.35 (p=.000)	-.57(p=.000)	.51 (p=.000)	.57 (p=.000)	-.54 (p=.000)
33	.17 (p=.050)	.31 (p=.000)	-.58 (p=.00)	.53 (p=.000)	.58 (p=.000)	-.50 (p=.000)
34	.21 (p=.019)	.36 (p=.000)	-.57(p=.000)	.52 (p=.000)	.56 (p=.000)	-.51(p=.000)
9	.26 (p=.002)	.32 (p=.000)	.62 (p=.000)	-.57(p=.000)	-.67(p=.000)	.03 (p=.762)
10	.29 (p=.001)	.36 (p=.000)	.60 (p=.000)	-.54 (p=.000)	-.65 (p=.000)	.01 (p=.927)
13	.28 (p=.001)	.05 (p=.610)	.57 (p=.000)	-.50 (p=.000)	-.64 (p=.000)	.27 (p=.002)
11	.22 (p=.014)	.14 (p=.115)	.49 (p=.000)	-.43 (p=.000)	-.59 (p=.000)	.15 (p=.094)
22	-.02 (p=.880)	.03 (p=.746)	-.04 (p=.680)	.05 (p=.560)	.02 (p=.815)	-.11(p=.196)
30	-.09 (p=.320)	.03 (p=.736)	.00 (p=.967)	.02 (p=.844)	-.02 (p=.797)	.005 (p=.960)
31	-.34 (p=.000)	-.25(p=.004)	-.13(p=.152)	.09(p=.313)	.12 (p=.188)	0.05 (p = .584)

Length of hair on the 5th abdominal segment was positively correlated with altitude ($r = 0.65$) and weakly with latitude ($r = 0.27$), and negatively correlated with maximum ($r = -0.59$) and minimum ($r = -0.66$) temperatures. This result indicates that honeybees from higher altitudes have longer body hair, as the region is cooler. On the other hand, honeybees from the lowland areas, where the temperatures are higher have

shorter body hair. With an increase in latitude from the southern region to the central highlands, the body hair of honeybees is longer than on those found at lower latitudes, which are mostly lowland areas.

All measured morphometric characters associated with body size (width of tergites 3 and 4, longitude of sternite 3 and width of the wax plate on sternite 3) have positive correlations with altitude and negative correlations with temperature. However, unlike pigmentation, except for the width of the wax plate on sternite 3, there were no significant correlations between body size and rainfall. The correlation between honeybees body size and altitude and temperature showed that the honeybees from higher altitudes have a larger body size than those from lower altitudes, which are usually characterised by higher temperatures. All morphometric characters associated with body size except for the longitudinal measurement of sternite 3 were weakly positively correlated with latitude.

The forewing venation angles (angle B4 and angle N23) showed no correlation with either physical environment (latitude, longitude and altitude) or climate such as temperature and rainfall. On the other hand the forewing venation angle O26 showed weak significant negative correlation with latitude and longitude (Table 10).

4.4 Analysis of variance

Table 11 shows the analysis of variance results for each of the morphometric characters used for discrimination of southern Ethiopian honeybee populations over 26 sampling localities. This result reveals that there was a highly significant variation in pigmentation: scutellum, scutellar plate, tergite 2, tergite 3, tergite 4 and body size: width of tergite 3, tergite 4, longitudinal of sternite 3, width of wax plate on sternite 3 and length of hair on 5th abdominal segment over the sampling localities ($p < 0.0001$). This demonstrates that these pigmentation and body size characters are very useful tools for the discrimination of the honeybee samples from different honeybee populations of southern Ethiopia.

Except for angle O26 all other wing angle venations (angle B4 and angle N23) did not significantly vary between localities ($p > 0.05$), implying that the wing venation angles B4 and N23 showed no discriminatory power for southern Ethiopian honeybees population (Table 11). In other words, unlike the rest of the morphometric characters, these angles made no contribution to the discrimination of south Ethiopian honeybees.

Table 11. Analysis of variance of morphometric characters along the sampling localities in southern Ethiopia.

Characters	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	P
SCUTLUM (35)	516.30724	25	20.65229	133.35500	104.00000	1.28226	16.10617	0.00000
PLATE (36)	24.07156	25	0.96286	20.28000	104.00000	0.19500	4.93776	0.00000
HAIR (1)	0.05184	25	0.00207	0.01672	104.00000	0.00016	12.90093	0.00000
TERG2PIG (32)	924.43916	25	36.97757	209.24699	104.00000	2.01199	18.37860	0.00000
TERG3PIG (33)	820.28502	25	32.81140	203.42000	104.00000	1.95596	16.77507	0.00000
TERG4PIG (34)	606.78792	25	24.27152	139.96800	104.00000	1.34585	18.03439	0.00000
TER3LOG (9)	0.54276	25	0.02171	0.11186	104.00000	0.00108	20.18432	0.00000
TERG4LOG (10)	0.57280	25	0.02291	0.13240	104.00000	0.00127	17.99792	0.00000
SRT3LOG (11)	0.64508	25	0.02580	0.16271	104.00000	0.00156	16.49292	0.00000
SRT3TRS (13)	0.49355	25	0.01974	0.17584	104.00000	0.00169	11.67618	0.00000
ANGLEB4 (22)	314.88342	25	12.59534	955.79073	104.00000	9.19030	1.37050	0.13747
ANGLEN23 (30)	102.10808	25	4.08432	310.72798	104.00000	2.98777	1.36701	0.13936
ANGLEO26 (31)	157.72905	25	6.30916	251.15567	104.00000	2.41496	2.61253	0.00037

In order to establish the variation indicated in the analysis of variance and to identify for which sampling localities the mean differences of each morphometric character occurred, Tukey *post hoc* mean comparison tests (HSD) were conducted (Tables 55.1-13).

Accordingly, except for the forewing venation angles: B4 and angle N23 (which were not significant over all localities) and angle O26 (which was significant over only four localities, Tables 55.11-13), the means of each other morphometric character were found to be highly significantly different ($p < 0.0001$) over many of the sampling localities. This conforms that all morphometric characters used (with the exception of forewing venation angles) were important for discrimination of honeybees of the

southern Ethiopian region and reveals that honeybee samples were not from the same population of southern Ethiopia as indicated in the analysis of variance.

4.5 Multivariate results

The principal components analysis of 13 morphometric characters of 2600 worker honeybees from 130 colonies of 26 localities was carried out to classify morphometric characters and select the most important ones which would detect the possible morphoclusters in southern Ethiopian honeybee populations.

Accordingly, four factors with eigenvalues greater than one were isolated (Table 12): Factor 1: associated with colour, including pigmentation of scutellum (35), abdominal tergite 2 (32), tergite 3 (33) and tergite 4 (34); Factor 2 related to body size: width of abdominal tergite 3 (9), width of tergite 4 (10), length of sternite 3 (11), width of wax plate on sternite 3 (13) and length of hair on the 5th abdominal segment (1); Factor 3: pigmentation of scutellar plate (36), forewing venation angle B4 (22); and Factor 4: including angle N23 (30) and angle O26 (31) (Table 13). These factors accounted for 81.3% of variance in the data (Table 12). Factor 1 alone accounted for 43.76% of the total variance, while factor 2 and factor 3 accounted for 20.84% and 8.98% of variance in the data respectively. The remaining balance of (7.72%) variation in the data was accounted for by the fourth factor.

The factor loading of each morphometric character is indicated in Table 13. Each character had an absolute value greater than 0.54. Except for the scutellar plate, all morphometric characters related to pigmentation had the highest factor loading values (greater than 0.96) followed by body size characters (greater than 0.86). This result

revealed that morphometric characters associated with pigmentation and body size are very useful characters for discrimination of southern Ethiopian honeybees.

The graph of scores was plotted using the two factors that had the highest discriminatory power: Factor 1 and Factor 2. The graph (Fig. 4) shows the formation of four clusters or groups. Colonies from Itang (Gambella) (S2) and Woyito (S7) form group 1 in the upper and lower left-hand quadrant of the plot; colonies from Korre Tule (S15), Dudi Affi (S16) and Deriri Arba (S17) formed group 2 in the upper left-hand quadrant of the plot; colonies from Serofta (S12), Mararo (S13), Alage (S20), Hosaina (S21), Effo Yachi (S23), Boter Bacho (S24), Roge (woliso) (S25), Boke Tiko (S18) and Gado Lama (S26) formed group 3 in the upper right-hand quadrant of the plot and colonies from Gechi (S1), Masha (S3), Woshi (S4), Waka (S5), Sodo (S6), Arero (S9), Har Kalo (S10), Eshido Aliyo (S11) and Sawla (S22) formed group 4 in the lower right hand of quadrant of the plot. Colonies from Woltae Atote (S14) were scattered into groups 2, 3 and 4; colonies from Konso (S8) into group 1, 2 and 4 and colonies from Nazrieth (S19) distributed to group 2 and 4.

All the morphometric characters without pigmentation could not clearly separate the groups. In other words, the plot failed to produce the same morpho-groups when the pigmentation characters were excluded (Fig. 5). On the other hand, using only pigmentation three distinct morpho-groups were obtained (Fig. 6) showing that the pigmentation characters are very useful morphometric characters in discriminating the southern honeybee populations of Ethiopia.

Table 12. Factors extracted and total variances caused by each factors in the southern Ethiopian honeybee population.

Factors	Eigenvalues	Percent of total variance	Cumulative eigenvalues	Percent of cumulative variances
1	5.688879	43.76061	5.688879	43.76061
2	2.709069	20.83899	8.397947	64.59959
3	1.16718	8.978311	9.565128	73.57791
4	1.003439	7.718761	10.56857	81.29667

Table 13. Factor loadings of each character extracted in the principal components analysis.

Characters	Factor 1	Factor 2	Factor 3	Factor 4
Scutellum	0.962*	0.154	0.059	0.001
Scutellar plate	-0.280	0.244	-0.649*	-0.145
Hair	-0.309	-0.694*	-0.052	0.142
Tergite 2 pigment	0.973*	0.185	0.050	0.015
Tergite 3 pigment	0.965*	0.216	0.015	0.005
Tergite 4 pigment	0.966*	0.181	0.015	0.008
Tergite 3 width	-0.180	-0.927*	0.036	0.109
Tergite 4 width	-0.130	-0.925*	0.045	0.093
Sternite 3 longitudinal	-0.329	-0.874*	-0.429	0.032
Sternite 3 transversal	-0.207	-0.862*	-0.087	-0.075
Angle B4	0.021	-0.139	-0.853*	0.123
Angle N23	0.024	0.040	0.068	-0.896*
Angle O26	-0.173	0.374	-0.073	-0.544*
Explained variance	4.143	4.062	1.181	1.182

* morphometric characters in each factor

Fig. 4. Factor scores plot using the most discriminant factor scores Factor 1 (pigmentation) and Factor 2 (related to body size). The plot indicates the formation of four groups.

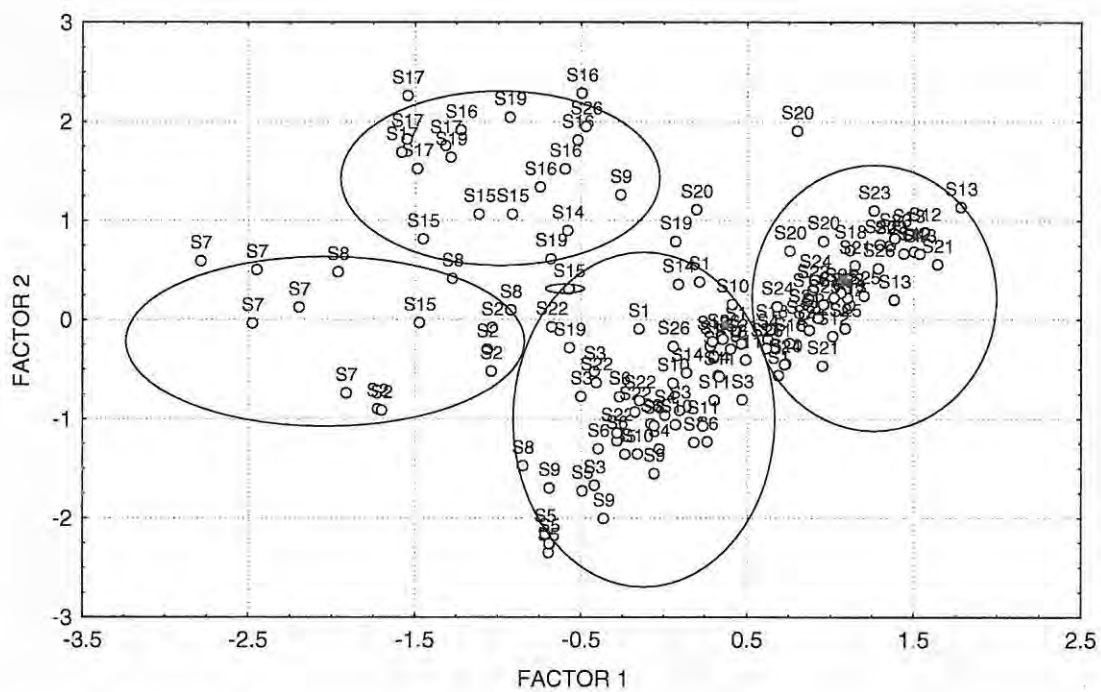


Fig. 5. Factor scores plot using morphometric characters excluding those of pigmentation.

The plot indicates no distinct groups

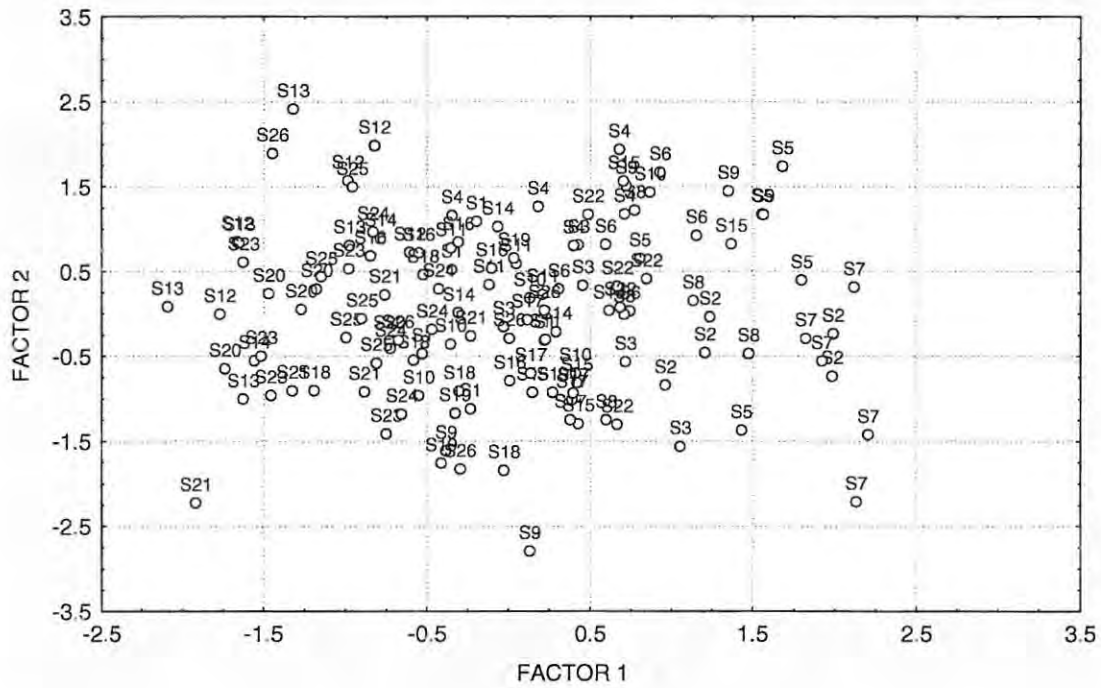
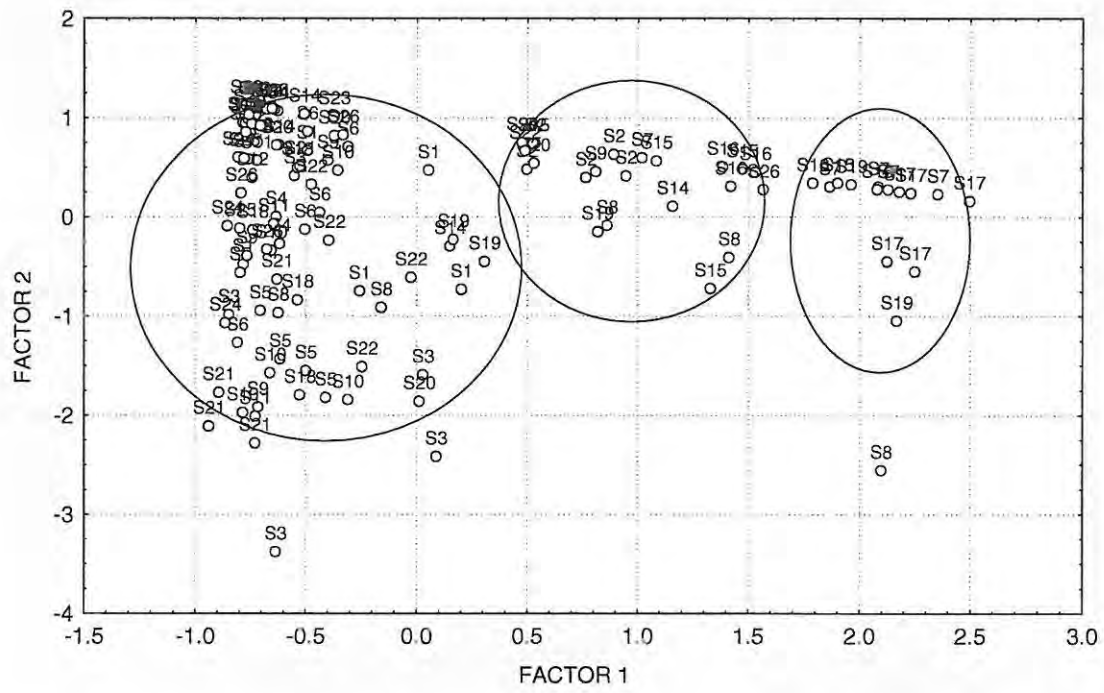


Fig. 6. Factor scores plot using pigmentation only. The plot shows three separate groups



Stepwise discriminant analysis using the colony means of the morphometric characters confirmed the separation of the four groups obtained by the principal components analysis (Fig. 7). The 3 forewing venation angles did not enter the discriminant functions due to lack of discriminatory power in these characters for discrimination of honeybees of southern Ethiopian region. Thus, 10 morphometric characters were entered into the linear discriminant functions (Table 15). These were ranked according to their discriminatory power. Accordingly, pigmentation of tergite 4, width of tergite 3 and length of hair on the 5th abdominal segment were identified as the first, second, and third most powerful discriminatory characters of the southern Ethiopian honeybee populations and were followed in order of importance, by pigmentation of tergite 3, tergite 2, scutellum, scutellar plate, width of wax plate on sternite 3, length of sternite 3 and width of tergite 4.

In the linear discriminant analysis the characters associated with pigmentation and body size were once again entered into the discriminant function. Using these functions 94.78% of the honeybee colonies were correctly classified in four groups (Table 14). Table 16 shows the Mahalanobis distance among the groups. The D^2 , Mahalanobis distance between group 1 and group 2 is 22.7; between group 1 and group 3 is 61.46; between group 1 and group 4 is 31.36; between group 2 and group 3 is 52.78; between group 2 and group 4 is 40.43 and between group 3 and group 4 is 11.36, indicating that that groups 3 and 4 are closer to each other than the other groups. Each colony was assumed to have an equal probability of being in any one of the groups.

Table 14. Classification matrix obtained by discriminant analysis.

Groups	Percent of colonies correctly classified	Predicted classification			
		Group 1 p = 0.0869	Group 2 p = 0.1304	Group 3 p = 0.39130	Group 4 p = 0.39130
Group 1	100	10	0	0	0
Group 2	93.3333	1	0	14	0
Group 3	93.3333	0	0	42	3
Group 4	95.5556	0	0	2	43
Total	94.7826	11	14	44	46

Table 15. Morphometric characters entered into the discriminant function ranked according to their discriminatory power.

Rank	Characters entered into function	F to enter	Df	P- value
1	Tergite 4 pigment	125.42	3, 111	0.0000
2	Tergite 3 width	73.549	3, 110	0.0000
3	Hair	11.562	3, 109	0.0000
4	Tergite 3 pigment	8.3131	3, 108	0.0001
5	Tergite 2	10.154	3, 107	0.0000
6	Scutellum	4.4014	3, 106	0.0058
7	Scutellar plate	2.4502	3, 105	0.0676
8	Sternite 3 (11)	1.9101	3, 104	0.1325
9	Sternite 3 (13)	2.1741	3, 103	0.0956
10	Tergite 4	1.8073	3, 102	0.1506

Table 16. Squared Mahalanobis distances (D^2) between the four groups of honeybees.

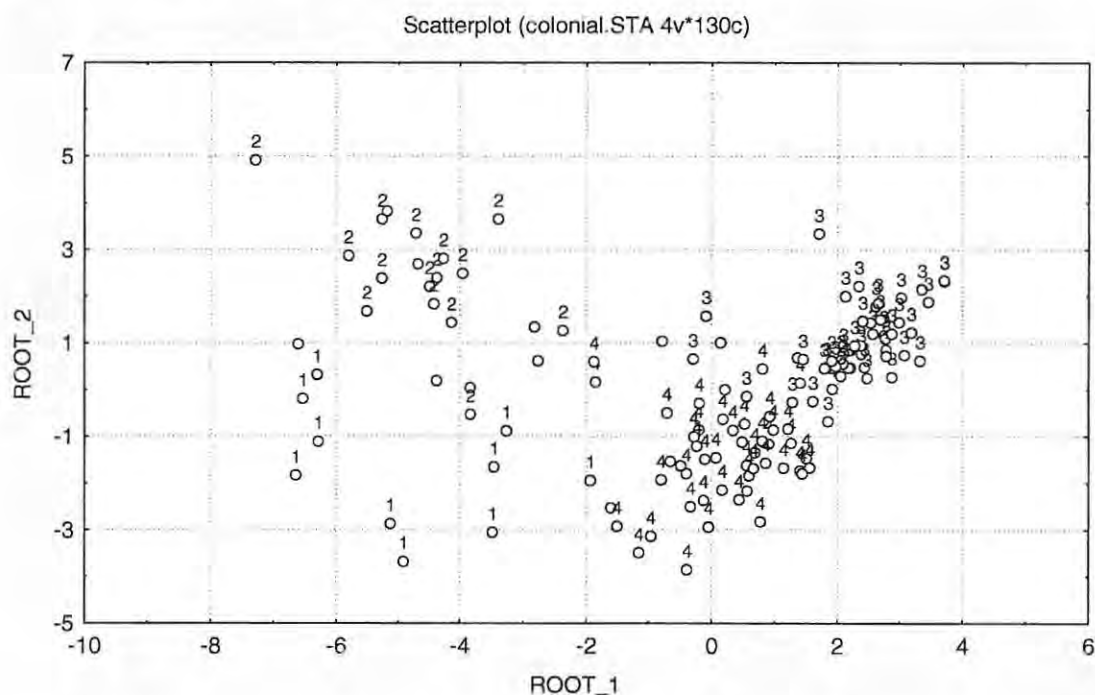
Groups	Group 1	Group 2	Group 3	Group 4
Group 1	0	22.7595	61.4603	31.36239
Group 2	22.7595	0	52.7793	40.4274
Group 3	61.46032	52.7793	0	11.36126
Group 4	31.36239	40.4274	11.3613	0

The linear discriminant function resulting from the most discriminatory morphometric characters (Table 15) classified 100% of colonies from Itang and Woyito correctly into group 1 with posterior probabilities of $p = 0.97 - 1.00$ for 19 colonies and $p = 0.71$ for one colony from Woyito. 93.33% of the colonies from Karre Tule, Dudi Affi, and Deriri Arba were correctly classified into group 2 with posterior probabilities of $p = 0.997 - 1.00$ for 13 colonies, $p = 0.95$ for one colony and one colony from Karre Tule was misclassified into group 1 with posterior probability of $p = 0.996$. 93.33% colonies from Serofta, Mararo, Boke Tiko, Alage, Hosaina, Boter Bacho, Effo Yachi, Roge and Gado Lama were correctly classified into group 3 with posterior probabilities of $p = 0.913 - 1.00$ for 41 colonies and $p = 0.751$ for one colony from Gado Lama; three colonies from this localities were misclassified: one colony from Gado Lama into group 4 with posterior probability of $p = 0.593$ and two colonies from Boke Tiko into group 4 with posterior probability of $p = 0.703$ and $p = 0.561$. 95.56% of colonies from Gechi, Masha, Woshi, Waka, Sodo, Arero, Har Kalo, Eshido Aliyo and Sawla were classified correctly into group 4 with posterior probabilities $p = 0.80 - 1.00$ for 40 colonies and $p =$

0.76 for one colony from Eshido Aliyo and $p = 0.57$ for one colony from Har Kalo. Moreover, two colonies from the group were misclassified: one colony from Woshi into group 3 and one colony from Har Kalo into group 3 with the posterior probabilities of $p = 0.93$ and $p = 0.737$ respectively (Table 54).

Colonies from Konso were distributed among three groups: one colony to group 1, two colonies to group 2 and the remainder to group 4. In the same way colonies from Woltae Atote were scattered among the three groups: one colony into group 2, two colonies into group 3 and two colonies into group 4; three colonies from Nazrieth joined group 2 and the other two colonies group 4, revealing that honeybees of Konso, Woltae Atote and Nazrieth exhibited intermediate morphometric scores which might indicate a hybridisation or transitional zone.

Fig. 7. Discriminant plot using the most discriminatory functions (root 1 and root 2) and the formation of four clear groups (G1, G2, G3 and G4)



The score of factor 1 of each honeybee were computed and the variances of these factor scores were used to test the homogeneity of the intracolony variances at each locality. A highly significant variation was found between the intracolony variances over all localities (Levene's test $F = 37.89$, $df (25, 2574)$, $p < 0.001$). The variance values obtained from Itang, Konso, Woltae Atote, Karre Tule, Dudi Affi, Nazrieth, Alage, Sawla and Gado Lama (Table 17) were very large compared to the other localities.

Intercolony variances were also computed in a similar way, except that colony mean was used to determine the colony factor scores for each colony. A significant difference in variances was found among the localities (Levene's test $F = 1.85$, $df (25, 104)$, $p < 0.0167$) (Table 17). Higher variances were again obtained from Konso, Woltae

Atote, Nazrieth and Gado Lama, suggesting a high degree of hybridisation at these localities.

Table 17. Intercolonial and intracolony variances of factor scores of morphometric characters for each locality (Values > 0.50 and > 0.71 in inter and intra colonial variance respectively are significantly larger than others).

Locality	Intercolonial	Intracolony
Gechi (S1)	0.30736	0.437646
Itang (S2)	0.36650	0.935907*
Masha (S3)	0.42277	0.653483
Woshi (S4)	0.26547	0.305812
Waka (S5)	0.20579	0.457045
Sodo (S6)	0.25882	0.499696
Woyito (S7)	0.32722	0.595715
Konso (S8)	0.69211*	0.916148*
Arero (S9)	0.36923	0.6076
Har Kelo (S10)	0.35041	0.678218
Eshido Aliyo (S11)	0.17336	0.402105
Serofta (S12)	0.31934	0.345266
Mararo (S13)	0.24246	0.280801
Woltae Atote (S14)	0.77956*	0.951625*
Korre Tule (S15)	0.37887	0.976975*
Dudi Affi (S16)	0.29931	0.819448*
Deriri Arba (S17)	0.10591	0.285968
Boke Tiko (S18)	0.32267	0.43345
Nazrieth (S19)	0.50044*	0.902643*
Alge (S20)	0.39956	0.816503*
Hosaina (S21)	0.43158	0.417371
Sawla (S22)	0.21638	0.842639*
Effo Yachi (S23)	0.20502	0.422823
Boter Bacho (S24)	0.11161	0.279099
Roge (woliso) (S25)	0.09070	0.316228
Gado Lama (S26)	0.65416*	0.712972*

* high variances

4.6 Morphometric characteristics of the groups

Table 18 indicates the group means and standard deviations of the morphometric characters used in the discriminant functions (wing angles were not included in the model). The Wilks' lambda value approximated by F-statistic revealed significant differences among the means of the four groups ($\Lambda = 0.0256$, $F(30, 300) = 24.28$, $p < 0.0001$)

Table 18. Means and standard deviations of morphometric characters of each group of honeybees (measurements in mm, angles in degree).

Characters and Ruttner No.	Group 1 (n=10)		Group 2 (n= 15)		Group 3 (n= 45)		Group 4 (n= 45)	
	Mean	St.dev.	Mean	St.dev.	Mean	St.dev.	Mean	St.dev.
Scutellum (35)	4.13	2.11	5.47	1.25	0.34	0.94	0.52	0.70
Plate (34)	0.04	0.07	0.11	0.22	0.41	0.56	0.81	0.63
Hair (1)	0.13	0.01	0.16	0.02	0.19	0.02	0.17	0.02
T2 pig. (32)	6.44	1.96	7.28	1.60	0.62	1.44	1.03	1.15
T3 pig. (33)	6.43	2.00	7.17	1.57	0.87	1.43	1.53	1.19
T4 pig. (34)	4.95	1.71	6.36	1.46	0.65	0.98	1.23	1.00
T3 width (9)	1.92	0.05	2.037	0.04	2.10	0.04	1.99	0.04
T4 width (10)	1.84	0.05	1.98	0.05	2.04	0.04	1.93	0.04
St3 long (11)	2.35	0.04	2.44	0.05	2.55	0.05	2.45	0.05
St3 width (13)	1.93	0.05	2.02	0.06	2.08	0.05	2.02	0.06
Angle B4 (22)	104.5	4.46	104.1	2.85	104.9	3.22	104.2	2.92
Angle N23 (30)	86.97	1.21	87.68	1.94	87.03	1.58	88.02	2.07
Angle O26 (31)	38.17	1.43	36.45	1.50	36.61	1.63	38.00	1.72

4.6.1 Morphometric characteristics of Group 1 honeybees

The pigmentation values of the scutellum ranged from 2.25 to 8.00 with an average of 4.13 and standard deviation of 2.11 and about 70% of the population have mean scutellum pigmentation values between 2 and 4. The scutellar plate varied from 0 to 0.2 with an average of 0.04 and standard deviation of 0.07. The colour of abdominal tergite 2 and tergite 3 ranged from 4 to 9 and that of tergite 4 ranged from 2.5 to 7.8 with averages of 6.44 ± 1.96 , 6.43 ± 2.00 and 4.95 ± 1.71 respectively. The pigmentation values for tergite 2, tergite 3 and tergite 4 are greater than 5 for 60%, 60% and 40% of the population respectively. However, the group is predominantly yellow but the wide range shows that these populations are also comprised of black honeybees. The proportion of yellow to black honeybees in the group is 2.33 : 1 (Table 48). Pigmentation of the scutellar plate is darker than the scutellum and the pigmentation of tergites 2 and 3 is brighter than the fourth tergite.

The length of hair on the fifth abdominal tergite ranged from 0.12 to 0.17mm with an average of 0.13 ± 0.01 and 70% of the population had cover hair length of between 0.12 and 0.15mm (Fig. 10). The width of tergite 3 and tergite 4 ranged from 1.80 to 2.00 and 1.75 to 1.91 (Figs. 14 and 15) with an average of 1.92 ± 0.05 and 1.84 ± 0.05 mm in that order (Table 18). The length of sternite 3 and the width of the wax plate on sternite 3 ranged from 2.30 to 2.43 and 1.83 to 2.01 (Figs. 16 and 17) with an average of 2.35 ± 0.04 and 1.93 ± 0.05 mm respectively. 70% of the group 1 honeybee population had a tergite 3 width of between 1.80 and 1.95mm and a tergite 4 width between 1.80 and 1.90mm, while 80% of the population had a sternite 3 length of between 2.3 and 2.4mm and width of the wax plate on sternite 3 between 1.85 and 2.00mm.

4.6.2 Morphometric characteristics of Group 2 honeybees

The scutellum pigmentation of honeybees from group 2 varied from 3 to 7.5 (Fig. 8) with an average of 5.47 ± 1.25 and pigmentation of the scutellar plate ranged from 0 to 0.7 (Fig. 9) with an average of 0.11 ± 0.22 , showing that pigmentation of the scutellum varied widely among honeybees of group 2 compared to pigmentation of the scutellar plate. About 66.67% of the population had scutellum pigmentation values between 5 and 7. The abdominal pigmentation: tergites 2, 3 and 4 varied from 4 to 8.8, 3.8 to 9 and 2.5 to 7 (Figs. 11-13) with an average of 7.28 ± 1.6 , 7.17 ± 1.57 and 6.36 ± 1.46 respectively. 87% and 73.33% of group 2 honeybee populations had pigmentation values of tergite 2 and tergite 3 greater than 5 respectively and 53.33% had pigmentation values of tergite 4 greater than 5. The means indicate that all three abdominal tergites are yellow in colour while the range shows that black honeybees also occur in the population. Hence the group consists of mixed yellow and black honeybees. The black honeybees in the population account for about 13% (Table 48).

The length of hair on the fifth abdominal segment ranged from 0.13 to 0.20mm (Fig. 10) and with an average of 0.16 ± 0.02 mm. About 80% of the population had hair length of between 0.14 and 0.18mm (Fig. 10). The width of abdominal tergite 3 and tergite 4 varied from 2.0 to 2.1, and 1.9 to 2.08mm (Figs. 14 and 15) with an average of 2.03 ± 0.04 and 1.98 ± 0.05 mm in that order; while the length of sternite 3 and width of the wax plate on sternite 3 ranged from 2.35 to 2.53mm and 1.93 to 2.13mm (Figs. 16 and 17) with an average of 2.44 ± 0.05 and 2.02 ± 0.06 mm respectively. 73.33% of the population have tergite 3 width of between 1.95 and 2.05mm and 80% the population have a tergite 4 width of between 1.90 and 2.00mm, while 86.67% have a sternite 3

length of between 2.36 and 2.5mm and width of the wax plate on sternite 3 of between 1.95 and 2.1mm. The honeybees of group 2 are brighter coloured and are larger than the group 1 honeybees.

4.6.3 Morphometric characteristics of Group 3 honeybees

The scutellum of the group 3 honeybees was darker than that of either group 1 or group 2. It ranged from 0 to 5.5 with an average of 0.34 ± 0.94 and the pigmentation values of scutellar plate varied from 0 to 2 with an average of 0.41 ± 0.56 . The abdominal tergites (tergites 2, 3 and 4) were generally dark in colour, having a pigmentation range from 0 to 8, 0 to 7.5 and 0.1 to 5 and an average of 0.62 ± 1.44 , 0.87 ± 1.43 and 0.65 ± 0.98 in that order. 91.1% of the group 3 honeybees had pigmentation values of the three tergites less than 2, showing that dark honeybees dominate the population. The range of values (Figs. 11-13) indicates that yellow honeybees exist among the population. The black honeybees in the population account for about 93% of the total population.

The length of hair ranged from 0.14 to 0.23mm, with an average of 0.19 ± 0.02 mm and 95.56% of the population had hair length of between 0.16 and 0.22mm. The width of abdominal tergite 3 and tergite 4 varied from 2.03 to 2.2mm and 1.95 to 2.12mm (Figs. 14 and 15) with an average of 2.10 ± 0.04 mm and 2.04 ± 0.04 mm in that order. The length of sternite 3 and width of the wax plate on sternite 3 ranged from 2.4 to 2.65mm and 1.97 to 2.21mm (Figs. 16 and 17) with an average of 2.55 ± 0.05 mm and 2.09 ± 0.06 mm respectively. Width of tergite 3 in 93.33% of the population was between 1.95 and 2.05mm (Fig 14). Width of tergite 4 in 80% of the population was between 1.9 and 2 mm (Fig. 15). The length of sternite 3 in 86.67% of the population was between

2.36 and 2.5mm (Fig. 16) and the width of the wax plate on sternite 3 was between 1.95 and 2.1mm (Fig. 17).

4.6.4 Morphometric characteristics of Group 4 honeybees

The pigmentation of the scutellum of the group 4 honeybees varied from 0 to 3 with an average of 0.52 ± 0.70 and the scutellar plate ranged from 0 to 2.5 with an average of 0.50 ± 0.63 , showing both characters are in the range of black colouration. The abdominal tergite 2 ranged from 0 to 5.5 with an average of 1.03 ± 1.15 ; tergite 3 ranged from 0.1 to 5 with an average of 1.53 ± 1.89 and tergite 4 ranged from 0 to 4 with an average of 1.23 ± 1.00 . Pigmentation variability among the population is low compared to group 3 (Figs. 11-13). As indicated in the box plot, 97.78% of the group 4 honeybee population have pigmentation values of tergite 2 and tergite 4 equal to or less than 2 showing that the group is black in colour.

The length of hair ranged from 0.13 to 0.21 with an average of 0.17 ± 0.02 mm and about 91.11% of the population have hair length of between 0.14 and 0.19mm. The width of tergite 3 ranged from 1.89 to 2.08mm with an average of 1.99 ± 0.04 mm and tergite 4 varied from 1.82 to 2.01mm with an average of 1.93 ± 0.04 mm. The length of sternite 3 and width of the wax plate ranged from 2.37 to 2.58mm and 1.92 to 2.16mm with an average of 2.45 ± 0.08 mm and 2.02 ± 0.07 mm respectively. Width of tergite 3 and longitudinal sternite 3 in 77.78% of the group 4 honeybees were between 1.95 and 2.05mm and 2.4 and 2.55mm respectively. The width of tergite 4 and transversal wax plate on sternite 3 in 75.56% of the population were between 1.85 and 1.95mm and 1.95

and 2.1mm respectively. The honeybees of group 4 are lighter in colour and smaller in size than those in group 3.

Fig. 8. Range and comparison of scutellum pigmentation by group.

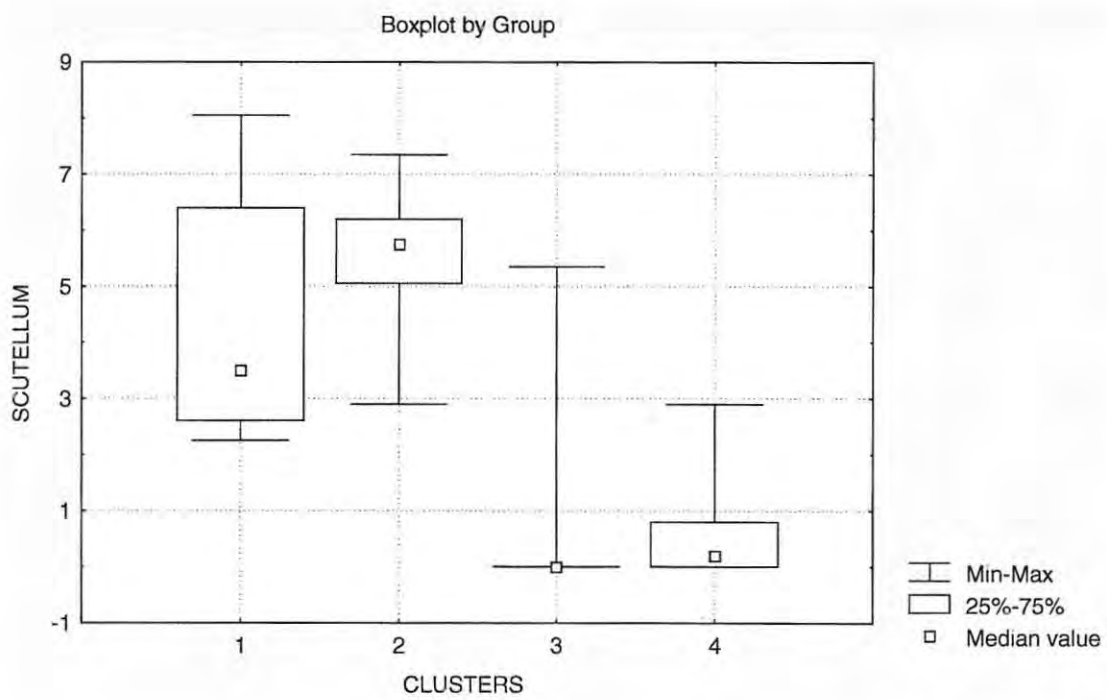


Fig. 9. Range and comparison of scutellar plate pigmentation by group.

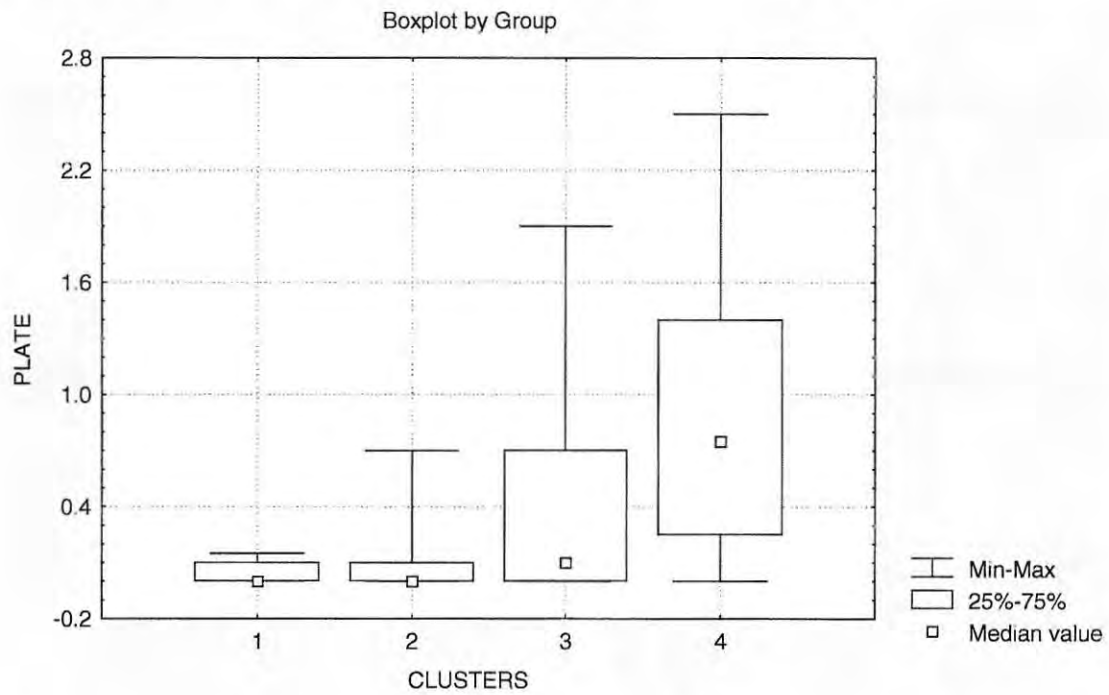


Fig. 10. Range and comparison of length of cover hair by group.

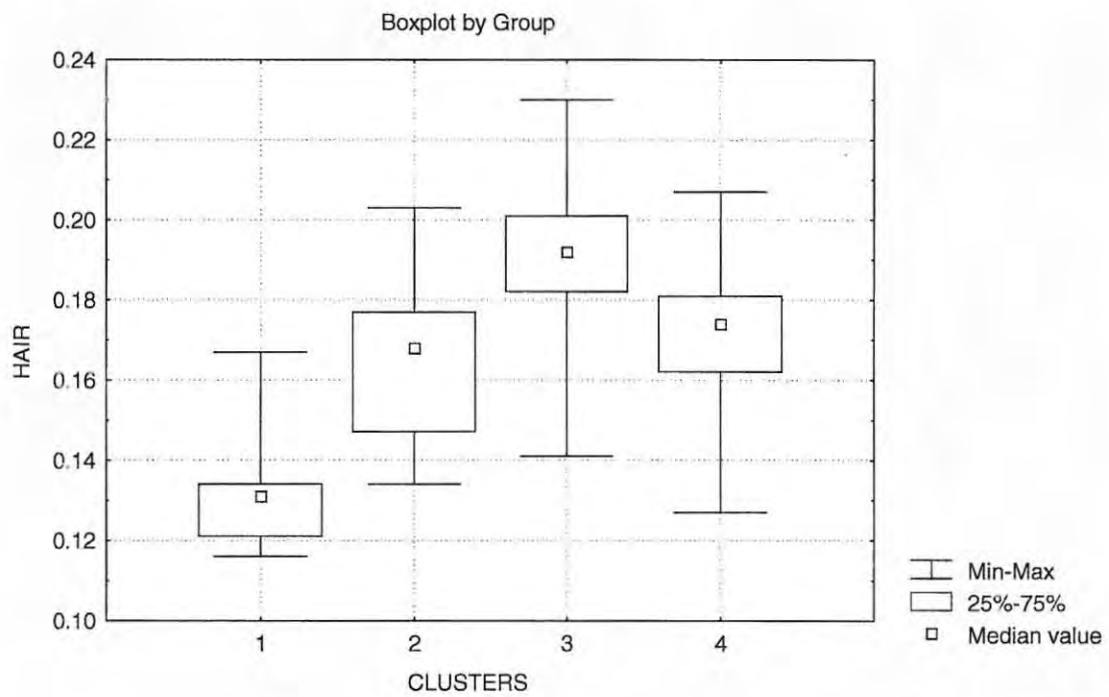


Fig. 11. Range and comparison of tergite 2 pigmentation by group.

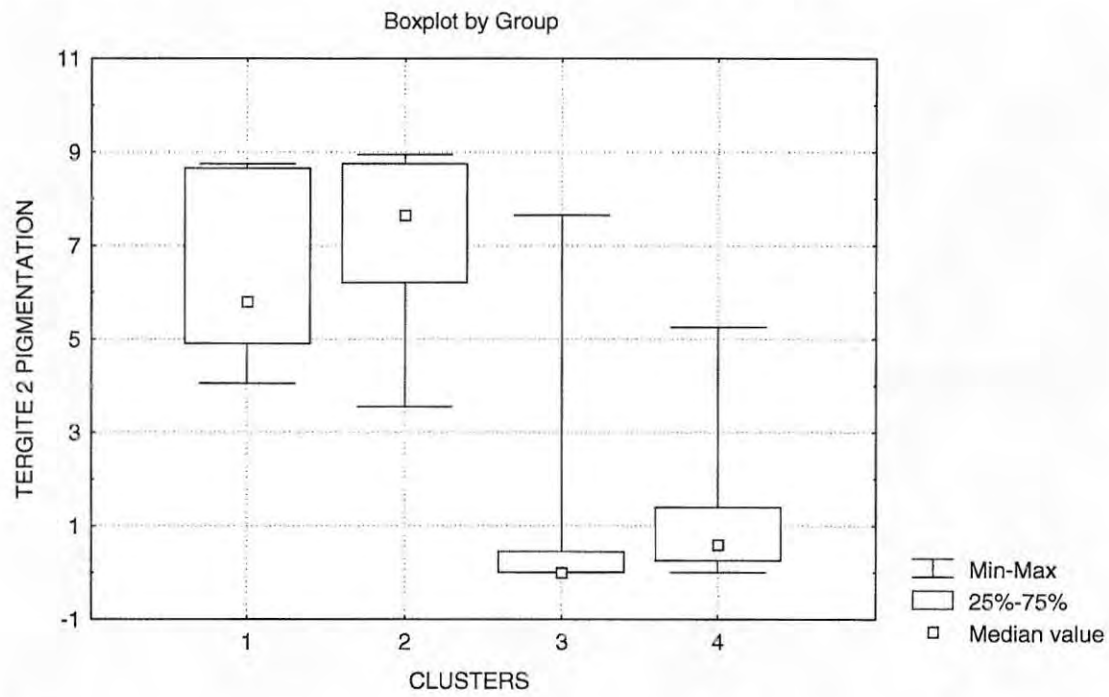


Fig. 12. Range and comparison of tergite 3 pigmentation by group.

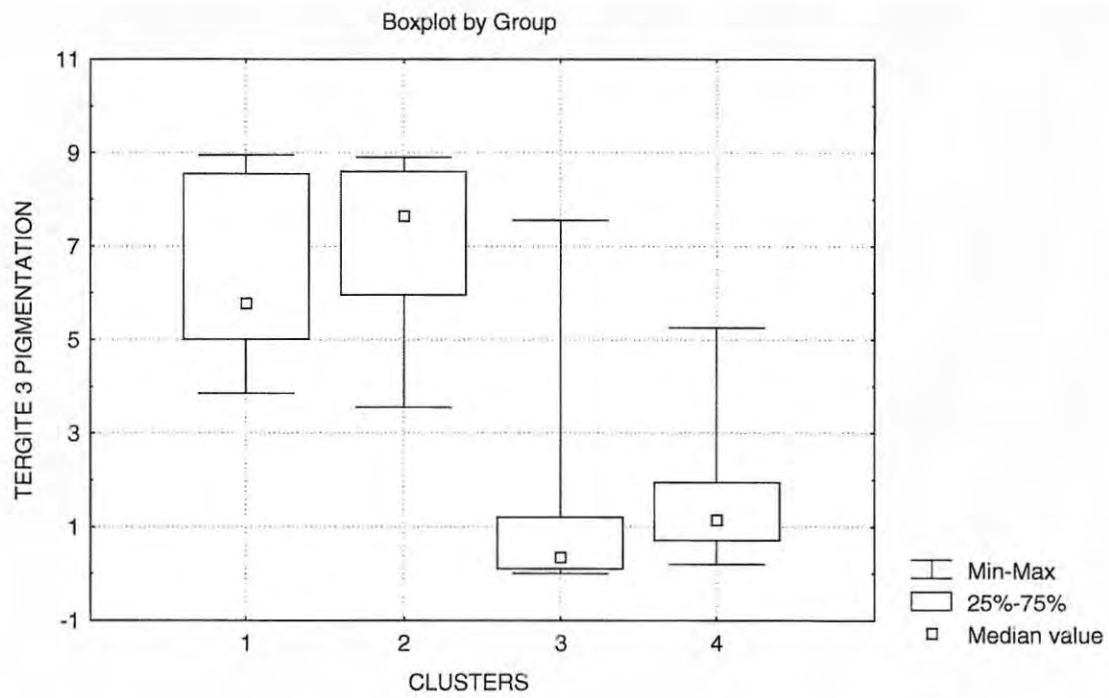


Fig. 13. Range and comparison of tergite 4 pigmentation by group.

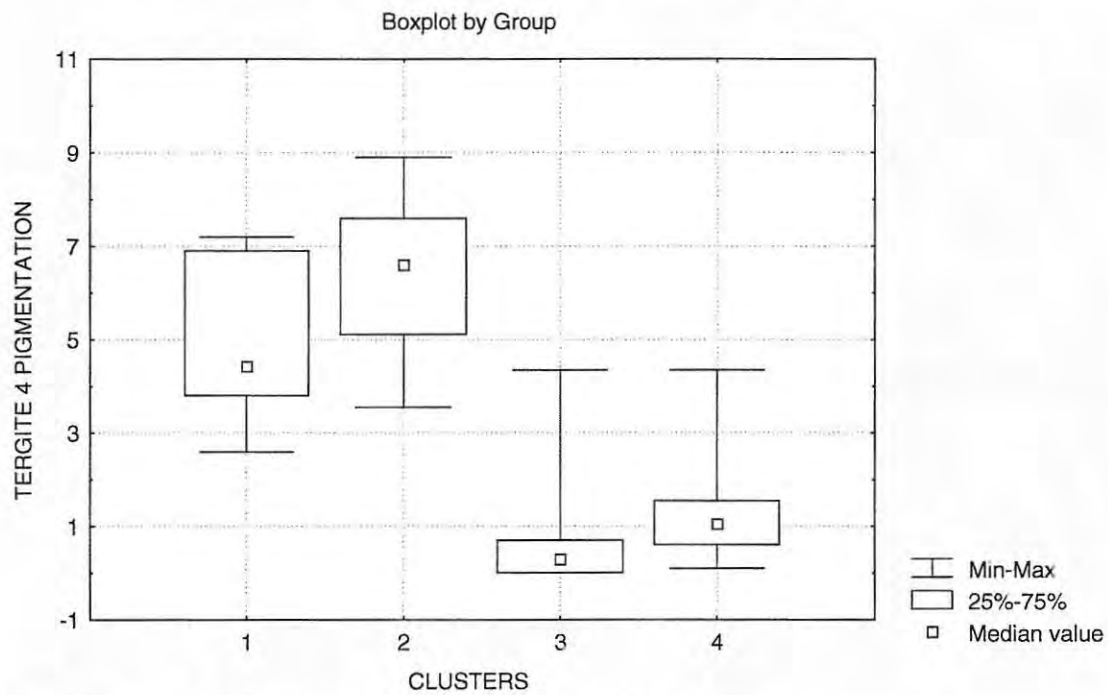


Fig. 14. Range and comparison of width of tergite 3 by group.

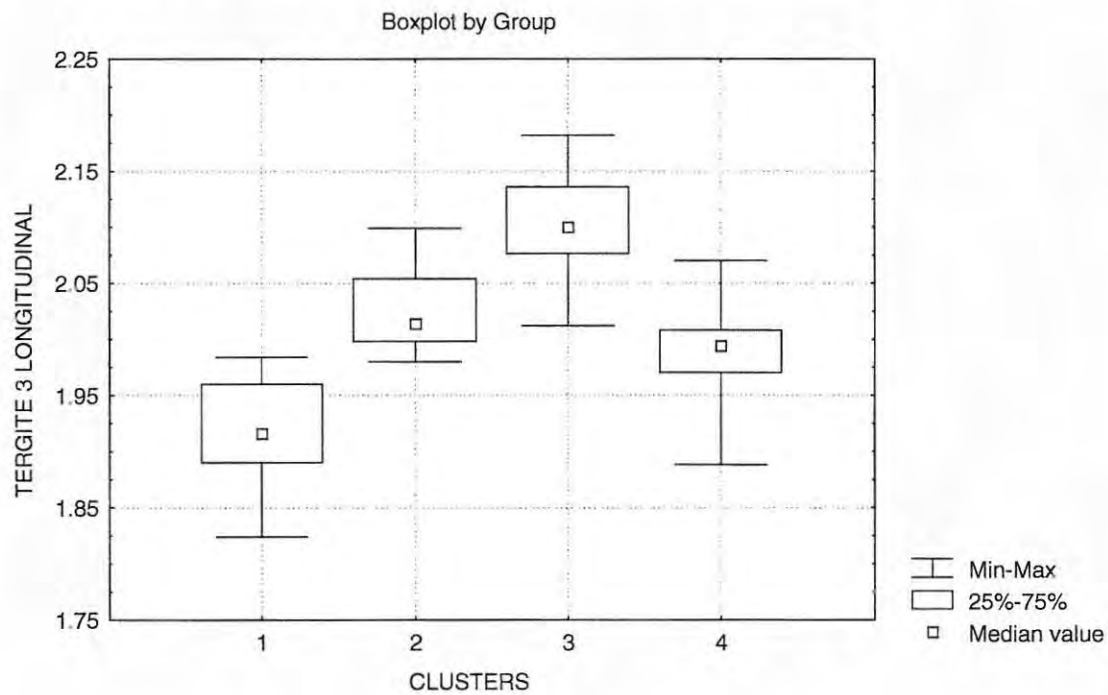


Fig. 15. Range and comparison of width of tergite 4 by group.

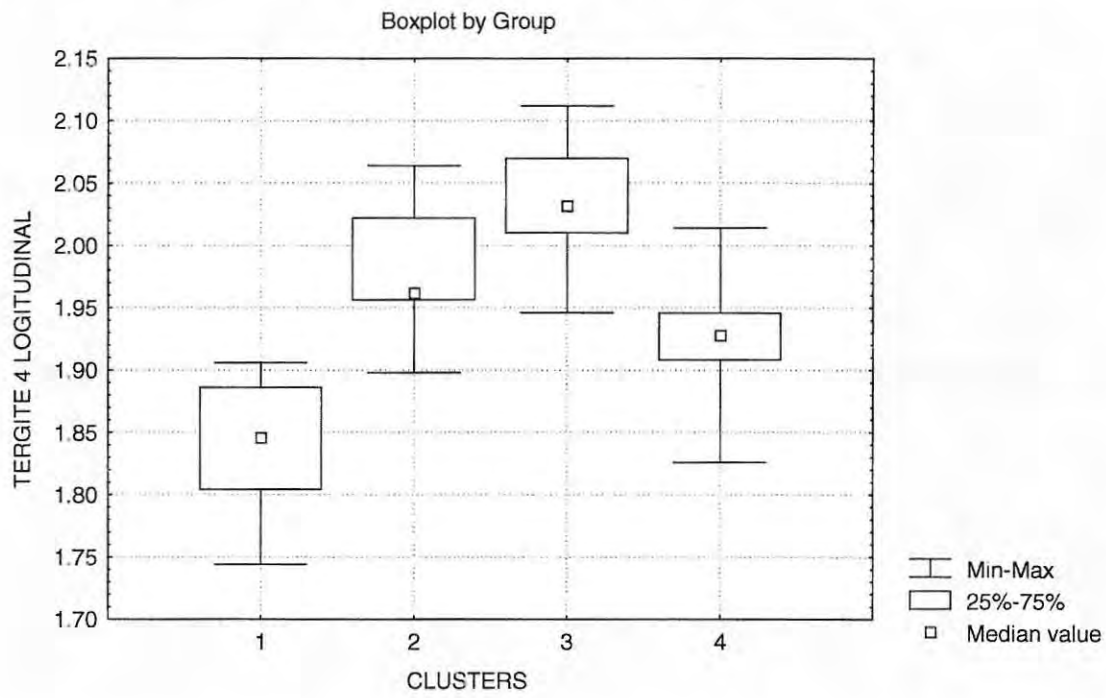


Fig. 16. Range and comparison of longitudinal sternite 3 by group.

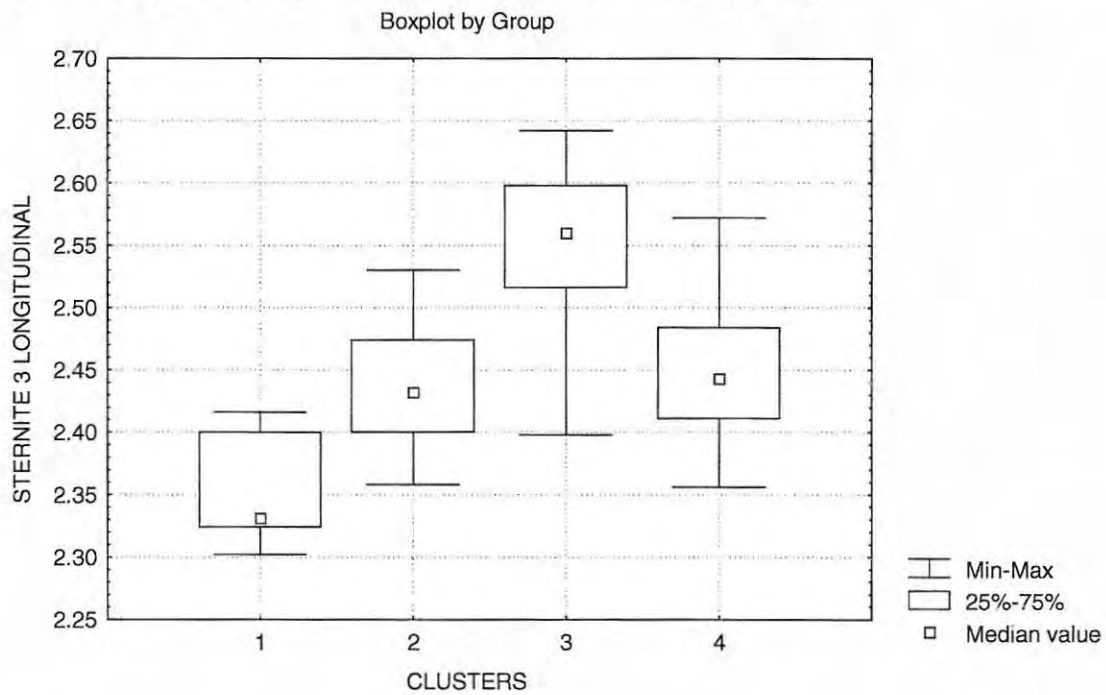
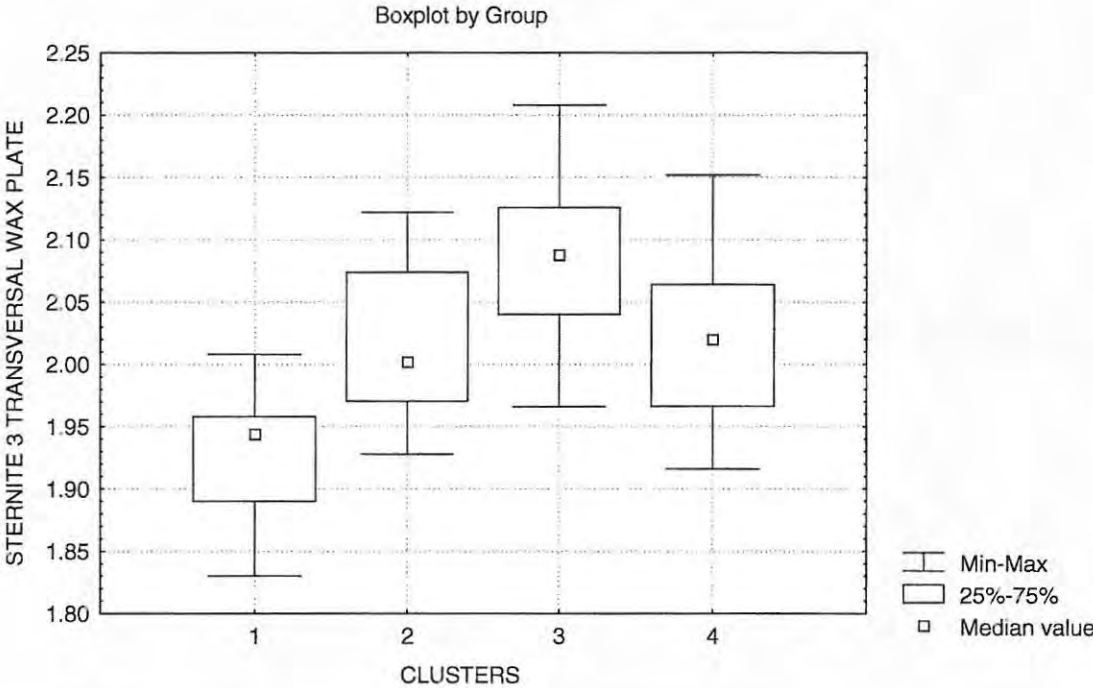


Fig. 17. Range and comparison of transversal wax plate on sternite 3 by group.



4.7 Agro-ecology of the honeybee groups

4.7.1 General

Honeybee samples were collected from 26 localities in the southern Ethiopian region. These localities are located between $4^{\circ} 49' 54.3''$ N to $9^{\circ} 7' 98''$ N latitude and $34^{\circ} 16' 07''$ E to $42^{\circ} 57' 57''$ E longitude with an altitude ranging from 456 to 2958 metres above sea level. The agro-climatic zone of this region is composed of 39.6% lowlands, 35.7% midlands and 24.7% highlands. Its annual minimum temperature varies from 5.9°C to 19.4°C with an average of 11.7°C and the annual maximum temperature ranges from 18.8°C to 34.7°C with an average of 25.5°C . This region receives an annual rainfall ranging from 522mm to 1874mm with an average of 1073mm. The land use pattern of the area comprises 15.0% forest, 10.8% shrub and bush land, 34.3% grazing, 23.0% cultivated land and 16.9% is used for other purposes (Table 19).

Table 19. Agro-climate (%), land use patterns (%), geographical co-ordinates (degrees), elevation (metres) and climate: temperature ($^{\circ}\text{C}$) and rainfall (mm) of the region studied.

Descriptions of the areas	Mean	Minimum	Maximum	Standard deviation
Agro-climate				
Lowland	39.6			0.3861
Midland	35.7			0.3234
Highland	24.70			0.3635
Land use				
Forestland	15.0			0.1463
Shrub and bush land	10.8			0.0755
Grazing land	34.3			0.2091
Cultivated land	23.0			0.2007
Other	16.9			0.1367
Geographical co-ordinate and altitude				
Longitude		34.16	42.57	
Latitude		4.49	9.70	
Altitude	1888.8	456.0	2958.0	504.01
Climate				
Minimum temperature	11.7	5.9	19.4	2.978
Maximum temperature	25.5	18.8	34.7	2.891
Rainfall	1073	522	1874	391.838

4.7.2 Honeybee groups of the region

As indicated in the discriminant function analysis, the honeybees of the region are clustered into four groups each comprising samples of different localities: group 1 Itang and Woyito honeybee samples, group 2 includes samples from Karre Tule, Deriri Arba, and Didi Affi, group 3 consists of samples from Boter Bacho, Mararo, Serofta, Alage, Hosaina, Boke Tiko, Effen Yachi, Woliso (Roge) and Gado Lama and group 4 includes samples from Gechi, Masha, Woshi, Waka, Sodo, Arero, Har Kalo, Eshido Aliyo and Sawla. (Fig. 7)

4.7.2.1 Group 1 honeybee agro-ecological areas

Group 1 honeybees occupy the area located between $5^{\circ} 16' 40.4''$ N to $8^{\circ} 11' 30.1''$ N latitude and $34^{\circ} 16' 07''$ E to $37^{\circ} 3' 33.3''$ E longitude (Fig 43) with an elevation ranging from 456 to 921 metres above sea level. The area is 100% lowland and includes the extreme western (Itang) and southern (Woyito) parts of the region; hence honeybees of this area are designated as western and southern lowland honeybees.

The localities fall in hot to warm sub-humid plains (SH1-1) and hot to warm semi-arid mountains and plateaus (SA1-5) sub-agro-ecological zone. The area has mean annual minimum and maximum temperatures of 18.12°C and 30.06°C respectively and receives a mean annual rainfall of 695mm. The land use pattern of the area includes 9.8% forest, 10.6% bush and shrub land, 30.68% grazing, 24.8% cultivated land and 24.12% other uses. The predominant cultivated crops in this area are maize and sorghum, while the predominant natural vegetation is *Acacia spp.*

Traditional and improved beekeeping are practiced in the area. Moreover, honey hunting is also traditionally practiced to harvest honey for family consumption and the traditional production system is mainly from forest beekeeping.

4.7.2.2 Group 2 honeybee agro-ecological areas

The group occupies the area located between 7° 3' 49" N to 9° 12' 21.6" N latitude and 41° 4' 4.5" E to 42° 57' 57" E longitude (Fig. 43) with an altitude ranging from 1194 to 1559 metres above sea level. About 98.6% of the area is lowland and has mean annual minimum and maximum temperatures of 14.7 °C and 29 °C respectively. It receives a mean annual rainfall of 590.2mm and it falls in the hot to warm sub-moist plains (SM1-1), hot to warm sub-moist mountains (SM1-7) and tepid to cool arid plain (A2-1) sub-agro-ecological zones. The land use of the sampling area is composed of 7.82% forest, 10.76% bush and shrub land, 14.45% grazing, 22.38% cultivated land and 12.06% other uses. As indicated by the geographical co-ordinates above, the area occurs in the eastern escarpment of the region and is designated as the eastern escarpment in this report. Maize and sorghum are the major crops grown and *Acacia senegal*, *Acacia mellifera*, *Euphorbia firucalli*, *Euphorbia abyssinica* and other *Acacia spp.* are the main honey plants of this area.

4.7.2.3 Group 3 honeybee agro-ecological areas

This honeybee group occurs in an area located between 6° 51' 58.2" N to 8° 43' 40.5" N latitude and 36° 30' 23" E to 40° 38' 33.4" E longitude (Fig. 43) with an altitude ranging from 1574 to 2958 metres above sea level. The average altitude of this area is

2241 metres above sea level and more than 40% of the area is highlands. This area includes the central and eastern highlands and is thus designated as the central and eastern highlands area. It has mean annual minimum and maximum temperatures of 9.5⁰C and 23.7 ⁰C respectively and has annual mean rainfall of 1184mm. Its land use pattern constitutes 12.39% forest, 12.69% bush and shrub land, 46.84% grazing, 16.31% cultivated land and 11.77% is used for other purposes. In this region both traditional and improved beekeeping are commonly practised. Beekeeping mainly takes place in backyard areas and under shelters.

This region falls mainly in the tepid to cool sub-humid mountains (SH2-7), tepid to cool sub-humid plateaus (SH2-6), cold to very cold humid highland mountains (H3-7), tepid to cool sub-moist lakes and rift valleys (SM2-2), tepid to cool sub-moist mountains (SM2-7) and tepid to cool humid highland mountains (H2-7) sub-agro-ecological zones. Wide ranges of cultivated and natural vegetation grow in the area. Some of the major honey plants are listed in Table 20 below.

Table 20. Major honey plants growing in the central and eastern highlands (determined during survey work)

Local name	Botanical name	Flowering time
Grari (Amharic)	<i>Acacia spp.</i>	March - April
Kontir (Amharic)	<i>Acacia spp.</i>	October - November
Dergu (Amharic)	<i>Achyranthes aspera</i>	October and June
Sasa (Amharic)	<i>Albizia gummifera</i>	February - April
Kerero (Amharic)	<i>Aningeria altissima</i>	April - May
Cheleleka (Oromigna)	<i>Apodytes dimidiata</i>	January
Adey ababa (Amharic)	<i>Bidens spp.</i>	September - November
Gomenzer (Amharic)	<i>Brassica spp.</i>	September - November
Agam (Amharic)	<i>Carissa edulis</i>	June - August
Buna (Amharic)	<i>Coffea arabica</i>	April and November - January
Wanza (Amharic)	<i>Cordia africana</i>	May - October
Yahiya suf (Amharic)	<i>Carthamus tinctorium</i>	October
Bisana (Amharic)	<i>Croton machrostachyus</i>	October and June - August
Lol (Amharic)	<i>Ekebergia capensis</i>	May - June
Akrima (Amharic)	<i>Eleusina floccifolia</i>	September - November
Asta (Amharic)	<i>Erica arborea</i>	September - February
Bahir zaf (Amharic)	<i>Eucalyptus spp.</i>	May - August
Noug (Amharic)	<i>Guizotia abyssinica</i>	September - November
Mech (Amharic)	<i>Guizotia scabra</i>	September - November

Koso (Amharic)	<i>Hagenia abyssinica</i>	December - January/ August - September
Galame (Oromigna)	<i>Helinus mystacinus</i>	April
Gremba (Oromigna)	<i>Hypericum revolutum</i>	April - May
Telba (Amharic)	<i>Linum usitatissimum</i>	October
Woyira (Amharic)	<i>Olea capensis</i>	May - June
Nolle (Oromigna)	<i>Olinia rochetiana</i>	January - May
Ater (Amharic)	<i>Pisum sativum</i>	September - November
Amshika (Amharic)	<i>Pittosporum viridiflorum</i>	November - May
Yezijero wonber (Amharic)	<i>Polyscias fluva</i>	November - April
Tikur inchet (Amharic)	<i>Pygeum africanum</i>	June
Enjori (Amharic)	<i>Rubus steudneri</i>	March
Getem (Amharic)	<i>Schefflera abyssinica</i>	March - May
Dinch (Amharic)	<i>Solanum spp.</i>	October
Mashila (Amharic)	<i>Sorghum bicolor</i>	September - October
Dokima (Amharic)	<i>Syzygium guineense</i>	January - June
Maget (Amharic)	<i>Trifolium spp.</i>	September - November
Grawa (Amharic)	<i>Vernonia amygdalina</i>	December - February
Bakela (Amharic)	<i>Vicia faba</i>	September - November
Bokolo (Amaharic)	<i>Zea mays</i>	August

4.7.2.4 Group 4 honeybee agro-ecological areas

Group 4 honeybees occupy the area located between $4^{\circ} 49' 54.3''$ N to $8^{\circ} 21' 2''$ N latitude and $35^{\circ} 28' 13.3''$ E to $39^{\circ} 23' 30.5''$ E longitude, elevation ranging from 1427 to 2157 metres above sea level. Approximately 36.5% of the land is midlands and constitutes the largest forest areas compared to areas occupied by the other honeybee groups. It receives the highest rainfall (Fig. 18). This area falls in the tropical rain forest region of the country and is regarded as wet tropical forest. The mean annual minimum and maximum temperatures of the area are 12.3°C and 26.0°C respectively and it receives an annual mean rainfall of 1288mm.

The area falls in the hot to warm sub-humid lowlands to mid-highland mountains (SH1-7), tepid to cool humid highland mountains (H2-7), tepid to cool moist plains (M2-1), tepid to cool moist mountains and plateaus (M2-5) and tepid to cool sub-moist mountains (SH2-7) sub-zones. The land use pattern of the area includes 18.1% forest, 8.5% bush and shrub land, 26.8% grazing, 30% cultivated land and 16.60% is used for other purposes. Both traditional and improved beekeeping are practiced, the former in the forest, the latter in backyards. A wide range of cultivated and natural vegetation grow in the area of which most are honey plants. Some of the important honey plants of the area are listed in Table 21 below.

Table 21. Major honey plants growing in the wet tropical forest areas (determined during survey work).

Local name	Botanical name	Flowering time
Ameressa (Oromigna)	<i>Acacia brevispica</i>	June - July
Garbi (Oromigna)	<i>Acacia lahai</i>	January - February
Saphensa (Oromigna)	<i>Acacia senegal</i>	December - January
Grar (Amharic)	<i>Acacia spp.</i>	March - may
Tadacha (Oromigna)	<i>Acacia tortilis</i>	December - January
Sasa (Amharic)	<i>Albizia gummifera</i>	March - April
Sasa (Amharic)	<i>Albizia schimperiana</i>	March - April
She'o (Kafigna)	<i>Allophyllus abyssinica</i>	September
Saragi (Oromigna)	<i>Allophyllus abyssinicus</i>	August - September
Hargesa (Oromigna)	<i>Aloe spp.</i>	December - February
Kerero (Amharic)	<i>Aningeria adolf</i>	March
Kerero (Amharic)	<i>Aningeria altissima</i>	December - March
Adey ababa (Amharic)	<i>Bidens macroptera</i>	September - November
Adey ababa (Amharic)	<i>Bidens pachyloma</i>	September - November
Adey ababa (Amharic)	<i>Bidens prestinaria</i>	September - November
Agam (Amharic)	<i>Carissa edulis</i>	April - September
Buna (Amharic)	<i>Coffea arabica</i>	February - March
Wanza (Amharic)	<i>Cordia africana</i>	August - November
Bisana (Amharic)	<i>Croton macrostachyus</i>	June - July
Sombo (Oromigna)	<i>Ekebergia capensis</i>	February
Bahir Zaf (Amharic)	<i>Eucalyptus spp.</i>	Year round

Chana (Oromigna)	<i>Filicium decipiens</i>	December - February
Kudumi (Oromigna)	<i>Galiniera coffeoides</i>	December - March
Harorressa (Oromigna)	<i>Grewia velutina</i>	June
Mech (Amharic)	<i>Guizotia scabra scabra</i>	September - November
Mech (Amharic)	<i>Guizotia scabra schimperi</i>	September - November
Koso (Amharic)	<i>Hagenia abyssinica</i>	March
Handerka (Oromigna)	<i>Lannea schimperi</i>	May - June
Kalkalcha (Oromigna)	<i>Maerva spp.</i>	December - February
Mango (Amharic)	<i>Mangifer indica</i>	December - February
Butuji (Oromigna)	<i>Manilkara butugi</i>	November - December
Woyira (Amharic)	<i>Olea capensis</i>	November - January
Baha (Kafigna)	<i>Olea welwitschii</i>	December
Ater (Amharic)	<i>Pisum sativum</i>	August - September
Tikur inchet (Amharic)	<i>Pygeum africanum</i>	March
Getem (Amharic)	<i>Schefflera abyssinica</i>	March - May
Mashila (Amharic)	<i>Sorghum bicolor</i>	November - December
Dokima (Amharic)	<i>Syzygium guineense</i>	March - April
Maget (Amharic)	<i>Trifolium rueppellianum</i>	August - November
Maget (Amharic)	<i>Trifolium simense</i>	August - November
Grawa (Amharic)	<i>Vernonia amygdalina</i>	January - February
Bakela (Amharic)	<i>Vicia faba</i>	August - September
Bokolo (Amharic)	<i>Zea mays</i>	June - August

4.7.3 Honeybee pests and predators in the southern Ethiopian region

Southern Ethiopian honeybees are more highly affected by pests and predators than by diseases. Farmer beekeepers of the region claim that pest and predators cause major damage to their honeybee colonies and hive contents (honey, brood, honey comb, etc) often resulting in the absconding of the entire colony. Pests and predators reported by farmer beekeepers of the region are listed here in descending order of economical importance: ants, wax moth, honey badgers, monkeys, spiders, bee-eating birds, lizards and beetles.

Ants are the most common pests of honeybees and eat honey and brood, kill adult honeybees and cause absconding of entire colonies. They are mostly prevalent during the honey flow and wet seasons in all the areas in this study.

Wax moth is the second most economically damaging honeybee pest in the region. The larvae of these pests feed on pollen and contents in comb cells and convert the comb into piles of debris and thus weaken the colonies and cause absconding. Wax moth infestation is problematical in the region during the dearth period, when there is a shortage of forage.

Honey badgers and monkeys are also problematical mainly during the honey flow. They eat honey and brood, destroy colonies and beehives by throwing them down from trees and thus cause absconding. They are frequently prevalent in areas where forest beekeeping is mainly practiced.

Spiders, lizards and bee-eating birds are minor predators in comparison but still economically affect beekeeping in the region. They prey on forager bees and thus cause a loss of foragers.

Man is also considered as one of the main enemies of honeybees in the region. Honey-hunting is widely practised in south and southwest parts of the region. The hunters use fire to subdue or kill honeybees during honey-hunting and occasionally cause forest fire. Forest beekeeping is also practised widely in the region. Beekeepers pay no attention to honeybee colonies. Moreover during honey harvest they force bees to leave their nest either by throwing hives from the tree to the ground, using heavy smokes or remove the whole contents of hives. In coffee growing areas (southwest) chemicals (pesticides and herbicides) which are harmful to bees and deforestation are widely practised. Thus all these activities of human being in the region are directly or indirectly affect the life of honeybees. A summary of pests and predators is given in Table 22 below.

Table 22. Pests and predators, incidence time and damage caused in the region.

Pests and predators	Incidence time	Damage caused
Ants	Honey period and wet season	Eat honey and brood, kill bees, absconding
Bee-eating birds	Dearth period	Eats bees
Honey badgers	Honey period	Eat honey and brood, release offensive smell, destroy beehive and cause absconding
Spiders	Year round	Eats bees
Wax moth	Dearth period	Destroy combs and weaken colonies
Lizards	Dearth period	Eat bees
Monkeys	Honey flow period	Destroy beehive, eat brood & honey
Beetles	Honey flow period	Eat honey, absconding
Men	Year round	Rob honey and wax, eat brood, destroy forest and Colonies and cause absconding

Fig. 18. Annual mean rainfall for the four honeybee group areas.

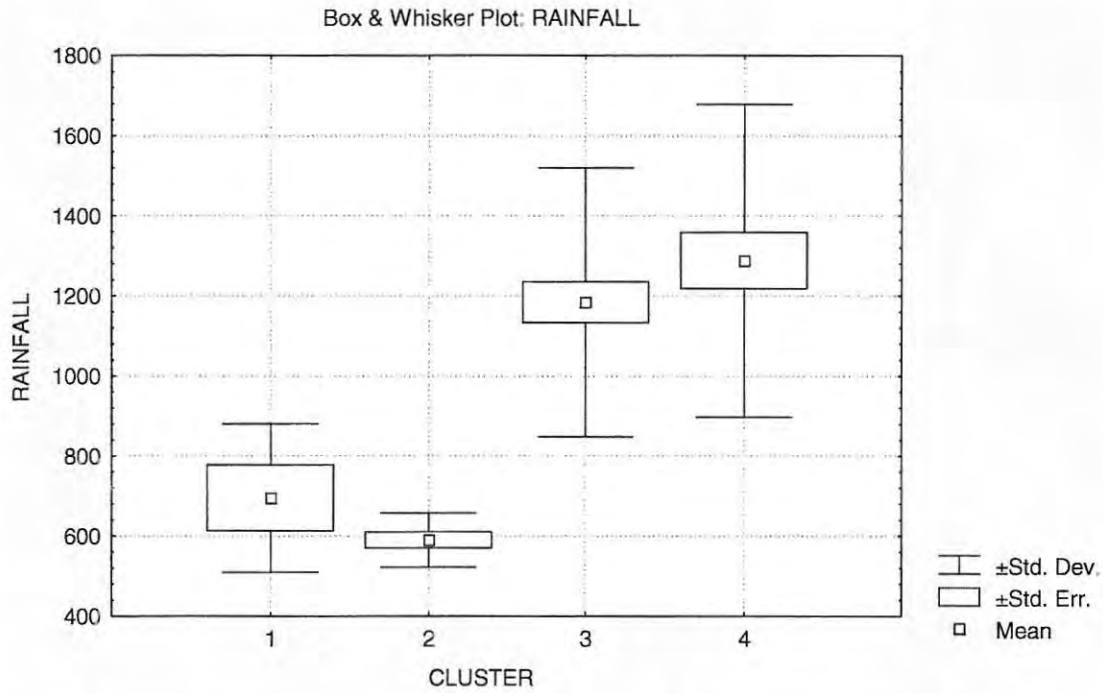


Fig. 19. Annual mean minimum temperatures for the four honeybee group areas.

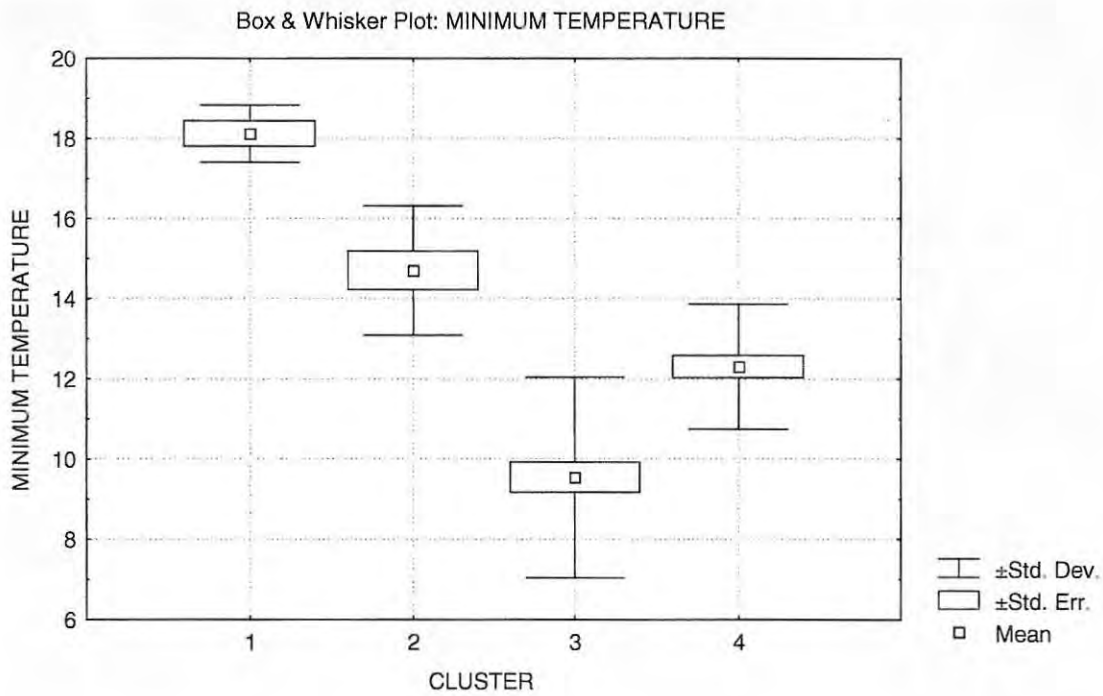


Fig. 20. Annual mean maximum temperatures of the four honeybee group areas.

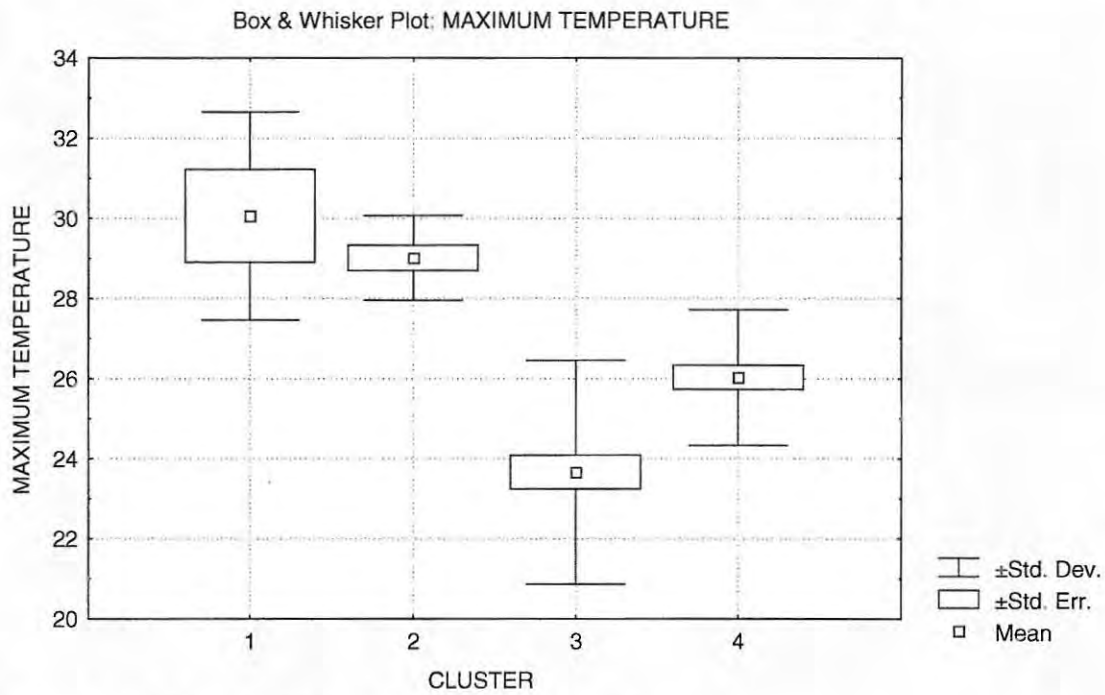


Fig. 21. Mean altitudes of the four honeybee group areas.

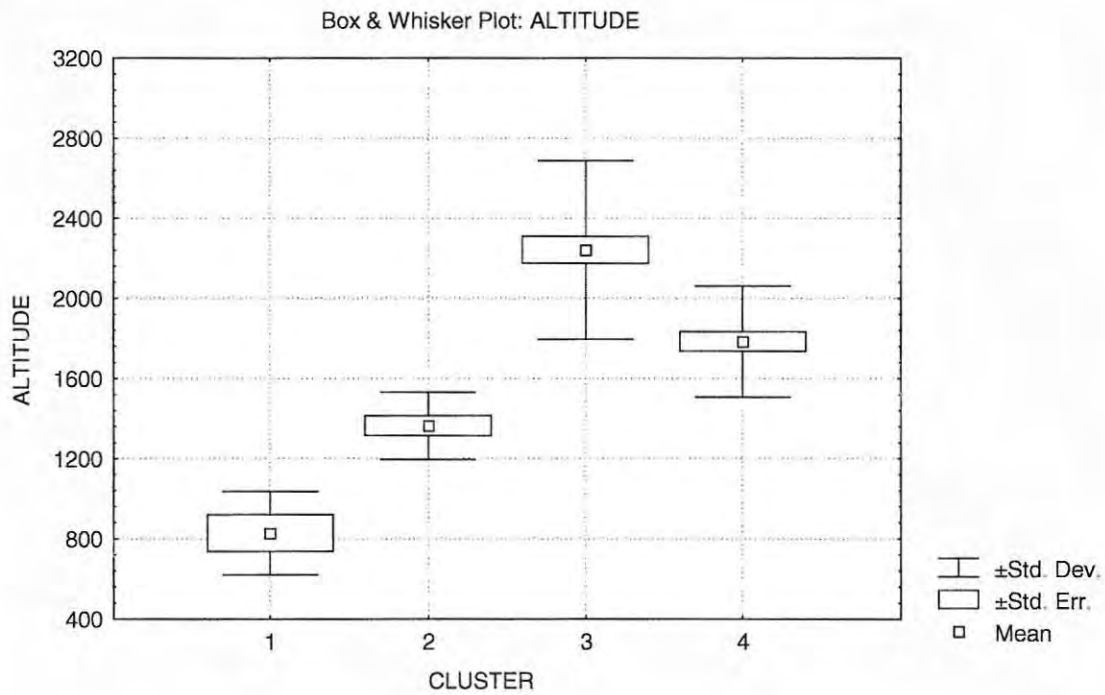
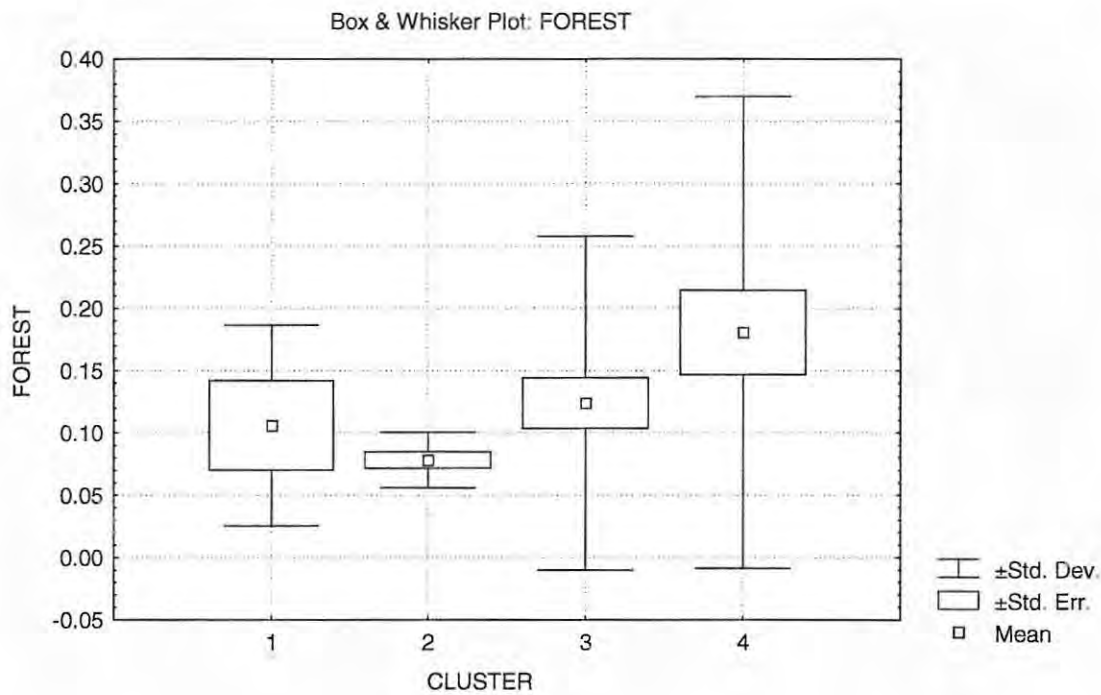


Fig. 22. Proportion of forest in the four honeybee group areas.



4.8 Behaviour of southern Ethiopian honeybees

The behavioural study of honeybees is very important in practical aspects of beekeeping. The present study includes this aspect to bridge information gaps existing for many years in the country. The survey was conducted to address inadequate information on the behaviour of southern Ethiopian honeybees. This study deals with reproductive swarming, migration and defence aspects of the honeybees of the region.

4.8.1 Reproductive swarming

4.8.1.1 Reproductive swarming tendency

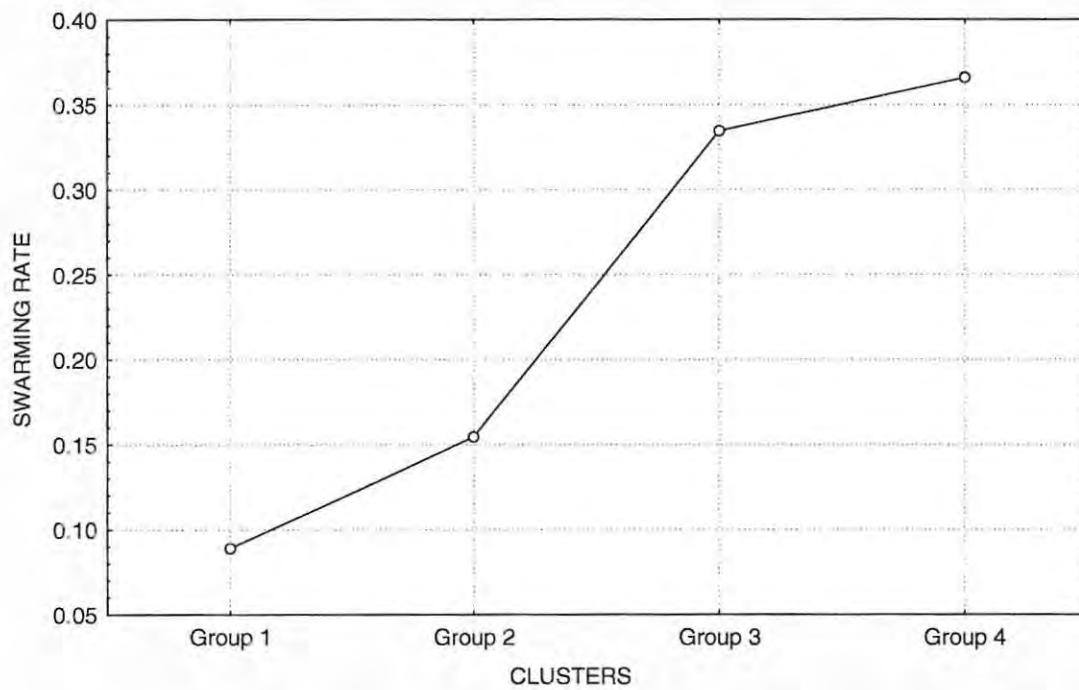
To determine the extent to which honeybee groups of southern Ethiopia swarm, the swarming rate of each group of honeybees was calculated from the ratio of the

number of honeybee colonies from which swarms were issued to the numbers of honeybee colonies owned by the sampling units (farmer beekeepers interviewed during the survey work). As the data violated the rules or assumptions of ANOVA, Kruskal-Wallis ANOVA was used for the analysis.

It has been found that reproductive swarming occurs in the region every year and the rate of reproductive swarming varies among the four groups of honeybees. The swarming rate in the region generally varies from 8.9% to 36.6% with an average of 23.6%. The reproductive swarming rates among the four groups of honeybees (the western and southern lowland honeybees, the eastern escarpment honeybees, the central and eastern highland honeybees and the wet tropical forest honeybees) were highly significantly different ($H(3, 89) = 14.55; p < 0.0023$). Reproductive swarming rates in honeybee groups of the wet tropical forests were significantly higher than those of the western and southern lowlands and the eastern escarpment ($p < 0.0083$) whilst reproductive swarming in the central and eastern highlands was significantly higher than the eastern escarpment honeybee group. The reproductive swarming rate between the central and eastern highlands and the wet tropical forests, and between western and southern lowlands and eastern escarpment honeybee groups were not statistically different ($p > 0.0073$) (Table 23).

Mean reproductive swarming rates in the western and southern lowlands, eastern escarpment, central and eastern highlands were 8.9%, 15.46%, 33.46% and 36.6% respectively (Fig. 23).

Fig. 23. Mean reproductive swarming rates of the southern honeybee groups expressed as percentage $\times 10^{-2}$.



Group 1 Western and southern lowlands honeybee group

Group 2 Eastern escarpment honeybee group

Group 3 Central and eastern highlands honeybee group

Group 4 Wet tropical forest honeybee group

Table 23. P-values for pair wise comparisons (Mann-Whitney U test) for reproductive swarming among rate of the four southern Ethiopian honeybee groups (numbers in brackets are the mean reproductive swarming rates reflected as percentages).

Groups	G1 (8.9%)	G2 (15.46%)	G3 (33.46%)	G4 (36.6%)
Group 1		0.794	0.078	0.001**
Group 2	0.794		0.005**	0.003**
Group 3	0.078	0.005**		0.643
Group 4	0.001**	0.003**	0.643	

The level of significant is adjusted using the procedure of multiple pair wise comparisons (Bonferroni). That is the difference is significant if $p < 0.05/6 = 0.0083$.

** significant ($p < 0.0083$).

4.8.1.2 Multiple reproductive swarming

The minimum and maximum multiple reproductive swarming were analysed using ANOVA as the data did not violate the ANOVA assumptions. The results indicate that multiple reproductive swarming occurs in the all groups of southern Ethiopian honeybees. The mean minimum number of reproductive swarms issued from a honeybee colony per annum in the region ranged from 1 to 3.2 with an average of 2.2. The mean minimum numbers of reproductive swarms issued from a colony in a year varied highly significantly among the groups ($F(3, 78) = 4.17, p < 0.0086$). The minimum mean numbers of reproductive swarms issued from a

honeybee colony of the central and eastern highlands group in a year is 3.2 and that of the wet tropical forests was 2.6 whereas in the western and southern lowlands and eastern escarpment were 1 and 2 respectively (Fig. 24). A statistically significant mean difference was found between the central and eastern highland and western and southern lowlands honeybee groups ($p < 0.05$) but not among the other groups.

The mean maximum number of reproductive swarms produced from a single colony in a year also varied among honeybee groups of the region, ranging from 3 to 7 swarms with an average of 5.1. The mean maximum number of swarms per colony per annum varied highly significantly among the groups ($F(3, 78) = 5.28, p < 0.0023$).

The mean maximum numbers of successive swarms from a colony in a year in the western and southern lowlands, eastern escarpment, central and eastern highlands and wet tropical forestland were 3, 4, 7 and 6.3 respectively (Fig. 25). The statistical results reveal that the western and southern lowlands and eastern escarpment honeybee groups have a significantly lesser tendency to multiple swarming than the central and eastern highlands honeybee group (Tables 24 and 25).

Fig. 24. The mean minimum number of successive swarms per colony per year in the four groups of southern Ethiopian honeybees.

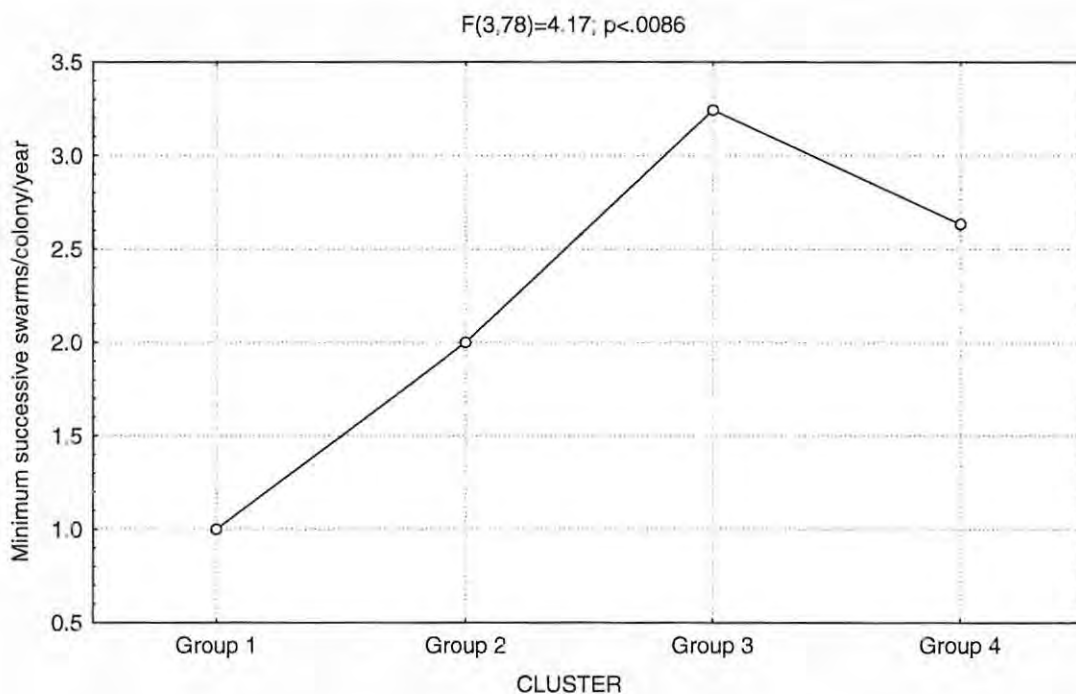


Table 24. P-values for the multiple comparisons (*Tukey HSD test*) of mean minimum successive reproductive swarms among the four southern Ethiopian honeybee groups (numbers in brackets are the mean minimum successive reproductive swarms).

Groups	Group 1 (1)	Group 2 (2)	Group 3 (3.24)	Group 4 (2.63)
Group 1		0.6615	0.0277	0.1769
Group 2	0.6615		0.0807	0.6263
Group 3	0.0277*	0.0807		0.3501
Group 4	0.1769	0.6263	0.3501	

Fig. 25. The mean maximum number of successive swarms per colony per year in the four groups of southern Ethiopian honeybees.

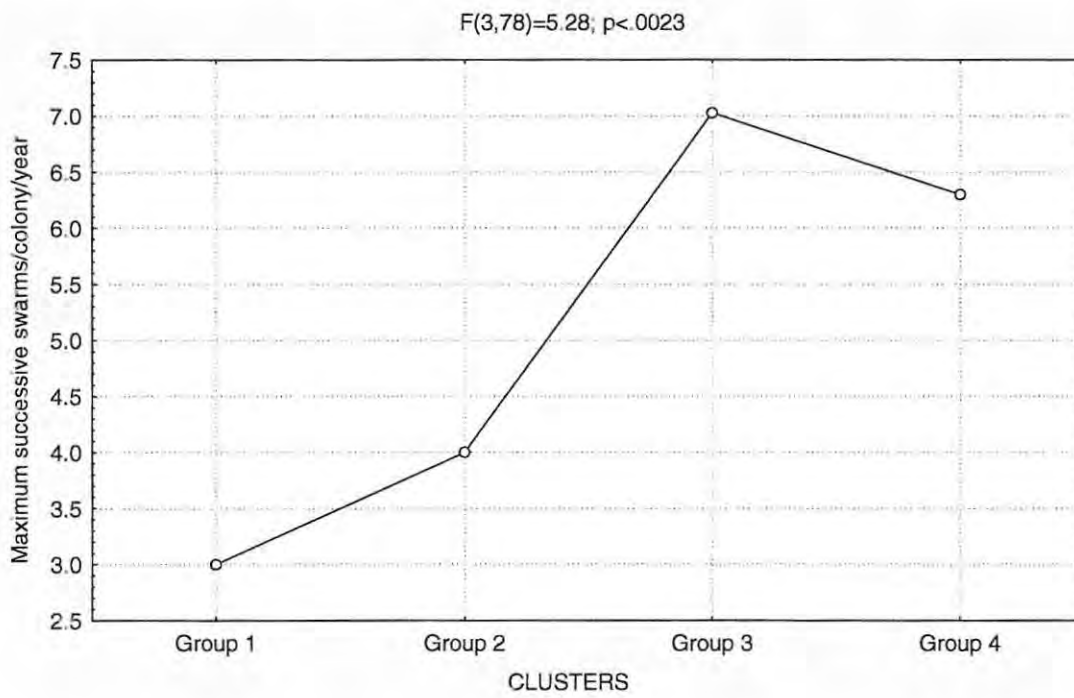


Table 25. P-values for the multiple comparisons (*Tukey HSD test*) of mean maximum successive reproductive swarms among the four southern Ethiopian honeybee groups (numbers in brackets are the mean maximum successive reproductive swarms).

Groups	Group 1 (3)	Group 2 (4)	Group 3 (7.03)	Group 4 (6.3)
Group 1		0.9244	0.0335*	0.1176
Group 2	0.9244		0.0103*	0.0973
Group 3	0.0335*	0.0103*		0.7048
Group 4	0.1176	0.0907	0.7048	

* significant at 5% significant level

4.8.1.3 Reproductive swarming tendency by colour and aggressive behaviour

It was found that the reproductive swarming tendency within all four groups varied. 100% of farmer beekeepers from the western and southern lowlands, 54.6% from eastern escarpment and 64.5% from the wet tropical forests honeybee group areas stated that yellow honeybee colonies swarm more frequently than black ones. Whereas 79% of the farmer beekeepers from the area of the central and eastern highlands honeybee groups claimed that black honeybee colonies swarmed more frequently (Table 26) (Yates chi-square adjusted = 22.18, df = 6; p = 0.0011).

Farmer beekeepers also associated swarming in relation to defensive behaviour. Of all the sample units, 100% farmer beekeepers from the eastern escarpment, 72.1% from the central and eastern highlands and 90.3% from the wet tropical forests stated that highly defensive honeybee colonies showed a greater tendency to swarm; but 80% of farmer beekeeper from the western and southern lowlands honeybee group areas claimed that defensive honeybees are the ones which have the greatest propensity to swarm (Yates chi-square =15.20, df = 3; p = 0.0016) (Table 27). Generally these results reveal that the colour and defensive behaviour of the honeybees are related to swarming tendency, differently in honeybee groups of the western and southern lowlands and the central and eastern highlands whereas yellow and highly defensive honeybees of the eastern escarpment and the wet tropical forestland honeybee groups seem to have high tendency for reproductive swarming. More over, although the results vary from group to group, the data generally revealed that yellow and highly aggressive honeybees (3 out of 4 groups) have high tendency to reproductive swarming (Tables 26 and 27).

Table 26. Reproductive swarming tendencies of honeybee groups by colour (numbers indicate the response percentage of the farmer beekeepers interviewed in the respective areas of the honeybee groups).

Groups	Yellow honeybees	Black honeybees	Both colours	Total (n = 90)
Group 1 (n =5)	100	0	0	5.6
Group 2 (n = 11)	54.6	45.5	0	12.2
Group 3 (n = 43)	20.9	79.1	0	47.8
Group 4 (n = 31)	64.5	32.3	3.2	34.4
Total	44.4	54.5	1.1	100

Yates chi-square adjusted = 22.18, df = 6; p = 0.0011

Table 27. Reproductive swarming tendencies of honeybee groups by defensive behaviour (numbers indicate the response percentage of the farmer beekeepers interviewed in the respective areas of the honeybee groups).

Groups	Highly defensive	Defensive	Total (n = 89)
Group 1 (n = 5)	20	80	5.6
Group 2 (n = 11)	100	0	12.2
Group 3 (n = 42)	72.1	27.9	47.8
Group 4 (n = 31)	90.3	9.7	34.4
Total	78.9	21.1	100

Yates chi - square adjusted = 15.20, df = 3; p = 0.0016

NB. Regarding the defensive behaviour of their honeybee colonies, farmer beekeepers define defensive and highly defensive in the following way: colonies that attack at close proximity are defensive while those attack at a distance are highly defensive.

4.8.1.4 Swarm catching rate

The swarm catching rates in each area of honeybee groups were calculated from the ratio of number of bait hives occupied by swarms to the total number of bee hives hung for swarm catch during a year by the sample units (farmer beekeepers) and the data were analysed using Kruskal-Wallis ANOVA.

The results show that farmer beekeepers of all the regions obtain their colonies mainly by trapping honeybee swarms. However, the rate of swarm catching was found to differ from place to place. The swarm catching rates of the region varied from 7.7% to 57.1% with an average of 36.4%. The swarm catching rate among the four honeybee group areas in ascending order was: western and southern lowlands, eastern escarpment, wet tropical forests and central and eastern highlands and these were statistically highly significantly different ($H(3, N = 81) = 16.928; p < 0.0008$). The highest swarm catching rate was recorded in the central and eastern highlands (57.1%) followed by wet tropical forests (54.15%), which is not statistically significantly different ($p > 0.0083$) (Table 28). The probability of catching swarms in the western and southern lowlands is significantly less than both central and eastern highlands and wet tropical forestlands while that of eastern escarpment is less than only central and eastern highlands. That is no significant differences in swarm catching rate between eastern escarpment and tropical forestland on one hand and between eastern escarpment and western and southern lowlands on other

hand. In general the result reveal that in the eastern escarpment and the western and southern lowlands areas, the swarm catching rates were statistically significantly low (Fig. 26 and Table 28).

Fig. 26. The mean swarm catching rate of the four honeybee group areas of southern Ethiopian honeybees expressed as percentage $\times 10^{-2}$.

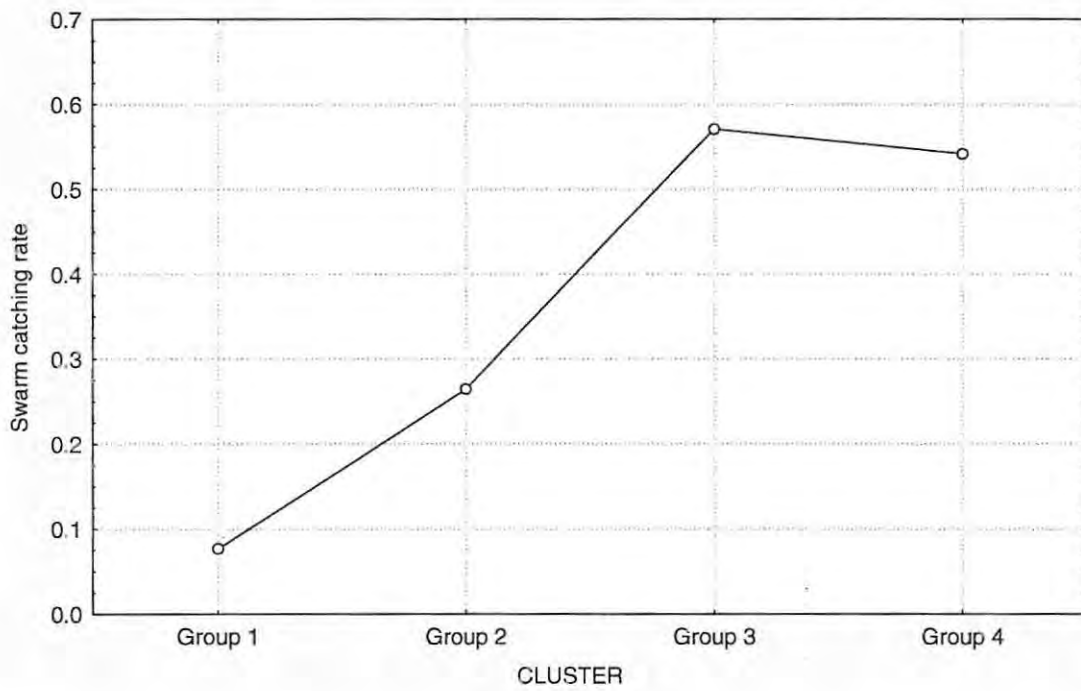


Table 28. P-values for the pair wise comparisons (Mann-whitney U test) of swarm catching rate among the areas of the four southern Ethiopian honeybee groups (figures in brackets indicate mean swarm catching rate as a percentage).

Groups	Group 1 (7.7%)	Group 2 (26.48%)	Group 3 (57.1%)	Group 4 (54.15%)
Group 1		0.496	0.001**	0.001**
Group 2	0.496		0.004**	0.086
Group 3	0.001**	0.0009**		0.276
Group 4	0.001**	0.086	0.276	

Level of significant adjusted using the multiple pair wise comparison procedures (Bonferroni). That is the difference is significant if $p < 0.05/6 = 0.0083$.

** significant ($p < 0.0083$)

The swarm catching rate was found to conform to the swarming rate and successive swarming of honeybee colonies of the area, revealing that the place where swarming rate and successive swarming of a colony is high, the swarm catching rate is also high. In other words where there is a high reproductive swarming rate, the chance of bait hives being occupied by a swarm is high.

4.8.1.5 Swarming phenology

An attempt was made to assess the reproductive swarming period of the southern Ethiopian honeybees during the survey work. Accordingly, the reproductive swarming periods in the region varied from place to place depending on the climate

which of course is related to forage availability and in some places took place twice a year and these are termed as major and minor swarming periods depending on the extent of swarming rate. In a broad sense, reproductive swarming in southern Ethiopia takes place mainly during September through November (Tables 29 and 30).

Table 29. The onset of major swarming for the four groups of the southern Ethiopian honeybees (numbers indicate the percentage of response of the sample units).

Groups	January	March	June	September	December	Total (n = 90)
Group 1 (n = 5)	0	0	80	20	0	5.6
Group 2 (n = 11)	0	27.3	27.3	0	45.5	12.2
Group 3 (n = 43)	0	0	0	100	0	47.8
Group 4 (n = 31)	6.45	19.4	22.6	43.4	3.2	34.4
Total	2.22	10	15.6	65.6	6.7	100

Pearson chi-square = 69.0304, df = 12; p < 0.0000001

Table 30. Ending times of major swarming for the four groups of the southern Ethiopian honeybees (numbers indicate the percentage of response of the sample units).

Pearson chi-square = 75.98717, df = 15; p < 0.000001

Groups	January	February	March	August	September	November	Total (n= 87)
Group 1 (n = 5)	0	0	0	80	0	20	5.8
Group 2 (n = 11)	0	45.5	27.3	27.3	0	0	12.6
Group 3 (n = 43)	0	0	0	0	11.6	88.4	49.4
Group 4 (n = 28)	3.57	7.1	10.7	25	0	53.6	32.2
Total	1.15	8.05	6.90	16.09	5.75	62.07	100

NB. Due to similar and identical responses from farmer beekeepers where samples were collected, low frequencies were obtained for some months. As a result of these conditions analyses of the onset and end of swarming times were not possible. However from tabulated data and the Pearson chi-square result it is obvious that the results are different.

As indicated in Table 29 the onset of the major reproductive swarming season for the western and southern lowlands honeybee group is during June, while that of the eastern escarpment group is during December. The central and eastern highlands and the wet tropical forests groups start reproductive swarming during September. August is the end of the reproductive swarming time for the western and southern lowlands, February for the eastern escarpment and November for the central and eastern highlands and wet tropical forests groups (Table 30). These results indicate that major reproductive swarming in the region takes place in three distinctive periods: during June through to August in the western and southern lowlands honeybee groups, during December through to February in the eastern escarpment honeybee group and during September through to November in the central and eastern highlands and the wet tropical forests groups of honeybees (Tables 29 and 30).

Some of central and eastern highlands and the wet tropical forests honeybee groups have another reproductive swarming time, which is referred to as the minor reproductive period. This takes place during March through May (Table 31). This demonstrates that reproductive swarming is biphasic in the central and eastern highlands and wet tropical forests groups, whereas no responses were recorded from the western and southern lowlands and eastern escarpment indicating that in these areas honeybees swarm only once a year. Moreover variations in reproductive swarming were observed within the eastern escarpment, central and eastern highlands and wet tropical forestland honeybee groups (Table 46 and Fig. 44). Honeybees of Deriri Arba (S17) in the eastern escarpment swarm during September through

November while the rest swarm during December to February. Honeybee population in the western and eastern part of the central and eastern highlands swarm during September to November and March to May while the rest swarm during only September to November. Similarly honeybee populations in northwestern and southern of wet tropical forestlands swarm during December to February and September to November respectively while the rest swarm during September to November and March to May (Table 47 and Fig. 44).

Table 31. Onset and ending times for minor swarming for the four groups of southern Ethiopian honeybees (numbers indicate the percentage of the response of the sample units, zero indicates no response).

Groups	Minor swarming onset month			Minor swarming ending month		
	March	September	Total (n = 22)	May	November	Total (n = 22)
Group 1 (n = 0)	0	0	0	0	0	0
Group 2 (n = 0)	0	0	0	0	0	0
Group 3 (n = 5)	100	0	15.6	100	0	15.6
Group 4 (n = 17)	81.5	18.5	84.4	81.5	18.5	84.4
Total	84.4	15.6	100	84.4	15.6	100

Pearson chi-square = 17.2549, df = 12; p = 0.14028

4.8.2 Migration

4.8.2.1 Migration tendency

The migration rate of southern Ethiopian honeybee groups was calculated from the number of honeybee colonies that deserted their beehives compared to the total number of honeybee colonies owned by the sample units before evacuation of these honeybees in the year 2000. The proportions of empty beehives were statistically analysed using Kruskal-Wallis ANOVA, as the variances were non-homogeneous.

The migration rate of honeybees of the region varied from 25.5% to 58.8% with an average of 38.9%. The variation in tendency to migrate among the four honeybee groups of the region was statistically highly significant ($H(3, N = 89) = 11.936; p < 0.0078$). The highest migration tendency (58.8%) was observed in the eastern escarpment honeybees and then in the western and southern lowland (39.6%) and wet tropical forest (31.9%) honeybees (Fig. 27). The migration tendency of these three groups (1, 2 and 4) was not statistically significant different ($p > 0.0083$) (Table 32). However, the rate of migration in the eastern escarpment varied highly significantly from the migration rate of honeybees from the central and eastern highlands, revealing that the eastern escarpment honeybee group has a higher migration tendency than that of the central and eastern highlands which was 25.5%.

Fig. 27. The migration rate of honeybee groups of southern Ethiopia (numbers indicate the proportion of honeybee colonies that migrated from the total honeybee colonies owned by sample units in the year 2000).

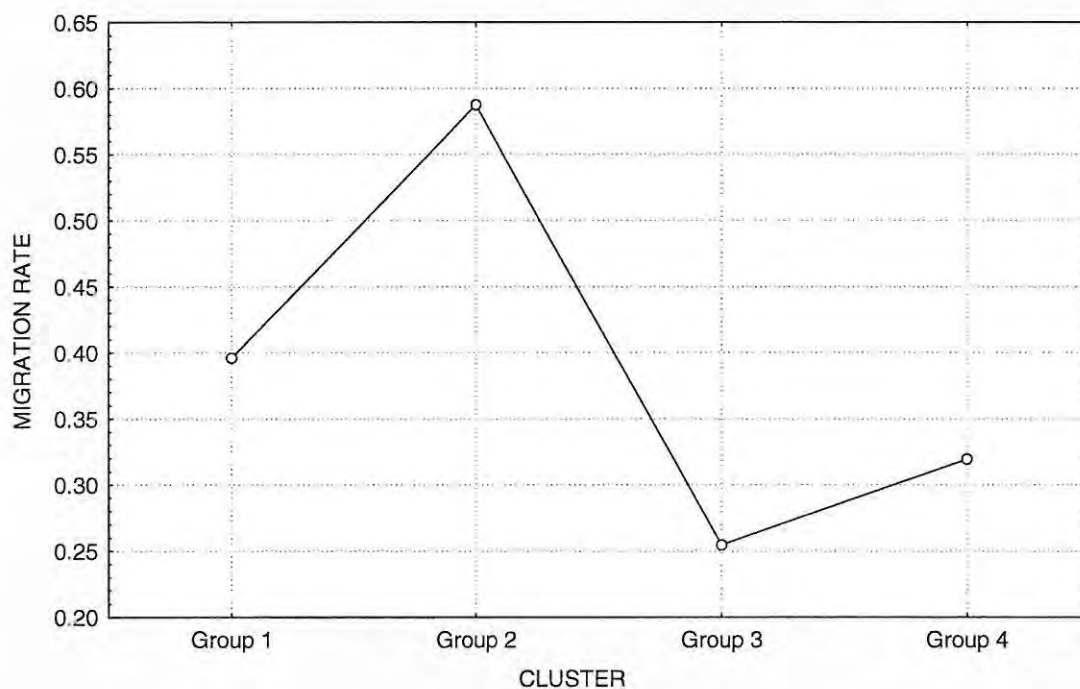


Table 32. P-values for the pair wise comparisons (Mann-Whitney U test) of migration rates among the four southern Ethiopian honeybee groups (figures in brackets indicate mean migration rates in percent).

Groups	G1 (39.6%)	G2 (58.8%)	G3 (25.5%)	G4 (31.9%)
Group 1		0.192	0.402	0.351
Group 2	0.192		0.001**	0.010
Group 3	0.402	0.001**		0.210
Group 4	0.351	0.010	0.210	

** Highly significant ($p < 0.0083$)

The honeybee group of the central and eastern highlands has a lesser tendency for migration than that of eastern escarpment. While migration rates in the western and southern lowlands and wet tropical forestlands were not statistically significantly different from either of the groups ($p > 0.0083$), revealing that they are intermediate in migration behaviour.

The percentage of non-occupied beehives seems to support this finding. That is, the highest percentage of unoccupied beehives was found in the places where the highest migration rates were found. Generally, unoccupied beehives in the region varied from 47.7% to 63.4% with an average of 52.8%. The highest percentage of non-occupied beehives (63.4%) was found in the areas of the eastern escarpment honeybee group followed by western and southern lowlands (55.4%) and wet tropical

forestland (48.8%) honeybee groups (Fig. 28). The percentage of non-occupied beehives in eastern escarpment area is significantly different from central and eastern highlands and wet tropical forestland areas (Table 33) while no significant differences were observed among the others.

Fig. 28. The mean unoccupied honeybee hives in the areas of the four honeybee groups of southern Ethiopia (numbers on the graph indicate the proportion of beehives that were empty during the survey).

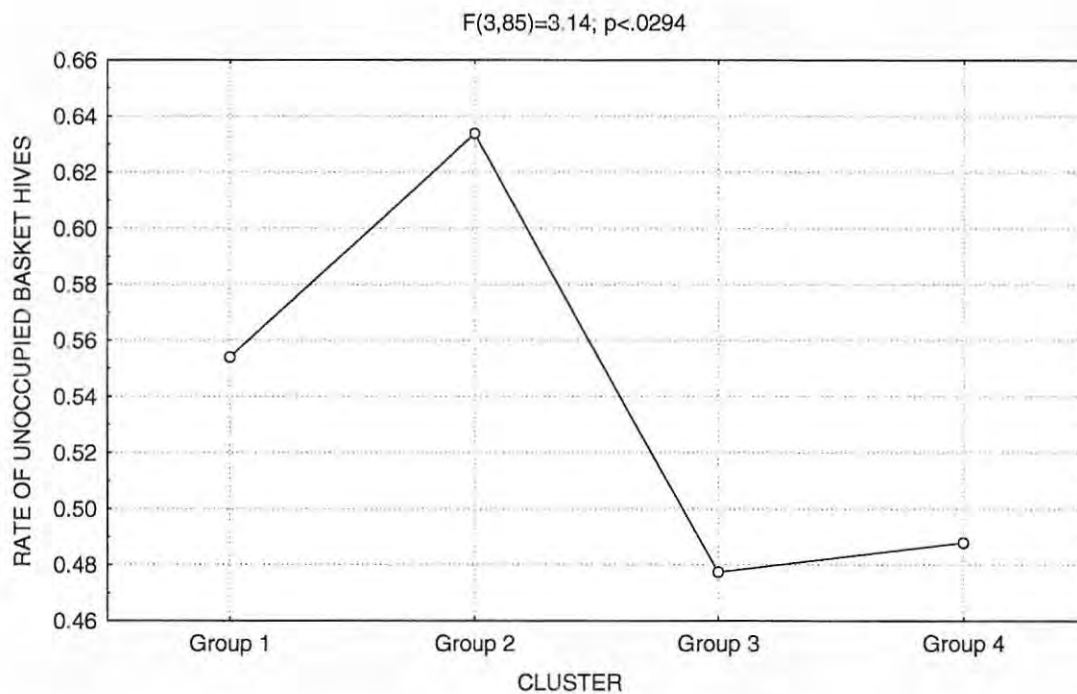


Table 33. P-values for the multiple comparisons (Tukey *post hoc* HSD test) of mean unoccupied beehives among the areas of the four southern Ethiopian honeybee groups (numbers in the brackets indicate mean unoccupied beehives as percentages).

Groups	G1 (55.4%)	G2 (63.4%)	G3 (47.7%)	G4 (48.8%)
Group 1		0.7450	0.8027	0.8796
Group 2	0.7450		0.0122*	0.0314*
Group 3	0.8027	0.0122*		0.9874
Group 4	0.8796	0.0314*	0.9874	

* significant, $p < 0.05$

4.8.2.2 Migration phenology

Tables 34 and 35 show the percentages of the responses for the onset and ending of migration for each honeybee group of the region. Highly significant differences were found among the responses. The onset of migration for the western and southern lowlands and eastern escarpment honeybee groups is in December and March respectively, while for the central and eastern highlands and wet tropical forests it is June and December (Yates chi-square =49.33, $df = 15$; $p < 0.0001$) (Table 34). February and May is the time at which migration ends in the western and southern lowlands and eastern escarpment honeybee group areas, whereas August and February are the ending time for both the central and eastern highlands and the wet tropical forests groups (Yates chi-square =42.12, $df = 12$; $p < 0.0001$) (Table 35). Hence, both the central and eastern

highlands and the wet tropical forests groups migrate during June through August and December to February while the western and southern lowlands and eastern escarpment honeybee groups migrate during December through February and March through May respectively.

Table 34. Onset of migration of the four groups of southern Ethiopian honeybees (numbers indicate the percentage of responses of the sample units).

Yates chi-square = 49.33, df = 15; $p < 0.0001$

Groups	January	February	March	June	July	December	Total (n = 88)
Group 1 (n = 4)	0	0	0	0	0	100	4.6
Group 2 (n = 11)	0	0	72.7	0	0	27.3	12.5
Group 3 (n = 43)	20.9	7.0	0	32.6	11.6	27.9	48.9
Group 4 (n = 30)	6.6	6.7	6.7	43.3	0	36.7	34.1
Total	12.5	5.7	11.4	30.7	5.7	34.1	100

Table 35. Ending time of migration of the four groups of southern Ethiopian honeybees (numbers indicate the percentage of the responses of the sample units).

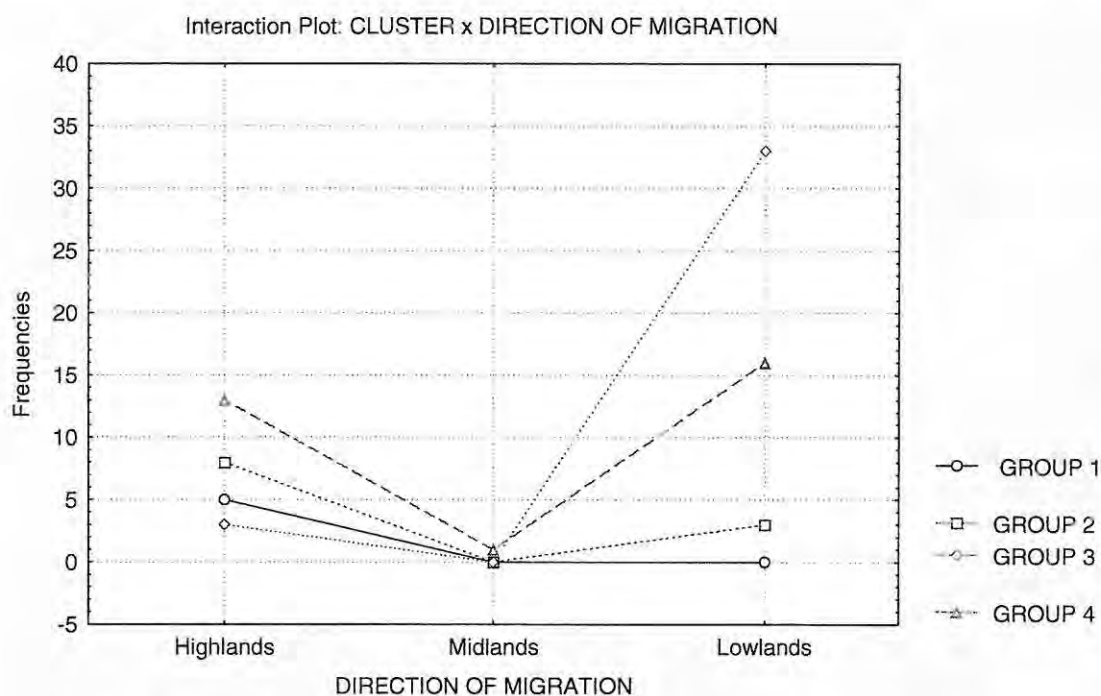
Yates chi-square = 42.12, df = 12; p < 0.0001

Groups	January	February	March	May	August	Total (n = 87)
Group 1 (n = 4)	0	100	0	0	0	4.6
Group 2 (n = 11)	0	27.3	0	72.7	0	12.7
Group 3 (n = 43)	18.60	30.2	0	7	44.2	49.4
Group 4 (n = 29)	0	37	10.3	6.9	44.8	33.3
Total	9.2	35.6	3.5	14.9	36.8	100

Honeybees of the western and southern lowlands and eastern escarpment groups were found to migrate to the highlands while those of the central and eastern highlands and wet tropical forests groups migrate to the lowlands area (Yates chi-square =27.48, df = 6; p = 0.0001) (Fig. 29).

Fig. 29. Direction of migration of the southern Ethiopian groups of honeybees.

Yates chi-square adjusted = 27.48, df = 6; p = 0.0001



4.8.2.3 Causes of migration

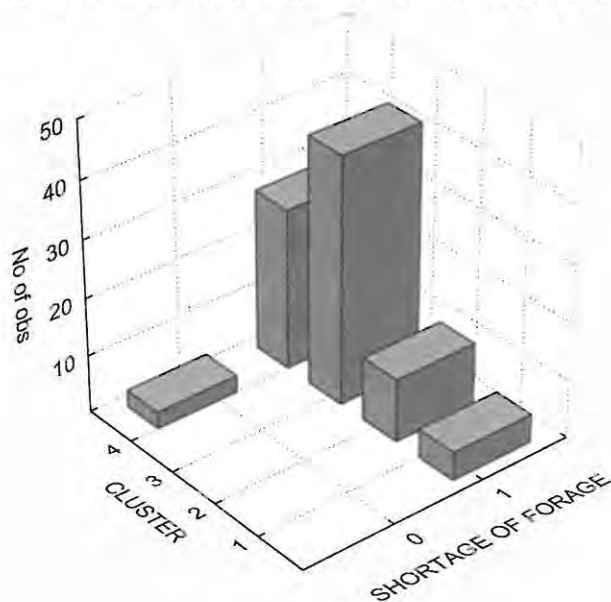
Honeybees of the southern Ethiopian region migrate from place to place for a number of reasons. Some of the reasons reported by farmer beekeepers of this region are: shortage of honeybee forage, shortage of water, high temperature, pests and predators, drought, high rainfall and excessive cold. However the relative importance of these factors to drive the migration of honeybee colonies varied from place to place.

Shortage of honeybee forage was found to be one of the major factors that cause honeybee colony migration in all four-honeybee group areas. All farmer beekeepers interviewed from the western and southern lowlands, eastern escarpment and central and

eastern highlands and 90.3% farmer beekeepers from the wet tropical forests stated that their honeybee colonies migrate when there is a shortage of honeybee forage in the area (Fig. 30). No significant differences were observed among the responses (Yates chi-square =3.67, df = 3; p = 0.2988). This implies that in all four group areas, shortage of honeybee forage is probably one of the most important factors forcing honeybee colonies to migrate.

Fig. 30. Response of farmer beekeepers: a shortage of forage is one of the causes for the migration of their honeybee colonies (0 = against and 1 = in favour).

CAUSE OF MIGRATION: CLUSTER x SHORTAGE OF FORAGE



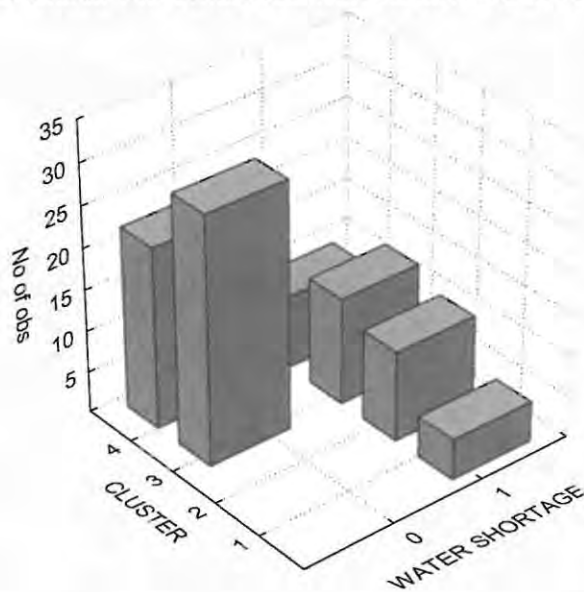
Yates chi-square adjusted = 3.67, df = 3; p = 0.2988

All of the farmer beekeepers interviewed in the western and southern lowlands and eastern escarpment honeybee group areas stated that a shortage of water is one of the main factors that cause the migration of honeybee colonies in the area. But 88.4% of 43 and 67.7% of 31 farmer beekeepers in the central and eastern highlands and wet tropical forests respectively reported that water shortage is not the problem, and went on to say that no honeybee colonies migrated due to a shortage of water (Fig. 31). The results were statistically highly significantly different (Yates chi-square = 24.5, df = 3; $p < 0.0001$), suggesting that shortage of water is a cause of honeybee colony migration in the western and southern lowlands and eastern escarpment honeybee groups but not in the central and eastern highlands and wet tropical forests groups. That is a shortage of water can cause honeybee migration in lowlands and dry areas, where there is a scarcity of water, while in the highlands and tropical forest areas, where there are ample water sources (rivers) honeybees never face a shortage of water and thus this factor is not an important reason for the migration of honeybee colonies in these areas.

Fig. 31. Response of farmer beekeepers: a shortage of water is one of causes for the migration of their honeybee colonies (0 = against, 1 = in favour).

Yates chi-square adjusted = 24.5, df = 3; p = 0.0001

CAUSE OF MIGRATION: CLUSTER x SHORTAGE OF WATER

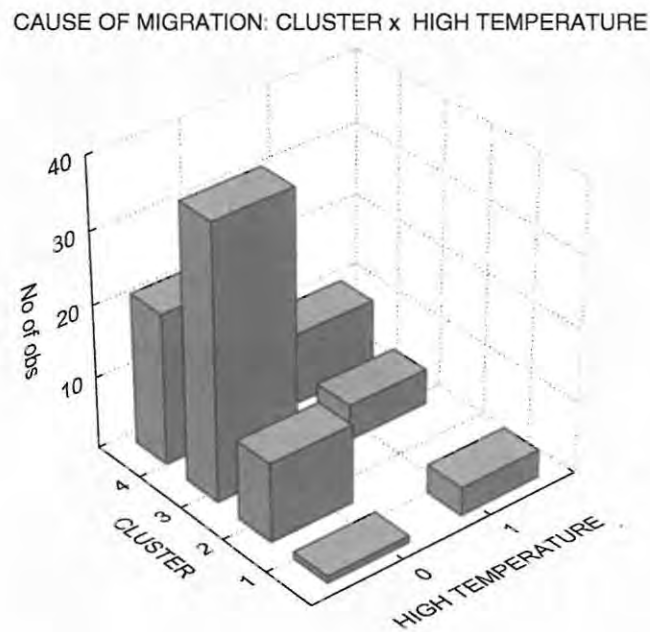


80% of 5 farmer beekeepers at the western and southern lowlands honeybee group area favoured high temperatures as a cause of honeybee colony migration while 100% of 11, 88.4% of 43 and 67.7% of 31 farmer beekeepers interviewed from the eastern escarpment, central and eastern highlands and wet tropical forests respectively did not agree that high temperatures cause migrations of their honeybee colonies (Fig. 32). The results varied highly significantly (Yates chi-square =16.35, df = 3; p = 0.0009), implying that excessive heat in the western and southern lowland areas could drive honeybee

colonies to migrate but not in the other three areas (central and eastern highlands, eastern escarpment and wet tropical forests), which have relatively lower temperatures than the former.

Fig. 32. Response of farmer beekeepers: high temperature is a cause for migration of honeybee colonies in their respective areas (0 = against, 1= in favour).

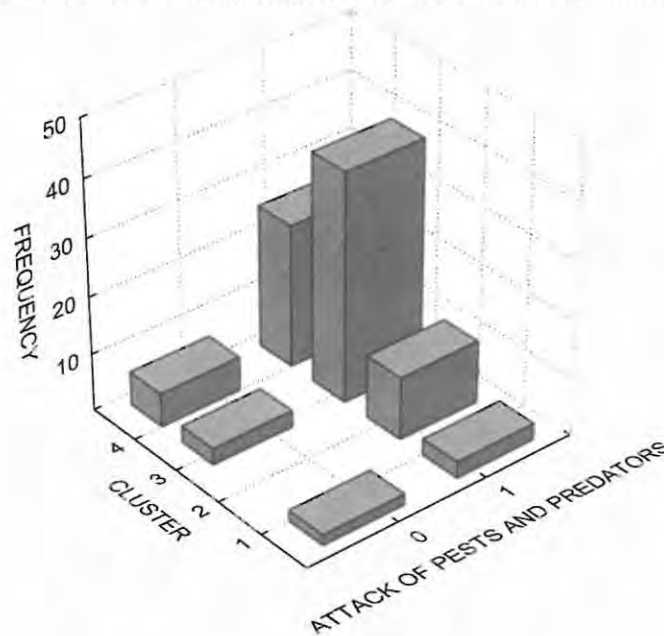
Yates chi-square =16.35, df = 3; p = 0.0009



60%, 100%, 93% and 80.6% of the sample units from the western and southern lowlands, eastern escarpment, central and eastern highlands and wet tropical forests claimed that pest and predator attacks forced honeybee colonies to migrate (Fig. 33). The results were not statistically significant (Yates chi-square = 7.24, df = 3; p = 0.6451), indicating that this problem is common in all four areas.

Fig. 33. Response of farmer beekeepers: attack of pests and predators is one of the causes for the migration of honeybee colonies in the area (0 = against, 1 = in favour).

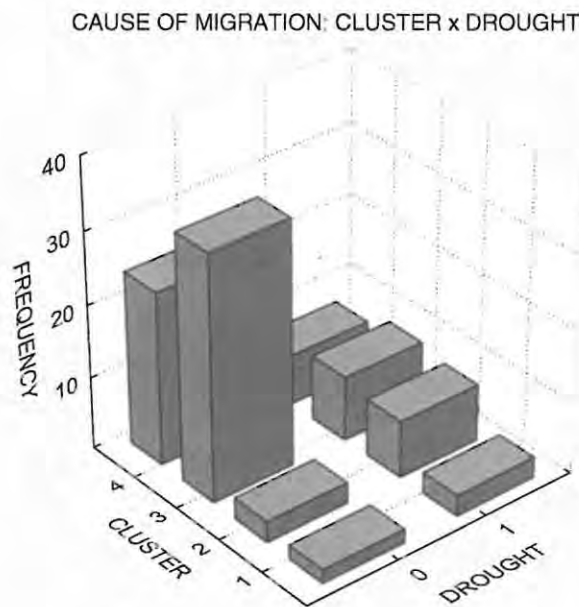
CAUSE OF MIGRATION: CLUSTER x ATTACK OF PESTS AND PREDATORS



Yates chi-square = 7.24, df = 3; p = 0.6451

60% and 72.7% of the sample units from the western and southern lowlands and eastern escarpment honeybee group areas respectively claimed that drought causes honeybee colony migration in their respective areas, while 79.1% and 77.4% farmer beekeepers from central and eastern highlands and wet tropical forests disagreed that honeybee colonies of their areas migrated due to drought (Fig. 34). The results varied highly significantly (Yates chi-square =13.71, df = 3, p = 0.0033) indicating that drought mainly causes migration of honeybee colonies only in the areas of the western and southern lowlands and eastern escarpment.

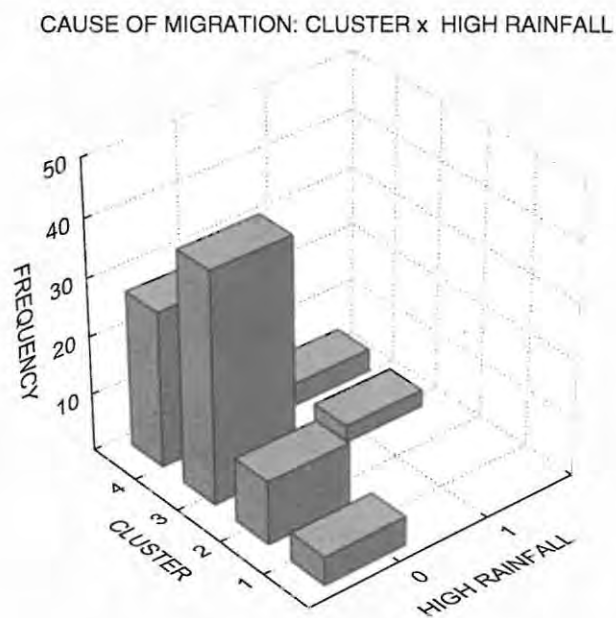
Fig. 34. Response of farmer beekeepers: drought is one of the factors that causes honeybee colony migration (0 = against, 1 = in favour).



Yates chi-square =13.71, df = 3, p = 0.0033

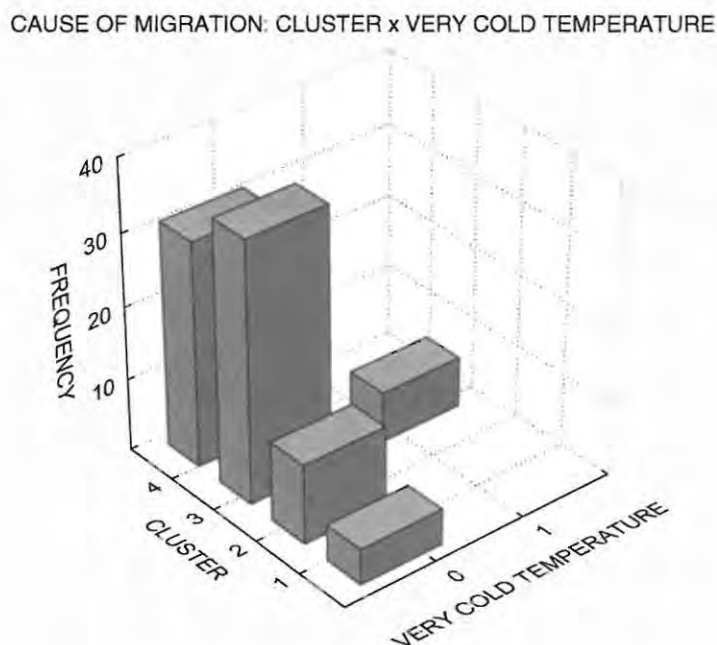
Even though cold and high rainfall were reported as causes of honeybee colony migration by a few farmer beekeepers from central and eastern highlands and wet tropical forests groups, the statistical results show that these were not important factors in causing migration (Figs. 35 and 36). Moreover, pesticides and high winds were not reported in any of the areas as causing migration of honeybee colonies.

Fig. 35. Response of farmer beekeepers: high rainfall is a cause for the migration of honeybee colonies (0 = against, 1 = in favour).



Yates chi-square adjusted = 1.29, df = 3; p = 0.7305

Fig. 36. Response of farmer beekeepers: very cold temperature is a cause for the migration of honeybee colonies in the area (0 = against, 1 = in favour).



Yates chi-square adjusted = 5.62, df = 3; p = 0.1313

4.8.3 Aggressive behaviour

An attempt was made to rate the aggressive behaviour of southern Ethiopian honeybees through interviewing farmer beekeepers. 75.3% of the sample units stated that honeybees of the region are aggressive while the balance (24.7%) stated that they are very aggressive (Table 36). None of the farmer beekeepers who were interviewed claimed that their honeybee colonies are docile. From the survey data an attempt was also made to evaluate each of the honeybee groups based on the response of farmer

beekeepers of their respective areas. Accordingly, 60% of the farmer beekeepers claimed that the western and southern lowland honeybee groups are aggressive and 40% highly aggressive, while 72.7% of the sample units claimed that the eastern escarpment honeybees are aggressive and the balance highly aggressive. Similarly, 88.1% and 61.3% of the sample units claimed that the central and eastern highland and wet tropical forests honeybees respectively are aggressive and the balance from each area highly aggressive (Table 36).

Table 36. The percentage responses of beekeepers for rating aggressive behaviour of southern Ethiopian honeybee groups.

Groups	Aggressive	Highly aggressive	Total (n = 89)
Group 1 (n = 5)	60.0	40.0	5.6
Group 2 (n = 11)	72.7	27.3	12.4
Group 3 (n = 42)	88.1	11.9	47.2
Group 4 (n = 31)	61.3	38.7	34.8
Total	75.3	24.7	100

Yates chi-square adjusted = 7.60, df = 3; p = 0.055

The claims made by farmer beekeepers from the respective areas for the honeybee groups were found to be statistically not significantly different (Yates chi-square adjusted = 7.60, $df = 3$; $p = 0.055$), implying that the majority of the farmers graded their respective areas of honeybees in the same category (aggressive and/or very aggressive). To confirm the claims made by farmer beekeepers, the highly aggressive rates of honeybees of each group were calculated from the ratio of numbers of honeybee colonies that are highly aggressive to the total numbers of honeybee colonies owned by sample units and the data were analysed using Kruskal-Wallis ANOVA due to the variances of the data were significantly different ($P < 0.05$). The numbers of stings a beekeeper receive during honey harvest were also analysed in the same way as the data violated the assumption of the ANOVA.

The percentage of highly aggressive honeybee population in the region ranges from 37 to 55 with an average of 42.8%. The number of sting a beekeeper receives during honey harvest varies from 27 to 48 with an average of 36. About 38% of western and southern lowlands, 55% of eastern escarpment, 41% of central and eastern highland and 37% of wet tropical forestland honey groups are highly aggressive and no significant differences were found among the groups ($H(3, N = 85) = 5.41$; $p = 0.144$). This implies that the proportions of highly aggressive honeybee colonies are almost same in all four honeybee groups. This result was further supported by the absence of significant differences in the number of stings imposed on an individual during honey harvest ($H(3, N = 88) = 1.784$; $p = 0.6184$) by all honeybee groups. The mean number of stings received from western and southern lowland, eastern escarpment, central and east

highland and wet tropical forestland honeybee groups during honey harvest are 27, 36, 35 and 48 respectively.

Farmer beekeepers associate the aggressive behaviour of their honeybee colonies with colour; 61.8% of the farmer beekeepers stated that yellow honeybee colonies are highly aggressive, while the remaining 38.20% claimed that the black honeybees are highly aggressive (Table 37). However it has been observed that this claim varied from place to place depending on type of the honeybee group, 80% of farmer beekeepers in the western and southern lowlands honeybee areas and 58.0% from wet tropical forests claimed that black honeybees are highly aggressive. 54.6% from the eastern escarpment group areas and 83.3% from the central and eastern highlands honeybee group areas stated that yellow honeybee colonies are highly aggressive. Moreover the overall results indicate that yellow honeybees are more aggressive than the black ones (Table 37).

Table 37. Aggressiveness rated by colour in the honeybee groups of Southern Ethiopia (numbers indicate the percentage of responses at each area of the groups).

Groups	Yellow honeybees	Black honeybees	Total (n = 89)
Group 1 (n = 5)	20.0	80.0	5.6
Group 2 (n = 11)	54.6	45.5	12.4
Group 3 (n = 42)	83.3	16.7	47.2
Group 4 (n = 31)	41.9	58.0	34.8
Total	61.8	38.2	100

Yates chi- square = 16.7, df = 3; p < 0.0008

The aggressive behaviour of honeybees changed from season to season depending on the conditions provoking the honeybees to be more aggressive. The western and southern lowlands honeybee group are more aggressive during June through August and the group from the eastern escarpment during December through February. The central and eastern highlands and wet tropical forests honeybee groups become more aggressive during September through November (Table 38).

Table 38. The seasons in which honeybee groups of southern Ethiopia become more aggressive (numbers are the response in percentage of the sample units).

Groups	Sept-Nov	Dec-Feb	Mar-May	Jun-Aug	Total (n =89)
Group 1 (n = 5)	20.0	0.0	0.0	80.0	5.6
Group 2 (n = 11)	0.0	45.5	27.3	27.3	12.4
Group 3 (n = 42)	83.3	16.7	0.0	0.0	47.2
Group 4 (n = 31)	64.5	0.0	32.3	3.2	34.8
Total	62.9	13.5	14.6	9.0	100.0

Yates chi-square adjusted = 63.93 df = 9; $p < 0.0001$

4.8.3.1 Conditions aggravating the aggressiveness of honeybees

To identify conditions and factors aggravating the aggressiveness of honeybees, 13 options were given to the sample units, farmer beekeepers, to sort out the factors driving honeybees to more aggressive behaviour than usual. The factors and conditions are: honey harvesting time, honey flow time, dearth period, rainy season, attacks of pest and predators, swarming time, migration time, foraging time, brood rearing time, early morning (6 - 11 am), midday (11.05 am – 2 pm), afternoon and when all honeybees are in the hive.

Accordingly, from their long experience, the sampled farmer beekeepers identified only 5 factors or conditions under which honeybees become more aggressive than usual. These are: honey flow period, honey harvesting time, brood rearing time, when attacked by pests and predators and at midday.

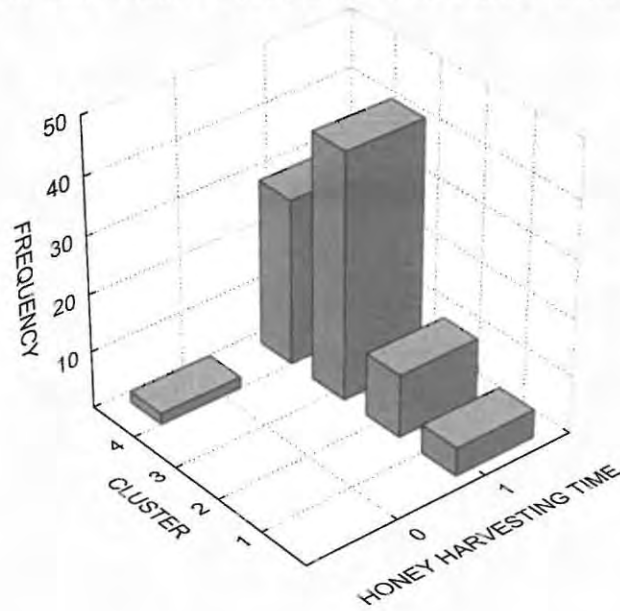
100% from 5, 11, and 43 sampled farmer beekeepers from the western and southern lowlands, eastern escarpment and central and eastern highlands respectively and 93.5% from 31 sample units from the wet tropical forests stated that honeybees become more aggressive during the honey harvest and brood rearing times (Figs. 37 and 40). Similarly, from the same number of sample units above, all from the western and southern lowlands, eastern escarpment and central and eastern highlands and 90.3% from the wet tropical forests claimed that honeybees become more aggressive than usual during the honey flow period (Fig. 38). Moreover, all sample units in the western and southern lowlands and eastern escarpment and 93% and 90.3% of sampled farmer beekeepers from the central and eastern highlands and wet tropical forests stated that

honeybee colonies are more aggressive during midday compared to early morning and late afternoon (Fig. 41). No statistically significant differences (Yates chi-square > 0.05) were observed in the above results implying that all four honeybee groups become more aggressive during honey flow period, harvesting time, brood rearing period and at midday.

On other hand, 60% of sample units from the western and southern lowlands, 100% from eastern escarpment and 70% from the wet tropical forests stated that attacks of pests and predators make honeybees more aggressive while 65.1% of the sampled farmer beekeepers from central and eastern highlands disagreed (Fig. 39). The results were statistically significant (Yates chi-square; $p < 0.0004$), indicating that attacks of pests and predators do not seem to cause aggressive behaviour of honeybees in the central and eastern highlands as in the other three honeybee groups.

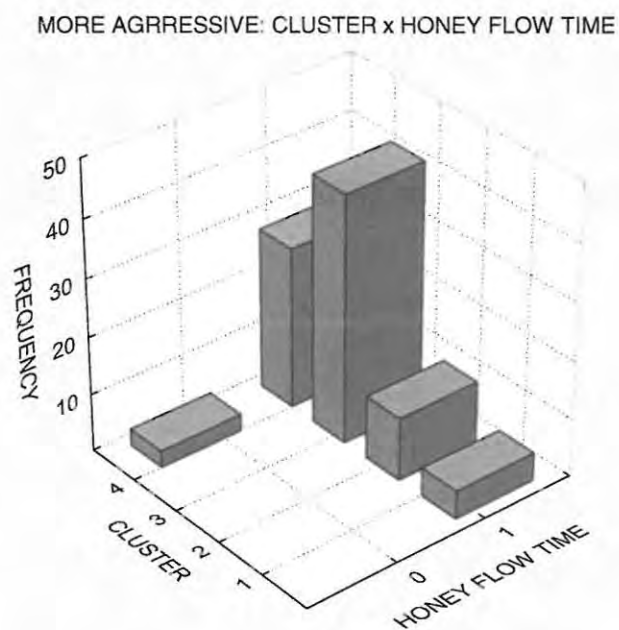
Fig. 37. Response of farmer beekeepers: honeybees are more aggressive during honey harvest (0 = against, 1 = in favour).

MORE AGGRESSIVE: CLUSTER x DURING HONEY HARVEST



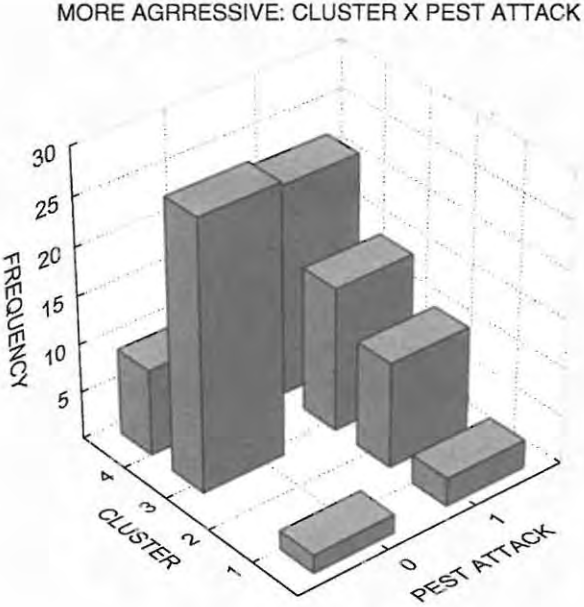
Yates chi-square adjusted = 2.28, df = 3; p = 0.5145

Fig. 38. Response of farmer beekeepers: honeybees are more aggressive during honey flow time (0 = against, 1 = in favour).



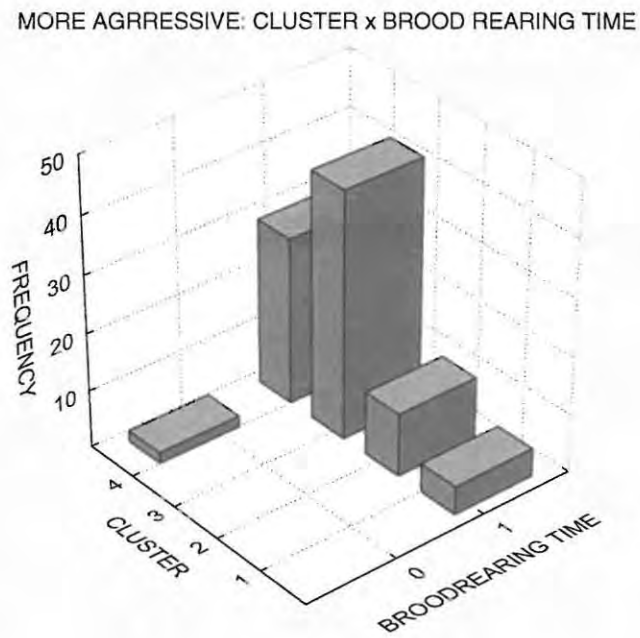
Yates chi-square adjusted = 3.67, df = 3; p = 0.2988

Fig. 39. Response of farmer beekeepers: honeybees are more aggressive when honeybee colonies are attacked by pests and predators (0 = against, 1 = in favour).



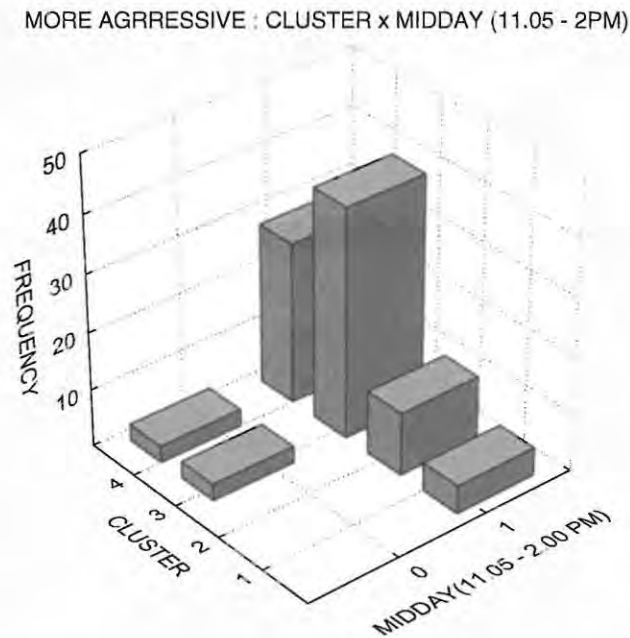
Yates chi-square adjusted = 18.13, df = 3; p = 0.0004

Fig. 40. Response of farmer beekeepers: honeybees are more aggressive during brood rearing time (0 = against, 1 = in favour).



Yates chi-square adjusted = 2.28 df = 3; p = 0.5145

Fig. 41. Response of farmer beekeepers: honeybees are more aggressive during midday (11.05 am – 2.00pm) (0 = against, 1 = in favour).



Yates chi-square adjusted = 0.55 df = 3; p = 0.9076

A number of accidents and deaths due to honeybee attacks were reported from all areas. The death of a child and a number of goats were reported in Itang and Woyito respectively, which represent the western and southern lowlands honeybee group area. In the area of the eastern escarpment honeybee group deaths of a donkey, a cow, a camel and cattle in the Karre Tule were reported. In the areas of wet tropical forests honeybee group deaths of a 15 years old girl in “Jaul peasant association” in 2000, an old woman in “Late peasant association”, and another elderly woman in Sawla in 1999 and number of

cattle, horses and mules were reported. In areas of the central and eastern highlands honeybee group the deaths of two girls, one 4 years old and the other 15 years old in Alage, 4 donkeys and a number of chickens in Boke Tiko, 3 donkeys and 2 calves in Wolison (Roge) in 1999 were reported due to honeybee attacks (stung). A number of cattle in the field, 30 sheep in a shelter and 5 children were stung in Dudi Affi when honeybee samples were collected from this site for this study.

4.8.4 Correlations of honeybee behaviour with climate and physical environmental factors

The analysis of correlations (Table 39) shows that the reproductive swarming rate of the southern Ethiopian honeybee groups is significantly positively correlated with minimum and maximum temperatures and rainfall of the region and significantly negatively correlated with longitude and altitude. The correlations of swarming rate with longitude (-0.84) and rainfall (0.87) were very strong compared to the other factors. The swarm catching rate in the region was also correlated significantly positively with rainfall and negatively with latitude.

These results reveal that higher temperature and rainfall induce reproductive swarming. One of the possible reasons may be that an increase in the environmental temperature would increase the hive temperature and thus create an unpleasant environment to conduct hive activities. One of the mechanisms honeybees use to cool down their hives is to reduce the population in the hive to create enough place for fresh air to circulate inside the hive hence this situation could induce swarming. Furthermore warm temperature stimulates plants to bloom fast and abundantly.

On other hand, rainfall creates an environment conducive for vegetation of the areas to bloom, supplying ample forage for honeybees and this drives brood production and swarming. But at higher altitudes, the temperature is cooler. This makes honeybees spend much of their time warming the brood in particular and the hive in general and limits foraging activities thus decreasing the tendency to swarm.

Longitude is negatively correlated with swarming that is, as longitude increases the swarming rate decreases. In other words as one moves eastwards the swarming tendency of honeybees is lower. This is may be because from the west to the east part of the region, the vegetation coverage is in progressive decline and climatic conditions for honeybees is not as suitable as the in western parts, thus the tendency to swarm is lower as one proceeds from west to east. Where there is a high swarming rate there would be a higher chance to catch swarms which explains why rainfall and swarm catching rates were positively correlated to each other.

Migration rates in the region were significantly negatively correlated with altitude and significantly positively correlated with maximum and minimum temperatures. This indicates that the highland honeybees have less of a migration tendency than the lowlands honeybees. A possible reason may be that the majority of lowland areas have a harsher climate and a shortage of forage and water compared to the highland areas.

Table 39. The correlations among some honeybee behaviours and climate and physical environment of the region.

Behaviour	Latitude	Longitude	Altitude	Maximum temperature	Minimum temperature	Rainfall
Swarming rate	0.32 P= 0.082	-0.84 P< 0.0001	-0.43 P= 0.004	0.50 P= 0.004	0.51 P= 0.004	0.87 P < 0.0001
Migration rate	0.30 P= 0.103	-0.05 P= 0.782	-0.50 P=0.004	0.51 P= 0.003	0.50 P= 0.004	-0.04 P=0.844
Swarm catching rate	-0.66 P< 0.001	-0.25 P= 0.172	0.30 P= 0.107	-0.33 P= 0.074	-0.34 P= 0.65	0.49 P= 0.005

(The levels of significance were adjusted using the Bonferroni procedure that is significant correlation if p-value < 0.0083).

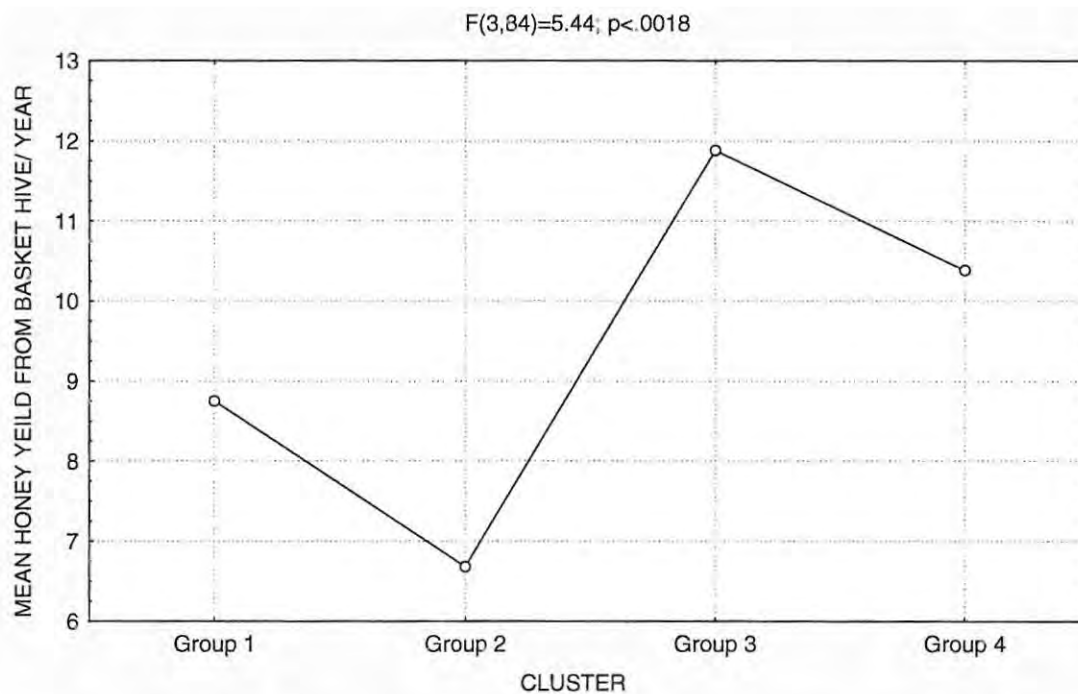
4.9 Honey

4.9.1 Honey production

The mean honey yield of 1999/2000 from basket hives in the southern Ethiopian region varies from 6.7 to 11.9 kg with an average of 9.4 kg per hive. As indicated in Figure 42 the mean honey yield among the four honeybee groups was found to be highly significantly different ($F(3,84) = 5.44, p < 0.0018$). The highest honey yield was recorded from the central and eastern highlands and the wet tropical forests honeybee groups followed by the western and southern lowland honeybee group. However, there

was no statistically significant difference in honey yield among these three groups ($p > 0.05$, Table 40). The lowest honey yield was recorded from the eastern escarpment honeybee group, which is significantly less than that of the wet tropical forestland and highly significantly less than the honey yield from the central and eastern highlands honeybee group (Table 40).

Fig. 42. Mean honey yield of the four southern Ethiopian honeybee groups (units in kg) in the year 1999/2000.



Group 1 Western and southern lowlands honeybee group

Group 2 Eastern escarpment honeybee group

Group 3 Central and eastern highlands honeybee group

Group 4 Wet tropical forest honeybee group

Table 40. P-values multiple comparisons (Tukey *post hoc*, HSD test) for mean honey yield (1999/2000) among the four honeybee groups of southern Ethiopia (figures in brackets indicate mean honey yield in kg).

Groups	Group 1 (8.75)	Group 2 (6.68)	Group 3 (11.88)	Group 4 (10.39)
Group 1		0.8048	0.4301	0.8620
Group 2	0.8048		0.0011**	0.0429*
Group 3	0.4301	0.0011**		0.3826
Group 4	0.8620	0.0429*	0.3826	

* statistically significant, $p < 0.05$

** statistically highly significant, $p < 0.01$

4.9.2 Honey flow period

The region has two honey flow periods: the main one in which most of the honey of the year is expected is commonly referred to as the major honey flow period, and a second period in which less honey is expected is termed the minor honey flow period. Though this varies from place to place, the major honey flow period of the region occurs mainly during September through November (Table 41). The major honey flow period in areas of the central and eastern highlands and wet tropical forests is from September through November, October being the peak time, while December to February and June

to August are the major honey flow periods for the eastern escarpment and west and southern lowland honeybee groups respectively (Table 41). The minor honey flow period in the areas of central and eastern highlands, wet tropical forests and western and southern lowlands is March to May while for the eastern escarpment honeybee groups the minor honey flow period is June through August (Table 42).

Table 41. The major honey flow periods for the four southern Ethiopian honeybee groups (numbers are the response percentages of the sample units).

Yates chi-square =74.95, df = 9; p < 0.0001

Groups	Sep - Nov	Dec - Feb	March - May	June - August	Total (n = 89)
Group 1 (n = 5)	20.0	0.0	0.0	80.0	5.6
Group 2 (n = 11)	0.0	72.7	27.3	0.0	12.4
Group 3 (n = 42)	83.3	16.7	0.0	0.0	47.2
Group 4 (n = 31)	54.8	9.7	32.3	3.2	34.8
Total	59.6	20.2	14.6	5.6	100

Table 42. Minor honey flow periods for the four southern Ethiopian honeybee groups (numbers are the response percentages of the sample units).

Yates chi-square =13.37, df = 3, p = 0.0038

Groups	March - May	June - August	Total (n = 63)
Group 1 (n = 2)	100.0	0.0	3.2
Group 2 (n = 8)	0.0	100.0	12.7
Group 3 (n = 37)	64.9	35.1	58.7
Group 4 (n = 16)	75.0	25.0	25.4
Total	60.3	39.7	100

Chapter Five

5 Discussion

5.1 General

The morphometric characters associated with pigmentation of honeybees of the southern Ethiopian region had average values between 2.64 and 8.95, indicating that they are highly variable in pigmentation. Mixed yellow and black honeybees in a single colony and in different colonies of the same group were observed. However, southern Ethiopian honeybees are predominantly dark in colour. About 78% of the population is dark, while the balance (22%) is yellow. In the eastern escarpment honeybee group, yellow drones were also observed. The variations in pigmentation observed in the honeybees of southern Ethiopia were in accord with the findings of Radloff and Hepburn (1997a) and Hepburn and Radloff (1998) which indicate that the honeybees of Ethiopia exhibit a high degree of variability in pigmentation the whole length of the country. The works of Rashad and El-Sarrag (1978, 1980), Saeed (1981), Mogga (1988) and El-Sarrag *et al.* (1992) showed similar variability in pigmentation of Sudanese honeybees. The honeybees of southern Ethiopia are darker in colour than those of neighbouring Sudan, which may be due to the higher altitudes of Ethiopia.

Similarly, all morphometric characters associated with body size (widths of tergite 3 (9), tergite 4 (10) sternite 3 (11) and sternite 3 (13)) revealed variability both within and between southern Ethiopian honeybee groups. These results concur with the findings of Kassaye (1990), Radloff and Hepburn (1997a) and Hepburn and Radloff (1998) who also reported a high degree of variability in the size of Ethiopian honeybees.

The body size of southern Ethiopian honeybees showed a trend of decreasing

from the central highlands to the extreme southwest lowlands. That is, the central highland bees (group 3) are bigger than those of the wet tropical forestlands (group 4) bordering them to the southwest. These wet tropical forestland bees are in turn larger than those of the western and southern lowlands (group 1), which occupy the southwest of the group 4 area. However, these results do not support the zoogeographical rules of Bergman and Allen which, when reviewed by Ruttner (1985), showed that body size decreases from north to south. This is because the eastern escarpment honeybees (group 2), which occur between 7.3⁰N and 9.1⁰N latitude, are smaller than the central highlands honeybees distributed between 6.5⁰N and 8.3⁰N. The western and southern lowland honeybees that occupy the area between 5.2⁰N and 8.2⁰N are smaller than the wet tropical forestland honeybees found between 4.5⁰N and 8.2⁰N latitudes.

The southern Ethiopian honeybees showed some similarities with the Sudanese honeybees for certain body size measurements. The mean width of tergite 3 (2.03), tergite 4 (1.97) and sternite 3 longitudinal (2.48) of the southern Ethiopian honeybees (Table 8) closely match the body size of Sudanese honeybees: width of tergite 3 (2.03), tergite 4 (1.96) and sternite 3 longitudinal (2.48) (Mogga, 1988).

One of the interesting results of this study was that, unlike the previous studies of Radloff and Hepburn (1997a) and Hepburn and Radloff (1998), no significant differences were observed in the forewing venation angles used to discriminate the southern Ethiopian honeybees, except for the angle O26, across the study areas. A significant mean difference in forewing venation angle O26 was only noted between colonies from Woshi (S4) and colonies from four localities (Boke Tiko (S18), Nazrieth (S19), Effo

Yachi (S23) and Boter Bacho (S24)). The same result was also obtained in morphometric studies of northern Ethiopian honeybees (Nuru, unpublished).

5.2 Correlation of morphometric characters with each other and environmental factors

Highly positive correlations were found among all morphometric characters associated with pigmentation, with the exception of the scutellar plate. This revealed that pigmentation characters follow the same pattern. That is, change in pigmentation of one such character will also be observed in the other pigmentation characters. In other words honeybees that have a dark thorax may also have a dark abdomen. This may be due to the fact that characters associated with pigmentation are commonly governed either by the same genetical and/or environmental factors (Newell, 1915). This result is in agreement with the findings of Kassaye (1990) and Radloff and Hepburn (1997a) that the ranges of abdominal pigmentation of Ethiopian honeybees are significantly correlated to each other and to the pigmentation of the thorax. However, on the contrary, the scutellar plate was found negatively correlated to other pigmentation characters in the present study. In the southern Ethiopian honeybee groups, honeybees with yellow abdominal pigmentation were observed to have a darker scutellar plate and vice versa.

Morphometric characters associated with body size (width of tergite 3 (9), tergite 4 (10), sternite 3 longitudinal (11), sternite 3 transversal (13) and hair length on the fifth abdominal segment (1)) show strong positive correlations among themselves and negative correlations with pigmentation. Increase in one aspect of body size will also be manifested in other morphometric characters associated with body size. For example, the

long body hair would most likely indicate relatively large honeybees, while those with shorter body hair would be relatively smaller in size. This relationship cannot however, be generalised as some exceptions exist (*A. m. litorea*, the smallest honeybee, has a longer proboscis (Ruttner, 1988)). On other hand, the larger honeybees have a darker pigmentation than the smaller honeybees. These results agree with those of Mogga (1988), Kassaye (1990) and Radloff and Hepburn (1997a).

Forewing venation angles, B4 and N23 had no significant correlation to each other or to the other morphometric characters associated with pigmentation and body size. However angle O26 was weakly significantly negatively correlated to body size (tergite 3 (9) and 4 (10) and sternite 3 (13)) and body hair (1). The larger honeybees of the southern Ethiopian honeybee groups have a relatively small forewing venation angle O26 compared to smaller honeybees. These correlation results generally revealed that the existence of inter-relationships among the morphometric characters used in the discrimination of the southern Ethiopian honeybees, except forewing venation angle B4 and N23 and pigmentation on scutellar plate.

These morphometric characters are also correlated with climate and the physical environmental factors of the regions. It was found that abdominal pigmentation was greatly influenced by altitude, temperature and rainfall and to some extent by latitude and longitude. Honeybees in the warmer regions are lighter in colour than those of the cooler regions. Although colour is partially genetically based, temperature has a great effect on the body colouration of honeybees. Brood reared at higher temperatures developed as yellow, while those reared at lower temperatures became black honeybees (Tsurata *et al.* 1989; Spivak *et al.*, 1990). On other hand, pigmentation is negatively affected by altitude

and rainfall. At higher altitudes there is relatively higher rainfall and lower temperatures and hence the honeybees are darker in this region. That is, as the altitude increases the pigmentation of the honeybees becomes darker as a result of low temperatures. Although, not as strong a factor as climate (temperature and rainfall) and altitude, longitude also has a positive correlation to honeybee pigmentation (except for the scutellar plate). In the southern region of Ethiopia, an increase in longitude leads to the eastern parts of the region becoming semi-arid and/or arid and temperatures are relatively higher compared to the central parts of the country, hence colour is lighter than in the central parts of the region. Thus an increase in longitude correlates with an increase in the intensity of honeybee pigmentation. In other words, as one proceeds further eastwards there is more chance of observing lighter honeybees than in the central areas.

Altitude and temperature have a great influence on body size and hair length of honeybees of the region. Altitude has a positive effect while temperature has a negative impact on these morphometric characters. The highland honeybees are larger in size and have longer body hair than those from the lowland. Honeybees from regions of high temperature and low precipitation are smaller (Ruttner, 1988). Generally, gradual size variation in eastern Africa was correlated with altitude, going from the plains upwards to the Mts Meru and Kilimanjaro (Smith, 1961; Ruttner, 1976b). This may be because the highlands are cooler than the lowlands, so the honeybees are black, larger and have longer hair to minimize heat loss. Moreover greater size may be associated with the presence of a richer bee flora in the highlands than the lowlands, as morphometric characters associated with body size are influenced by quantity and quality of brood food (Ruttner, 1988; Goetz and Koeniger, 1992). The larger body size in highland honeybees

might also be an adaptation to minimize heat loss encountered in the prevailing weather conditions in the highlands. That is because of a larger volume of these honeybees and the correspondingly reduced surface area to the volume, there will be a decrease in heat loss.

5.3 Morphometric characters for the discrimination of honeybees of southern Ethiopia

As indicated in section 2.3, after careful screening, Ruttner (1978) used a standard set of 36 morphometric characters for the discrimination of honeybee races of the world. He indicated the possibility of reducing this standard set of morphometric characters by two-thirds, depending on the region under investigation and when using stepwise discriminant analysis statistics. 9-11 morphometric characters were used for the discrimination of African honeybees (Crewe *et al.*, 1994; Radloff, 1996; Radloff *et al.*, 1996; Radloff and Hepburn, 1997a, b; Hepburn and Radloff, 1998). Using these few morphometric characters they were able to discriminate the African honeybees as successfully as Ruttner (1978) did using the standard set of 36 morphometric characters. This indicated that instead of using large numbers of morphometric characters, a few well-chosen morphometric characters, which have good discriminatory power, would save time and labour. This is because not all morphometric characters have a high discriminatory power. Hence the most useful morphometric characters for the discrimination of honeybees may well vary from place to place.

This phenomenon was observed in morphometric analyses of southern Ethiopian honeybees. Of 13 morphometric characters used in the morphometric analysis, only 10

were entered into the discriminant functions. The other 3 morphometric characters (forewing venation angles B4, N23 and O26) had shown no discriminatory power. On the other hand morphometric characters associated with pigmentation and body size had a high discriminatory power. They had high factor loadings and were entered into the discriminant function in the factor analysis and stepwise discriminant analysis respectively. These two sets of morphometric characters accounted for about 64.6% of variance in the honeybee population. On other hand, the mean values of forewing venation angles did not show significant differences across the sampling localities, indicating a lack of discriminatory power. This result is not in agreement with the findings of Radloff and Hepburn (1997a) and Hepburn and Radloff (1998) who indicated that these forewing venation angles were important morphometric characters for the discrimination of Ethiopian honeybees along their transect of the country.

The differences in the results are probably due to the smaller sample sizes and larger sampling distance variations between their transect and the present study. In the transect study only 40 colonies from 8 localities with an average sampling distance resolution of about 140km were used for the discrimination of honeybees (Radloff and Hepburn, 1997a; Hepburn and Radloff, 1998). In the present study of the southern Ethiopian honeybees, which constitutes only half the country, 130 honeybee colonies collected from 26 localities at an average sampling distance between localities of 89km was employed. The greater the distance and the smaller the sample size, the greater difference in morphometric characters. This is in line with the results of Radloff *et al.* (1998) and Radloff and Hepburn (2000) who showed that the greater distance between the samples the more distinct the morphoclusters. Moreover, the present results are

consistent with the findings of the multivariate morphometric analysis of the northern Ethiopian honeybees (Nuru, unpublished) and multivariate morphometric analyses of honeybees in the Ethiopian region (Amssalu *et al.*, in press) that show the forewing venation angles (B4, N23 and O26) lack discriminatory power for Ethiopian honeybees. Therefore when adequate sample sizes and a greater sampling distance resolution are used, Ethiopian honeybees could be successfully discriminated using the morphometric characters associated with pigmentation and body size, exclusive of wing venation angles. That is, the type and number of morphometric characters used in the discrimination of honeybees depend on the region under investigation (Ruttner, 1988).

5.4 Morphoclusters

Factor and stepwise discriminant analyses revealed the existence of four morphometrically different honeybee groups in the southern Ethiopian region. These groups occupy different ecological areas having different environmental factors: group 1 occupies the western and southern lowlands; group 2 is distributed in the eastern escarpment which is characterised by semi-arid conditions and group 3 and group 4 are honeybees of the central and eastern highlands and wet tropical forestlands respectively. Generally Ethiopia has a complex physiography (Van Chi-Bonnardel, 1973; Mammo, 1976). It is comprised of mountains, hills, plateaus, plains, valleys and gorges and has ranges of elevations and slopes with the lowest point at the Denakil depression at about 126 metres below sea level and the highest at the top of Rasdashen (Rasdejene) Mt about 4620 metres above sea level. It comprises 18 major agro-ecological regions and 48 sub-agro-ecological areas, which may vary greatly over short distances. Indeed, in some

places, one can experience different types of ecology within one kilometre distance (for example, from extreme highlands to lowlands MOA, 1998). These wide variations make the country a homeland for highly diversified fauna and flora. Therefore it seems reasonable that different honeybee groups are found which have adapted to the diverse ecology in this physiographically complex country. This is consistent with a number of findings: Ruttner and Kauhuesen (1985) stated that, in spite of the absence of natural barriers in tropical African countries, as in European countries, honeybees are significantly geographically variable due to the selective adaptation to biotopes. For example, Kigatiira (1984) indicated that Kenyan honeybees are characterised by a specific geographical distribution confined by natural barriers and Mbaya (1985) stated that the morphology and behaviour of Kenyan honeybees vary according to ecological zones. Rashad and El-Sarrag (1978, 1980), Saeed (1981), Mohamed (1982), Mogga (1988) and El-Sarrag *et al.* (1992) stated that different agro-ecological zones of Sudan are occupied by different geographically definable honeybee groups. Smith (1961), Ruttner (1975), Radloff and Hepburn (1997a), Kassaye (1990) and Hepburn and Radloff (1998) reported the existence of various honeybee groups in different ecological areas of Ethiopia.

The enormous differences in ecological conditions, including temperature, humidity, wind and vegetation produced a number of different types of honeybees in the course of evolution that differ clearly in ecological adaptations, morphological and behavioural characteristics. Each ecological area has its own honeybee group. Due to colonization of wide ranges of similar ecology, African honeybees have a number of specific morphological and behavioural characters in common (Ruttner, 1976).

The groups of southern Ethiopian honeybees were compared to other African honeybees to investigate whether similarities exist among them. Data from Ruttner (1988), Radloff and Hepburn (1997a) and Hepburn and Radloff (1998) were used for comparisons.

In the western and southern semi-arid to sub-moist lowlands of Ethiopia the honeybees (group 1) were very small and lighter in colour than those of group 3 and group 4. Their size did not correlate with any of the identified honeybees from Africa. Group 1 is generally yellow in colour following group 2 (eastern escarpment honeybees) as the lightest in colouration. However the population is a mixture of yellow and black in a proportion of 2.3 : 1. In distribution, group 1 occupies the lowlands directly below the territory of group 4 honeybees at the southwestern border of Ethiopia. Group 1 is significantly different from group 4 honeybees in both colour and body size. In comparing honeybees of group 1 to other honeybees in areas closest to the neighbouring countries of Sudan, Somalia, Kenya and Uganda, the factor analysis was run by merging this data with the data obtained from Grahamstown on honeybee colonies from Yei, Kajiko and Jwatoka in southern Sudan ($3.56^{\circ}\text{N} - 4.05^{\circ}\text{N}$ and $30.39^{\circ}\text{E} - 31.13^{\circ}\text{E}$), Buale and Dugiume in Somalia ($1.14^{\circ}\text{N} - 1.2^{\circ}\text{N}$ and $42.34^{\circ}\text{E} - 42.36^{\circ}\text{E}$), Mombasa, Malindi and Shimba in northern Kenya ($3.14^{\circ}\text{S} - 4.12^{\circ}\text{S}$ and $34.47^{\circ}\text{E} - 40.05^{\circ}\text{E}$) and Kampala, Masindi, Hoima, Arapai, Lira, Mbale, Kitguma and Bugoye in Uganda ($0.17^{\circ}\text{N} - 19.0^{\circ}\text{N}$ and $30.06^{\circ}\text{E} - 34.12^{\circ}\text{E}$).

The results indicate that this Ethiopian honeybee group forms a separate cluster at the right-hand quadrant of the plot, revealing that group 1 is statistically significantly different from honeybees from the neighbouring countries and other African honeybee

groups. This finding is consistent with the results of Kassaye (1990) who indicated that Gambella honeybees (which was one of my sampling localities, (Itang)) were the smallest of the African honeybees and had no similarities to honeybees from neighbouring countries. He further stated that they formed a single, separate cluster unit, representing the lowland areas of the country. However Kassaye (1990) identified these honeybees as *A. m. litorea*, which does not, in this present study, correspond to the honeybees of group 1 either by morphometric characteristics (Table 43) or ecological distribution. That is, the ecological distributions of these two groups are quite different: *A. m. litorea* occurs in the eastern coastal plains (Ruttner, 1988, 1992), while group 1 occupies the southwestern lowlands of the mainland. The macrosatellite and mitochondrial DNA analyses of African honeybees revealed that the Ethiopian honeybee lineage is different to other African honeybees (Franck *et al.*, 2001). Hence, it is no wonder that this honeybee group is different from all African honeybees known so far.

The distance between the two localities Itang (Gambella) and Woyito is large compared to our sampling inter-locality distance, but areas between these localities have a similar ecology. As extracted from an atlas of Ethiopia (Mesfin, 1970), more than 66% of the area between Itang and Woyito is located below 1000m above sea level. The annual temperatures vary between 18⁰C - 25⁰C and about 51% of the area has an annual temperature of 20⁰C - 25⁰C. This area receives an annual rainfall of between 600mm and 1800mm. The natural vegetation constitutes tropical woodland and thorny bush, grassland and savannah. Thus, due to the ecological similarities of the area between Itang (Gambella) and Woyito, honeybees of this region might be similar to those of group 1. However, further studies in this area are required to refine these results. Honeybees of

group 1 were named “*A. m. woyi-gambella*”, for working purposes until the area is more extensively studied. This name derived from a contraction of two localities, Woyito and Gambella as is customary in the Amharic language.

Table 43. Morphometric comparisons of *A. m. litorea* and group 1 honeybees. (Data on *A. m. litorea* was obtained from the amalgamated honeybee databases from Oberursel and Grahamstown, Hepburn and Radloff, 1998).

Characters (Ruttner Nos.)	<i>A. m. litorea</i>		Group 1 Mean values
	Means	Ranges	
11	2.46	2.4 – 2.52	2.35
13	2.07	2.03 – 2.11	1.93
1	0.22	0.20 – 0.24	0.13
32	7.67	6.98 – 8.36	6.44
34	7.3	6.5 – 8.1	1.84
35	6.36	5.89 – 6.83	4.22

Honeybees of the eastern escarpment (group 2) are larger than those of *A. m. woyi-gambella* (group1) but smaller than those of the central and eastern highlands (group 3) and the wet tropical forestlands (group 4). This group occupies the area between Dudi Affi (Jijjiga), Somali region and Korre Tule (Bale), Oromia regional states, which is climatically characterised as a semi-arid region of the southeastern parts of

Ethiopia (Fig. 43). This group of honeybees is the yellowest of all honeybees of this region although a few black worker honeybees were observed in some colonies. The proportion of yellow to black worker bees was nearly 5:1. Moreover, yellow drones were observed in honeybee colonies at Dudi Affi, Jijjiga. Morphometrically this group of honeybees match *A. m. jemenitica* for 6 morphometric characters associated with both pigmentation and body size. The mean pigmentation values of the scutellum (5.42) and tergite 2 (7.28) of group 2 fall within the pigmentation range of values for *A. m. jemenitica*, morphometric pigmentation characters: scutellum (3.91 – 7.83) (Hepburn and Radloff, 1998) and tergite 2 (0.33 – 8.67) (Radloff and Hepburn, 1997a). Similarly, the mean size of sternite 3 (11) (2.44), sternite 3 (13) (2.02), tergite 3 + tergite 4 (4.02) and hair length (1) (0.16) for this group also falls within the range of values for *A. m. jemenitica*, which correspond with morphometric characters: sternite 3 (11) (2.36 – 2.55) (Hepburn and Radloff, 1998), sternite 3 (13) (1.97 – 2.15) (Radloff and Hepburn 1997a), tergite 3 + tergite 4 (3.8 – 4.04) (Ruttner, 1988) and hair length (1) (0.16 – 0.22) (Radloff and Hepburn, 1997a) (Table 44).

Table 44. Comparison of morphometric measurements of group 2 honeybees with those of *A. m. jemenitica* honeybees.

Characters (Ruttner Nos.)	<i>A. m. jemenitica</i>		Group 2 Honeybees Mean values
	Range values	Source of data	
11	2.36 – 2.5	Radloff and Hepburn (1997a)	2.44
13	1.97 – 2.15	Hepburn and Radloff (1998)	2.02
1	0.16 – 0.22	Radloff and Hepburn (1997a)	0.16
T 3 + T 4	3.80 – 4.04	Ruttner (1988)	4.02
32	0.33 – 8.67	Radloff and Hepburn (1997a)	7.28
35	3.91 – 7.83	Hepburn and Radloff (1998)	5.42

The results also reveal ecological similarities between these two groups of honeybees: *A. m. jemenitica* is distributed in the hot arid zones of east Africa (Ethiopia, Somalia and Sudan) extending to Saudi Arabia, Yemen, Oman (Ruttner, 1988; Mogga, 1988; Kassaye, 1990; Radloff and Hepburn, 1997a). There are no natural barriers within these east African countries, but there is the narrow belt of the Red Sea between Ethiopia and the Middle East. However, these are also connected by the Suez Canal and Babl Mandeba outlet. Therefore group 2 honeybees are regarded *A. m. jementica* as they have close morphological and ecological similarities. The recent discovery of a Y lineage in Ethiopia and Y mitotypes in *A. m. jemenitica* (Franck *et al.*, 2001) supports the

conclusion that *A. m. jemenitica* is one of the distinct Ethiopian honeybee groups. *A. m. jemenitica* is east African honeybee but has emigrated to the Arabian Peninsula (Dutton, 1981; Ruttner, 1988). Moreover these results are also in line with the findings of Kassaye (1990) who indicated that the honeybees of the eastern lowlands of Ethiopia are related to *A. m. jemenitica*.

Honeybees of the central and eastern highlands (group 3) are the largest and darkest with the longest body hair of all honeybee groups of the southern Ethiopian region. Although these honeybees are generally dark, a few yellow worker bees were observed in the colonies. Black and yellow honeybees within the population are in the ratio of 13:1, black being predominant. These honeybees have morphometric characteristics that are intermediate between the mountain honeybees (*A. m. monticola*) and honeybees from the wet tropical forestlands groups (group 4). However a stepwise discriminant analysis showed that these group 3 honeybees significantly varied from both honeybee groups (*A. m. monticola* and group 4) and formed a separate cluster. The mean pigmentation values of scutellum (35), scutellar plate (36), tergite 2 (32) and size of sternite 3 (11), sternite 3 (13) and hair length (1) of group 3 fall within the range values for the morphometric characters of darker and larger honeybees found in the savannah and eastern regions of Sudan towards the Ethiopian borders, which were classified as *A. m. bandasii* (Mogga, 1988) (Table 45). This result was in agreement with the findings of Radloff and Hepburn (1997a), who regarded the honeybees of the central regions of Ethiopia as *A. m. bandasii* in their study on multivariate analysis of honeybees along a transect through the Horn of Africa. The honeybees of the central and eastern highlands were morphometrically inseparable from the honeybees of Sudan both in colour and size.

A. m. bandasii differs from other Sudanese honeybees both in colour and size and have a closer affinity to Ethiopian honeybees (Mogga, 1988). The absence of natural geographical barriers between these two countries may result in the highland honeybees of Ethiopia expanding their territory to eastern Sudan along the Nile River where bee forage exists year round. This is supported by Mogga (1988) whose results indicate that the honeybees of Ethiopia have an affect on the honeybees of savannah and eastern region of Sudan. Mogga named these honeybees *A. m. bandasii*. Thus the name *A. m. bandasii* is used for these honeybees of the central highlands of Ethiopia.

Table 45. Morphometric measurements comparison of group 3 with those of *A. m. bandasii* honeybees.

Characters (Ruttner Nos.)	<i>A. m. bandasii</i> Range values*	Group 3 honeybees Mean values
Scutellum (35)	0 - 0.62	0.34
Scutellar plate (36)	0 - 0.46	0.08
Tergite 2 (32)	0 - 3.26	0.62
Hair length (1)	0.18 - 0.26	0.19
Sternite 3 (11)	2.57 - 2.71	2.55
Sternite 3 (13)	2.08 - 2.24	2.08

* Data from Radloff and Hepburn, 1997a

In the wet tropical forestlands of southern Ethiopia, large, dark honeybees (group 4) were observed second in size to the central highland honeybees (*A. m. bandasii*). These honeybees exhibited similarities in pigmentation of the scutellar plate and sizes of sternite 3 (11) and sternite 3 (13) to eastern and southern African honeybees, *A. m. scutellata* (Hepburn and Radloff, 1998) and honeybees of eastern coastal plains, *A. m. litorea* (Ruttner, 1988). The honeybees from the wet tropical forestlands also showed some variation compared to *A. m. scutellata* and *A. m. litorea* in that their ecological distribution and hair length were different from *A. m. litorea*, while colour variation was the main difference between these honeybees and *A. m. scutellata*. These honeybees are darker than *A. m. scutellata*, having yellow and dark honeybees in the proportion of 1:10 and close to *A. m. sudanensis* in colour but larger in size.

In the multivariate morphometric analysis of honeybees in the region of Ethiopia (Amssalu *et al.* in press), the wet tropical forestland honeybee group clustered with the honeybees of northwestern wet tropical forestland honeybees and corresponded well with *A. m. scutellata* with regard to the morphometric characters thoracic pigmentation and length of body hair (1), size of sternite 3 (11) and sternite 3 (13) compared to other honeybee groups mentioned above. *A. m. scutellata* was also recognised as the southernmost honeybees of Ethiopia and northern most honeybees of Kenya (Hepburn and Radloff, 1998), which match the present distribution of these honeybees from the wet tropical forestlands. *A. m. scutellata* occupies altitudes between 500m and 2400m above sea level with temperatures ranging between 16⁰C and 23⁰C while the honeybees from the wet tropical forestlands occur at altitudes ranging from 1427m–2157m with annual temperatures of 12⁰C to 26⁰C which is similar to that of the ecology of *A. m. scutellata*.

Therefore from the point of morphometric and ecological distribution, similarities between these groups of honeybees allow them to be regarded as *A. m. scutellata* and this concurs with the suggestions and findings of Hepburn and Radloff (1998) and the results of Ruttner (1975), who indicated the presence of *A. m. scutellata* in Ethiopia.

5.5 Transitional zones

Both high intra and intercolonial variances were noticed in some localities of all groups of honeybees of southern Ethiopia. A high degree of intracolony variance (within colony) was found in honeybee colonies of Konso, Nazrieth, Woltae Atote, Gado Lama, Alage, Sawla, Itang, Korre Tule and Dudi Affi and intercolonial variance (between colonies) was observed in the colonies of the first three mentioned localities. Honeybee colonies from Konso, Woltae Atote and Nazrieth were distributed among morphoclusters. These localities are transitional areas between the ecological zones of southern Ethiopian honeybee groups (Fig. 43). Konso occurs between western and southern lowland honeybees, *A. m. woyi-gambella* and west tropical forest honeybees, *A. m. scutellata*. It is situated at an altitude of 1436m with an annual temperature of 14.1⁰C to 26.7⁰C and rainfall of 749mm. It is a transitional area between lowland and wet tropical forest ecology (Table 46). It also borders with *A. m. jemenitica* below the boundary of *A. m. scutellata*, suggesting an area of introgression between *A. m. woyi-gambella*, *A. m. scutellata* and *A. m. jemenitica*. Similarly, Woltae Atote falls between the boundaries of *A. m. jemenitica*, *A. m. bandasii* and *A. m. scutellata* and is an ecologically transitional area between semi-arid and highland areas with intermediate climatic conditions (Table

46). Thus it is a probable area of introgression between *A. m. jemenitica*, *A. m. bandasii* and *A. m. scutellata*.

Nazrieth occupies the Rift valley and has a climate intermediate between the eastern escarpment semi-arid and midlands (Table 46). Morphometrically, honeybee colonies of this area have a closer affinity to the eastern escarpment, *A. m. jemenitica*. Therefore these localities are the centre of gene flow among these statistically defined honeybee groups. This may also be associated with the high swarming and migration behaviour of the southern Ethiopian honeybees. Besides these localities (Konso, Woltae Atote and Nazrieth) are areas of low precipitation and insufficient bee forage. As a result of these conditions, honeybee swarms are a scarce resource for beekeepers who wish to increase the numbers of their colonies or to start beekeeping. Beekeeping is a deep-rooted, traditional practice among farmer beekeepers of these areas. Beekeepers obtain their colonies either through purchase or by trapping a swarm from the neighbouring forest areas (different ecology), which could belong to a different honeybee group and may lead to introgression in local honeybee groups. In Alage commercial beekeeping is practiced by a government institute (Zuway children centre). Because beekeeping is one of the cash generating agricultural activities for the centre, migratory beekeeping is extensively practiced to assure a high honey yield. On other hand, Itang, Gado Lama, Karre Tule and Dudi Affi and Sawla occur at the edge of *A. m. woyi-gambella*, *A. m. bandasii*, *A. m. jemenitica*, and *A. m. scutellata* boundaries respectively, reflecting the instability in localities and thus they are associated with a high intracolony variance. Therefore, these conditions might have a notable contribution to the flow of genes

between honeybee colonies of these localities, resulting in both high intercolonial and intracolony variance, suggesting areas of transition.

Therefore a high degree of variance in the population of honeybees is associated with ecological variation, instability and discontinuities of climatic conditions (Radloff, 1996), mobile behaviour (swarming and migration) of honeybees and transhumance. In other words, the population variance of honeybees is related to ecological conditions, which are reflected in the phenology of honey plants of the area. The absence of physical barriers and ecological changes within short distances (ecoclines) may result in the occurrence of variance within and/or between honeybee populations. Moreover the reproductive and migration behaviour also enhance variations in the population as these movements of colonies from place to place allow gene permeability among statistically distinct morphoclusters.

Similar significant high variances (both intra and intercolonial) in morphometric, pheromone and flight-related characters of Ethiopian honeybees in the area of *A. m. bandasii*, *A. m. jemenitica* and *A. m. scutellata* were reported (Radloff and Hepburn, 1997a; 2000; Hepburn and Radloff, 1998).

5.6 Behaviour of honeybee groups of southern Ethiopia

5.6.1 Reproductive swarming

Reproductive swarming is the natural multiplication of honeybee colonies to provide for future generations. This means that part or parts of a honeybee colony move from the maternal nest to an entirely new site to assure colony reproduction. African honeybees have a high reproductive swarming tendency compared to European ones. This is

attributed to a number of reasons, of which the main ones are: the African environment and climate favours the existence of different types of pests and predators which endanger the life and cause the loss of numerous honeybee colonies every year. This loss can only be regained through reproductive swarming (Fletcher and Tribe, 1977; Fletcher, 1978). The second reason may be associated with the floral resources. The environment is conducive to the growth of different types of vegetation, which have different flowering times and supply a succession of adequate honeybee forage (pollen and nectar) for longer periods of time and this may initiate reproductive swarming. Moreover some of the African honeybees have high fecundity, a shorter developmental period, and a higher foraging efficiency than European honeybees which, in combination, result in the economic production of more worker honeybees per unit time and space and subsequently reproductive swarming (Fletcher, 1978).

Although reproductive swarming varies between localities and honeybee groups, this still takes place in the southern Ethiopia every year. The reproductive rate of southern Ethiopian honeybees ranges from 8.9% to 36.6% with an average of 23%, and the average swarm catching rate in the region is about 36.4%. This implies that the southern honeybees are inclined to reproductively swarm and this presents the opportunity to bait swarms. This may be due to the fact that the region is rich in different types of honeybee flora, ranging from weeds to forest trees, that supply adequate bee forage every year and thus drives maximum brood rearing. These favourable conditions create a population growth within honeybee colonies beyond the accommodation capacity of traditional bee hives of the region (which measures in average 1.5 metre in length and 0.5 metre in width). Overcrowding as a result of population growth within

honeybee colonies induces reproductive swarming. Tropical honeybees have a strong reproductive swarming impulse and tendency to increase population very quickly leading to rapid multiplication of colonies (Smith, 1958b; Fletcher, 1977; Winston *et al.*; 1979). Some honeybee groups are more genetically disposed to reproductive swarming than other honeybee groups, but to comment further in this area is beyond the scope of the present investigation.

Even though the extent of reproductive swarming varies among honeybees, successive or multiple reproductive swarming is also exhibited in the southern Ethiopian honeybees. Although this is also connected to the ample forage resources of the region, it seems that this is an adaptation of the honeybee colony to ensure the next generation. All the swarms issued from a colony may not succeed and stabilise at new sites because of resource limitations and environmental hazards. An average of 76% of swarms that established nests in summer died in winter in the temperate zone (Seeley, 1985) and 20% of 200 colonies were lost in South Africa (Fletcher, 1978). Therefore successive reproductive swarming is advantageous for honeybees to maintain future generations, so that a high reproductive rate is a strategy of survival for tropical honeybees (Hepburn and Radloff, 1998).

Tendency to reproductive swarming in the wet tropical forestlands (*A. m. scutellata*) and central and eastern highlands (*A. m. bandasii*) is higher than in the eastern escarpment (*A. m. jemenitica*) and the western and southern lowland (*A. m. woyigambella*) regions. This may be attributed to the climate, weather and forage resources of the regions. The former two regions are richer in bee forage than the later regions because they are under the influence of the monsoon or deflected trade winds of similar moisture

content. Thus regions of wet tropical forestlands and the central and eastern highlands receive the highest rainfall and have more moderate temperatures than the eastern escarpment and lowlands. Thus the former areas are more favourable for the growth and flowering of diversified plants that provide sufficient pollen and nectar for honeybees for a longer period of time. This was supported by strong positive correlation between reproductive swarming and rainfall (Table 39).

This is in agreement with Ruttner (1975, 1976, 1988) who indicated that tendency to reproductively swarm varies within and between different honeybee groups and *A. m. scutellata* has tendency to reproductive swarming.

The simultaneous occurrence of a high tendency to reproductively swarm, successive reproductive swarming, and swarm catching rate in some regions (wet tropical forestlands and central and eastern highlands) indicate that where there is sufficient rainfall, there will be ample or adequate bee forage and higher successive (multiple) reproductive swarming and there by high chance of getting swarms. However the high chance of getting swarms is not only associated with high reproductive swarming and resource rich areas because the swarm catching rate in the eastern escarpment (resource poor area) was not significantly different from the wet tropical forestlands. This probably indicates that the swarm catching rate also associated with the mobility of honeybees. That is in areas where there is high mobility of honeybees (high migration rate in eastern escarpment), there might be also good chance to obtain swarms. Even though western and southern lowland area is better than eastern escarpment in honeybee forage, the swarm catching rate in this area is significantly different from both resource rich areas (central and eastern highlands and wet tropical forestlands). That is swarm catching is

significantly low in western and southern areas. This may be attributed to the mobility behaviour (low swarming and intermediate migration rates) of honeybee groups of this area.

In 3 of 4 honeybee groups yellow and highly aggressive honeybees showed high propensity to reproductive swarming (Tables 26 and 27). This may indirectly supports the results that temperature is positively correlated to swarming and strong colonies disposed to swarming respectively. Because the higher the temperature the lighter is the colour of honeybees and the stronger colony are usually highly defensive.

The time of year in which reproductive swarming occurs is very important to beekeepers since successive reproductive swarming may result in economic loss. Though several methods are available for the prevention of reproductive swarming, their successful application requires practical knowledge at which time of the year reproductive swarming occurs. Reproductive swarming in southern Ethiopia mainly occurs in September through November (Tables 29 and 30). However, the principal reproductive swarming periods vary from place to place depending on the weather, climate and phenology of honey plants irrespective of morphoclusters. This agrees with Hepburn and Radloff (1988) who noted the lack of coherence between biological traits and the morphoclusters or races of Africa. In the wet tropical forestlands and central and eastern highlands, reproductive swarming occurs in two periods of the year: during September through November (major) and March through May (minor). In the western and southern lowlands and eastern escarpment reproductive swarming occurs only once a year during June through August and December through February respectively. Thus

reproductive swarming in *A. m. bandasii* and *A. m. scutellata* is biphasic while in the *A. m. jemenitica* and *A. m. woyi-gambella* honeybee groups it is monophasic.

One of the possible reasons could be that the regions of the former two honeybee groups have two good flowering and honey flow periods (September - November and March - May) during which honeybees collect sufficient pollen to support reproductive swarming in both periods of the year. On other hand, the regions of *A. m. jemenitica* and *A. m. woyi-gambella* have more limited honey plants and, unlike the former regions, provide forage for only a short time especially during the second flowering period (June - August and March - May respectively). Thus, the quantity of forage during the second period does not extend beyond the maintenance and steady growth of colonies. Therefore *A. m. bandasii* and *A. m. scutellata* have a double chance to multiply and spread their populations compared to the other two morphoclusters (*A. m. woyi-gambella* and *A. m. jemenitica*).

The reproductive swarming periods coincide with the flowering periods of honey plants of the region. This varies from year to year and from place to place because of the country's different rainfall patterns. The main causes of rainfall in the country are the tropical summer monsoon, easterlies and local convergence in connection with the land-sea-wind system (FAO, 1983). The summer rainfall (the main rain), which occurs from June through August, is caused by monsoon airflow patterns in almost all parts of the country except the southeast, which is dry during this particular period. In high rainfall areas of the southwest, rain extends from spring to autumn, whereas the autumn rainy season (September – November) brings the summer dry season to an end in the southeastern parts of the country (FAO, 1983).

In all cases reproductive swarming occurs during the flowering period of honey plants, which occurs either during or after the rainy season of the respective area. In other words reproductive swarming is associated with the rainy season (Table 47). The western and southern lowlands receives rainfall during March through November while reproductive swarming occurs June to August and in the eastern escarpment rain starts in summer and merges into autumn (September to November) while reproductive swarming occurs during December through February. In the areas of central and eastern highlands and wet tropical forestlands, rain occurs from June to August and March to May and reproductive swarming occurs during and after the rainy seasons, September - November and March - May respectively. Flowering, which is preceded by the rainy seasons, provides an intense flow of honeybee forage that drives brood production, which ultimately leads to reproductive swarming.

The reproductive swarming time varies within the same honeybee group (Table 47) depending on the climatic and rainy season prevailing in that particular locality. Thus a shift in time of the rainy season would result in a shift in time of the reproductive period. Reproductive swarming in the areas of *A. m. woyi-gambella* occurs during rainy season (June - August) and starts earlier than in the areas of the other honeybee groups and is followed by the wet tropical forestlands and central and eastern highlands (September -November), while that of eastern escarpment occurs later (December - February). This may be associated with the pattern of the rainy season of the country. The main rain in Ethiopia starts from the west and southwest and gradually extends to the eastern and southeast parts of the country. Moreover the rain starts to dissipate from the east and southeast and gradually proceeds to the west and southwest. In other words the

rain begins early and ends late in the west and southwest while rain reaches the eastern and southeast parts of the country later and stops earlier. Therefore these conditions may possibly explain why the reproductive swarming period is earlier in the western and southern lowlands but later in the eastern escarpment. The other possible reason why reproductive swarming occurs during the rainy season in the western and southern lowlands may be the fact that vegetation of the lowland areas responds faster and provides intense flowering within a short period of time as the rain starts due to the warmer temperatures of the areas and honeybees also adapt to cope with the fast and short flowering times.

5.6.2 Migration

Migration is the seasonal movement of an entire colony from an established nest in resource-poor areas to resource rich areas and it is more pronounced in some areas than others. Migration is highly developed in African honeybees and in an evolutionary sense it is an alternative to massive hoarding (Fletcher, 1978). The degree of the tendency to migrate depends on the behaviour and response to different stimuli (Chandler, 1976). However, this definition is misleading because there is also seasonal absconding which means the colony may vacate its nest due to seasonal fluctuations in resource availability, weather, incidence of pests (Winston *et al.*, 1979; Winston, 1987; Fletcher, 1975, 1978; Woyke, 1976). The causes for migration could also be the same for absconding, thus we limit the discussion of migration behaviour of southern Ethiopian honeybees because there is insufficient information to clearly demarcate the differences between migration and seasonal absconding. Hence, the term “migration” is used here in a broad sense.

As indicated in Section 4.8.2.1, honeybees of the region migrate every year. The average annual migration rate of southern Ethiopian honeybee groups varies between 25.5% and 58.8% with an average of about 39%, revealing that all honeybee groups of the region have a tendency to migrate to varying degrees. The highest migration rate was exhibited in *A. m. jemenitica*. This was supported by the highest rate of vacant beehives in the region of these honeybees. On other hand, although different rates of migration were observed among *A. m. bandasii*, *A. m. scutellata* and *A. m. woyi-gambella* honeybees, these differences were not statistically significant (Table 32). One of the reasons why the migration rate in *A. m. jemenitica* is higher compared to the highland honeybee groups is because it occupies one of the main regions in the country with low rainfall and the occurrence of drought. The southeastern lowlands receive considerably less rain because the monsoon air mass can only reach the lowlands after crossing the highlands, by which time most of the moisture content is lost (FAO, 1983). Thus the region is designated as a semi-arid zone, characterized by poor vegetation and water resources. Therefore, the climate, adverse conditions and shortage of forage force these honeybees to migrate compared to the highland ones, which have less adverse climatic conditions in their region. Though *A. m. woyi-gambella* honeybees are found in the lowlands where the temperature is relatively high compared to the regions of *A. m. bandasii* and *A. m. scutellata*, because it is under the influence of the monsoon air mass, the area receives high rainfall for a relatively longer period and has an abundant natural vegetation compared to the area of *A. m. jemenitica* and hence there is a reduced migration rate similar to that of the other southern Ethiopian honeybee groups (the central and eastern highlands and wet tropical forestlands).

This is supported by the findings of Kigatiira (1979) who indicated that migration is highly developed in eastern Africa and more pronounced in dry areas. In areas where very long dearth periods occur or receive less rainfall in a year, the majority of honeybee colonies will migrate while areas with adequate rainfall and suitable flora most of the year, fewer honeybee colonies migrate (Chandler, 1976). In the central and eastern highland areas of *A. m. bandasii*, beekeepers reported that a number of honeybee colonies stay in the same hives for many years. This also agrees with Chandler's reports (1976) that some ecotypes of African honeybees remain in the same hive for many years through many generations of queen. It has been noticed that weak colonies (small colonies) migrate more readily than strong (populous) colonies. Small colonies have little chance of survival even when dearth periods are short, while strong colonies are capable of maintaining themselves through out dearth periods.

Like *A. m. woyi-gambella*, *A. m. scutellata* honeybees exhibited an intermediate tendency to migrate. That is no significant variation in rate of migration between these honeybees and *A. m. jemenitica* that exhibit high migration rate in the region. This may be because even though *A. m. scutellata* occupies humid and resource-rich areas, migration rate in this honeybee group is relatively high. This may be partially attributed to a traditional method of destructive beekeeping practise in the area. In south and southwest areas of *A. m. scutellata*, beekeeping is practised in the forest and no attention is paid to honeybee colonies. Bees live as they live in wild state and thus they are exposed to pests and predators. Moreover during honey harvest beekeepers remove the entire hive contents and forces honeybee colonies to leave and collect hives for the next season.

The time at which migration occurs in the southern Ethiopian region varied from place to place depending on the climatic conditions. It mainly occurs during dry and rainy seasons. In the areas of *A. m. woyi-gambella* migration occurs right after the rainy season during December through February whereas in the areas of *A. m. jemenitica* it occurs on average three months after the first rainy seasons during March through May. In the areas of *A. m. bandasii* and *A. m. scutellata* it occurs during both dry and rainy seasons. In the southern regions of *A. m. scutellata* and eastern regions of *A. m. bandasii* migration occurs during the dry season between December through February while in the rest of the areas both honeybee groups migration occurs during rainy season (June to August Fig. 45). These results indicate that the migration period varied both within and between honeybee groups and occurs during dry periods (December - February) in less moist lowland and semi-arid areas while in moist and/or humid areas it occurs during rainy periods. These periods are times at which a decline of forage is prevalent. That is, dry areas are harsher during dry periods while moist and/or humid areas receive high rainfall for more than three months and this also might limit the foraging activities of honeybees and reduce forage resources available and hence honeybee colonies are vulnerable to any adverse conditions and forced to leave as they are weak in the absence of enough forage or stores.

In some areas of *A. m. scutellata* (Masha, S3 and Woshi, S4) and *A. m. bandasii* (Boter Bacho, S24) honeybee colonies migrate during honey harvesting periods due to the removal of all hive contents (honey, pollen, brood and combs). In other areas of central and eastern highlands farmer beekeepers are more conscientious about their honeybee colonies and leave some honey, pollen and brood to ensure the colonies stay

after honey harvesting. Moreover, beekeepers in some areas of *A. m. bandasii* (Serofta, S12) practice clipping the wings of the queen to protect their honeybee colonies from abandoning the nest.

The direction of migration of southern Ethiopian honeybee groups varies and is associated with the climatic conditions of their regions. *A. m. bandasii* and *A. m. scutellata* migrate to the lowlands mainly during the rainy season (June - August). This is a time when there is a shortage of forage in the highlands and wet tropical forestlands and plants in bloom and abundant forage is available in the western and southern lowlands. *A. m. woyi-gambella* and *A. m. jemenitica* honeybees migrate to the highlands during December through February and March to May respectively. Similarly March to May is a time of flowering in most areas of the highlands and even though December to February is dry period in most of the highlands, in the west midland and highland areas (Masha and Gechi) it is time in which plants bloom in these particular areas and these areas are close to *A. m. woyi-gambella* honeybees. Thus the direction of migration in both cases (to highlands and lowlands) seems reasonable and associated with forage available and agrees with the principle of honeybees migrating from resource-poor to resource-rich areas (Fletcher, 1978).

Shortage of forage, water, high temperatures, drought, cold temperatures and high rainfall were reported as factors driving the honeybees to migration by farmer beekeepers of the southern Ethiopian region. However, the importance of these factors as causes for migration vary from place to place depending on climate and ecological conditions. Shortage of forage and presence of pests and predators are common causative factors of migration in all regions of southern Ethiopia. Shortage of pollen and nectar are prevalent

in all areas of the region when honey plants of the region are not in bloom. Hence during this specific period the shortage of adequate forage is common in all regions. Similarly, even though the types and abundance of pests and predators vary from place to place, they occur everywhere as the tropical climate is a conducive environment for the existence of these honeybee enemies. A shortage of bee forage and pests and predators are therefore a problem in all regions. Migration is usually caused by the exhaustion of honey stores and adverse conditions triggered by various enemies (Ntenga, 1976). On the other hand high temperatures, drought and shortage of water and all except for high temperatures are additional causal factors for migration in the regions of *A. m. woyigambella* and *A. m. jemenitica* honeybees as the regions are lowland and semi-arid regions respectively. They have relatively high temperatures and low precipitation; on other hand, high rainfall and cold temperatures are not the significant causative factors for migration of *A. m. bandasii* and *A. m. scutellata* even though the regions are highlands and wetlands respectively and receive high rainfall. One of the main reasons may be that honeybee colonies are kept under house roofs or in shelters in the highlands and the hives are wrapped with bamboo and false banana leaves, which are waterproof, in the wet tropical forestlands. Both conditions also protect bees from cold.

The majority of the sample units reported that honeybee colonies which migrated return to their place, when the adverse conditions of the area improved. In other words they believed that the same honeybee colonies come back to their place when the honey plants of the area are in bloom and ample forage is available. However further investigation is required to verify whether the same colonies return to their original place

or other honeybee colonies from other places come to the place due to the depletion of forage resources they encountered in their original places.

5.6.3 Aggressiveness

Honeybee colonies have guard bees at their entrances. The main task of these guards is to intercept and examine any intruders coming into the entrance. They are the first to attack intruders and release alarm pheromones to recruit other honeybees to strengthen the defence force. Isoamyl acetate ($C_5H_{14}O$) and 2-heptanone ($C_7H_{14}O_2$) are the main alarm pheromones produced by these worker bees. The aggressive behaviour of honeybees is positively correlated with a high concentration of 2-heptanone (Gary, 1970). Higher amounts of 2-heptanone elicit more recruitment of large numbers of defending bees (Kerr *et al.*; 1974; Gary, 1970).

Despite several attempts to define honeybee colony defensive behaviour, there is still a lack of a systematic and quantitative approach for the study of this behaviour of honeybee colonies (Hepburn and Radloff, 1998). In this study an attempt was done to characterise the aggressive behaviour of southern Ethiopian honeybees by investigating the perceptions of beekeepers, determining the proportion of highly aggressive honeybee population and number of stings a beekeeper receive during honey harvest per hive.

Generally aggressive behaviour of African honeybees is associated with environmental conditions and the provocative factors that exist in the region. African bees are more aggressive than European honeybees. This is because the African climate appears to favour the existence of a number of factors that stimulate the aggressive behaviour of honeybee colonies. High temperatures and pests and predators are the major causes promoting aggressiveness in African honeybees (Fletcher, 1978). African

honeybees (*A. m. adansonii*) have a larger number of olfactory plates than European honeybees (*A. m. lingustica*) and thus a lower recruitment threshold may be required to stimulate bees to defence (Stort, 1974).

Possibly for the same reasons, southern Ethiopian honeybees are aggressive, easily irritated, fierce, and attack immediately. Hive operations can only be done after sunset at dusk and the temperature is cool. Although this differs from place to place, depending on the time of sunset, beehive operations are done after 6:30 pm in the region. At this time the responses of honeybees are reduced due to lower temperatures and darkness. It is common to receive a number of stings during beehive operations. 27–48 stings per person during beehive operations especially during honey harvesting were reported by farmer beekeepers. Between 1999 and 2000 the deaths of 6 people and a number of domestic animals were reported due to stings in different localities. This is a common feature in Africa. Many people and animals are killed by the stings of African honeybees (El-Sarrag, 1977). For example, between 1961 and 1967 the deaths of 24 people and severe suffering of 8 people due to the reactions of being stung were reported in South Africa (Ordman, 1968; Star, 1977). The intensity of sting imposed by honeybee colonies attributed to number of factors: poor management or handling of colonies, crushing of bees during hive operation, odour, poor quality smokes and protective clothes and jerky movements are some of factors that heighten the aggression behaviour of honeybees (Lowndes and Attridge, 1912; Smith, 1958a; Edmunds, 1922, 1930; Crisp, 1939; Hayter, 1946; Fletcher, 1978; Ntenga, 1969). In addition to aggressive behaviour of honeybees of the region these factors are also important in heightening the aggression

behaviour of honeybees as the beekeeping management in the region is mainly traditional and no care is taken to honeybees while operation.

The magnitude of aggressive behaviour varies from one colony of honeybees to another. The yellow (lowlands) honeybees are more aggressive than the black (highlands) honeybees. Although temperament is thought to be genetic, climate has a great influence on this behaviour. Aggressiveness is in part a function of climate (Castagné, 1983). Lowland honeybees are more aggressive than highland honeybees as the irascibility of honeybees is associated with high temperatures (Fletcher, 1978).

The behaviour of southern honeybees varies in the course of the seasons depending on weather conditions prevailing at these particular times. Midday (11.05 am – 2.00 pm) is a time at which the aggressive behaviour of southern honeybees is heightened. It is also a time of day when honeybees are actively foraging and defensive due to the high temperatures at this particular time. The seasonal aggressiveness of these bees also varies from place to place. The highland honeybees (*A. m. bandasii*) and wet tropical forestland honeybees (*A. m. scutellata*) are more aggressive during September through November, while the western and southern lowland (*A. m. woyi-gambella*) and eastern escarpment (*A. m. jemenitica*) honeybees are more aggressive during June through August and December and February respectively.

In these periods intense forage is available and there is maximum brood production resulting in rapid growth of the colonies. The populous colonies are very defensive. The highest aggressiveness is always associated with a strong nectar flow and intense foraging. This is because abundant pollen and nectar permit colonies to become extremely populous, which, in turn increases the number of honeybees available for

colony defence (Sawadogo, 1993). Therefore honey flow, brood rearing and honey harvesting are the periods at which honeybees exhibit more aggressive behaviour.

Moreover pest and predator attacks are factors which stimulate the aggressive behaviour in the honeybees of southern Ethiopia. Man, ants and honey badgers are the major pests and predators that provoke the honeybees. When honeybee colonies are invaded by ants, areas around an apiary are covered by a cloud of honeybees and it requires a long time to calm these honeybees even with heavy smoke. Pest attacks could be regarded as primary stimuli and environmental factors as secondary stimuli that cause a high level of aggressiveness in honeybees (Fletcher, 1978) and continued disturbances of the bees maintains a high order of defensive response (Smith, 1958; Ntenga, 1969; Fletcher, 1978). Generally the aggressive behaviour of honeybees is associated with environmental factors, genetic, strength of honeybee colonies, large stores and amount of alarm produced (Chandler, 1976) and poor handling of honeybees. In addition to high reproductive swarming and migration rates, pronounced aggressive behaviour in African honeybees also seems strategy for survival.

5.7 Honey yield

Generally in Ethiopia, where a rich nectar flow is abundant, a relatively small quantity of honey is produced. This could be attributed to a number of reasons for which the main one is probably because beekeeping is practised in uneconomical traditional ways with very little attention to honeybee management. In most cases honeybees are not protected from wind, pest and predators and extreme heat and are not harvested correctly.

Honey yields of *A. m. jemenitica* are significantly lower than those of all the other honeybee groups of the region (*A. m. bandansii*, *A. m. scutellata* and *A. m. woyigambella*). Honey yield is influenced by a number of factors and is significantly associated with characters of honeybees, total colony population, rapid build up, foraging efficiency, amount of empty comb available, amount of pollen collected, corbicular area, individual productivity, life span of worker bees, egg laying rate of queen and sealed brood areas (Spivak *et al.*, 1989). All of these factors directly or indirectly depend on the availability of forage and the characteristics of honeybees. The characteristics are fully or partially genetically based while forage resources are governed by climate and the ecological features of the region under which they exist. As repeatedly mentioned above, since the ecology of *A. m. jemenitica* is semi-arid it has limited vegetation resources compared to others groups. The main bee forage of this area are *Acacia* species, which flower intensively, but only for a short period. The honeybee colonies use these resources mainly to build up their colonies and by the time they become populous with a large number of foragers, the nectar supply is in a progressive decline. Honey production in all four regions of the honeybee groups is biphasic due to the fact that all areas in the southern region have two rainy seasons (big and small rainy season). Although these seasons and the amount of rainfall differ from area to area they are followed by warm temperatures, which favour the flowering of vegetation. However the intensity of flowering of honey plants during and after the small rainy season are less than during and after the big rainy season, thus a smaller quantity of honey is expected to be produced during this period.

Table 46. Average altitude, temperature, rainfall, swarming and migration periods of areas of morphoclusters and transitional zones.

No.	Morphoclusters and transitional areas	Altitude (m)	Temperature (⁰ C)	Rainfall (mm)	Swarming period	Migration period
1	<i>Woyi-gambella</i>	689	24	695	6-8	12-2
2	<i>A. m. jemenitica</i>	1376	21	590	12-2, 9-11	3-5
3	<i>A. m. bandasii</i>	2241	16.6	1184	9-11, 3-5	6-8, 12-2
4	<i>A. m. scutellata</i>	1792	19	1288	9-11, 3-5	6-8, 12-2
	Transional areas					
5	Woltae Atote	2050	16	784	9-11	6-8
6	Konso	1436	20	749	9-11, 3-5	12-2
7	Nazrieth	1699	18.5	826	9-11, 5	12-2

Table 47. Locality, rainy season, reproductive swarming and migration periods.

Code	Honeybee group and localities	Rainy season	Swarming time	Migration time
	1. <i>Woyi-gambella</i>			
S1	Itang	4-10	6-8	12-2
S7	Woyito	3-5 and 9-11	6-8	1-2
	2. <i>A. m. jemenitica</i>			
S15	Karre Tule	3-5 and 9-11	12-2	3-5
S16	Dudi Affi	7-11 and 3-5	12-1	3-5
S17	Deriri Arba	4-8	9-11	3-5
	3. <i>A. m. bandasii</i>			
S12	Serofta	6-8	9-11	6-8
S13	Mararo	6-8	9-11	6-8
S18	Boke Tiko	3-8	9-11 and 3-5	12-2
S20	Alage	3-8	9-11	6-8
S21	Hosaina	1-2 and 6-8	9-11	6-8
S23	Effo Yachi	Year round	9-11 and 3-5	6-8
S24	Boter Bacho	3-10	9-11 and 3-5	6-8
S25	Roge	3-8	9-11 and 3-5	12-1
S26	Gado Lama	3-8	9-11 and 3-5	6-8
	4. <i>A. m. scutellata</i>			
S1	Gechi	2-8	12-2	6-8
S3	Masha	6-2	12-2	6-8
S4	Woshi	4-1	9-11 and 3	6-8
S5	Waka	2-9	9-11	6-8
S6	Sodo	2-10	9-11 and 3-5	6-8
S9	Arero	3-8	9-11	12-2
S10	Har Kalo	4-6 and 9-11	9-11	12-2
S11	Eshido Aliyo	Year round	9-11 and 3-5	6-8
S22	Sawla	2-4 and 6-8	9-11 and 3-5	6-8
	5. Transitional areas			
S8	Konso	6-8 and 3-5	9-11 and 3-5	12-2
S14	Woltae Atote	3-5 and 9-11	9-11	6-8
S19	Nazrieth	6-8 and 3-5	9-11 and 5	12-2

Chapter Six

6. Summary and conclusion

6.1 General

The study area included 26 different localities located between 4° 49' 54.3" N to 9° 7' 98" N latitude and 34° 16' 07" E to 42° 57' 57" E longitude with altitudes ranging from 456m to 2958m. The agro-ecological zones are composed of 39.6% lowlands, 35.7% midlands and 24.7% highlands. Annual temperatures vary from 11.7°C to 25.5°C and annual rainfall from 522mm to 1874mm with an average of 1073mm. About 25.8% of the area is occupied by forest and bush lands. The area falls in 10 of the 18 major agro-ecological zones of Ethiopia. Both traditional and improved beekeeping production systems are being practiced in the backyards of farmer beekeepers and in the forests.

Size and pigmentation morphometric characters exhibited a high power to discriminate the honeybees of southern Ethiopia. Even though forewing venation angles of worker honeybees were considered powerful morphometric characters for discrimination of African honeybee (DuPraw, 1964; Ruttner, 1988; Crew *et al.*, 1994; Radloff and Hepburn, 1997a; Hepburn and Radloff, 1998), in the present study the mean angles of forewing venation (B4, N23 and O26) did not significantly vary across the localities and were not entered into discriminant functions to discriminate the honeybees of southern Ethiopia. Therefore it is possible to discriminate Ethiopian honeybees using size and pigmentation without including the forewing venation angles.

Great variation in size and pigmentation were observed both within and between honeybee groups. It is common to find yellow and black bees mixed and small and large worker honeybees within and between different colonies of the same honeybee group.

Moreover, it is also common to find yellow honeybee colonies and smaller sized honeybee colonies in predominantly black and larger honeybee groups and vice-versa.

In general the honeybees of southern Ethiopia are black. The pigmentation values of the scutellum and scutellar plate varied from 0 to 8 and 0 to 2.5 with averages of 1.6 and 0.5 while that of abdominal tergites 2, 3 and 4 ranged from 0 to 9 with an average of 2.38, 2.63 and 2.18 respectively. They are also relatively smaller and show similarities in size with but are darker than the honeybees of Sudan. The length of hair on the fifth abdominal segment is short ranging from 0.12mm to 0.23mm with an average of 0.17mm. The widths of tergite 3 and 4 vary from between 1.82mm to 2.18mm and 1.74mm to 2.11mm with an average of 2.03mm and 1.97mm respectively. The longitudinal sternite 3 ranged from 2.3mm to 2.64mm with an average of 2.48mm while width of wax plate on sternite 3 ranged from 1.83mm to 2.21mm with an average of 2.04mm.

The body size and pigmentation characters (except scutellar plate) of south Ethiopian honeybees showed strong correlations with each other and with climate (temperature and rainfall), altitude and to a lesser extent with the physical environment (latitude and longitude). The highland honeybees are darker and larger than the lowland honeybees. Darker honeybees are larger and covered with relatively longer hair than yellow honeybees while the southeastern honeybees are lighter and smaller than the central southern honeybees. The correlations among forewing angles and with other morphometric characters (size and pigmentation), climate (temperature and rainfall) and physical environment were not significant except for the angle O26 which was weakly significantly correlated to some of morphometric characters related to body size.

Even though the extent of reproductive swarming varied from place to place, it occurs in southern Ethiopia every year. The southern Ethiopian honeybees show a propensity to reproductive swarming. The rate of reproductive swarming varied from 8.9% to 36.6% with an average of 23.6%. Successive (multiple) swarming ranged from 2 to 5 per colony per annum. The swarm catching rate varied from 7.7% in resource-poor areas to 57% in resource-rich areas with an average of 36.4%. In the central highlands and wet tropical forestlands the chances of swarm baiting are higher than in the western and southern lowlands and eastern escarpment areas, implying that where there is a high swarming rate there is also a high rate of swarm bait success. Although varying from place to place, reproductive swarming mainly occurs during September through November. In some places reproductive swarming is biphasic. Reproductive swarming is strongly negatively correlated to longitude, moderately correlated to altitude, moderately positively correlated to temperature and strongly correlated to rainfall. Reproductive swarming rates increases sharply as annual rainfall increases above 1200mm and reaches its peak between rainfall of 1600mm and 1800mm (Fig. 44).

The honeybees of the region exhibited a high migration rate ranging from 25.5% to 58.8% with an average of 38.9%. This was in agreement with the percentage of unoccupied beehives in the region, which ranged from 47.7% to 63.4% with an average of 53%. The highest numbers of unoccupied beehives were found in areas where the highest migration occurred (eastern escarpment). Migration occurs in the region mainly when there is a shortage of food during December through February and June to August. Migration is moderately negatively correlated to altitude and positively to temperature.

Honey yield varied from place to place depending on the climate and vegetation. The honey flow period is biphasic in all regions, the major honey flow period is during September to November and the minor honey flow from March to May.

Honeybees of the region are regarded as aggressive and/or highly aggressive. The magnitude of aggressive temperament varied with season and time of day in which abundant forage and high temperature occurs. Pests and predators are also factors that increase the aggressive behaviour of honeybees in the region.

6.2 Morphoclusters/ honeybee groups of the region

Multivariate morphometric analysis of the honeybees of southern Ethiopia revealed the existence of four statistically distinct morphoclusters or groups: *A. m. woyi-gambella* in western and southern lowlands, *A. m. jemenitica*, on the eastern escarpment, *A. m. bandasii* in the central and eastern highlands and *A. m. scutellata* in the wet tropical forestlands (Fig. 43).

High intra and intercolonial variances were observed in all honeybee groups of southern Ethiopia. Areas with high intracolony variances include Itang (Gambell) within *A. m. woyi-gambella*, Dudi Affi and Kare Tule in *A. m. jemenitica*, Alage (Zuway) and Gado Lama (Robe, Arisi) in *A. m. bandasii* and Sawla in *A. m. scutellata* honey groups. Furthermore due to a high intercolonial variance, colonies from Nazrieth, Konso and Woltae Atote (Ginir, Bale) were distributed among all honeybee groups, revealing that honeybees of these areas exhibit intermediate morphometric characters. In other words they are natural transitional zones.

The morphometric characters that were entered into the discriminatory functions in descending discriminatory power were: pigmentation of tergite 4 (34), width of tergite 3 (9), hair length on the fifth abdominal segment (1), pigmentation of tergite 3 (33), pigmentation of tergite 2 (32), pigmentation of scutellum (35) scutellar plate (36), width of wax plate on sternite 3 (13) and length of sternite 3 (11).

6.2.1 *A. m. woyi-gambella*

A. m. woyi-gambella honeybees occupy the extreme western and southern semi-arid to sub-moist lowlands located between 5° 16' 40.4" N to 8° 11' 30.1" N latitude and 34° 16' 07" E to 37° 3' 33.3" E longitude (Fig.43). 66% of the area is below 1000m above sea level and annual temperatures range from 18°C to 25°C and annual rainfall from 600mm to 1800mm. The main vegetation is tropical wood and thorny bush land but it also includes grassland and savannah.

A. m. woyi-gambella honeybees are predominantly yellow and similar to *A. m. jemenitica*. The population also comprises dark honeybees. The proportion of yellow to black honeybees in the population is 2.33:1. *A. m. woyi-gambella* honeybees possess a black scutellum and scutellar plate. The pigmentation values of the scutellum and scutellar plate varied from 2.25 to 8.0 with an average of 4.13 and 0 to 0.2 with an average of 0.04 respectively. These honeybees have yellow abdominal pigmentation. Pigmentation values of tergite 2 and 3 varied from 4 to 9 with an average value of 6.4 while that of tergite 4 ranged 2.5 to 7.78 with an average value of 5. Pigmentation of tergite 2 and 3 is lighter than tergite 4.

A. m. woyi-gambella honeybees are the smallest and have the shortest hair cover of all African honeybees described so far. Mean length of hair on the fifth abdominal segment is 0.13mm. Mean widths of tergites 3 and 4 are 1.92mm and 1.84mm respectively while the mean of length of sternite 3 and width of wax plate on sternite 3 is 2.35mm and 1.93mm respectively.

A. m. woyi-gambella honeybees have less of a tendency to reproductive swarming than *A. m. scutellata* and *A. m. bandasii* and are not statistically different from *A. m. jemenitica*. The reproductive swarming rate in *A. m. woyi-gambella* honeybees is 8.9%. Successive reproductive swarming in this honeybee group ranges from 1 to 3 per colony per annum. Yellow and aggressive honeybee colonies in the group have a high propensity for reproductive swarming. The swarm catching rate (7.7%) in the area of *A. m. woyi-gambella* is statistically less than in the areas of *A. m. bandasii* and *A. m. scutellata*. Reproductive swarming in the *A. m. woyi-gambella* honeybees is monophasic and mainly occurs during June through August.

The migration rate (39.6%) of *A. m. woyi-gambella* was not statistically significantly different from any of the other honeybee groups of southern Ethiopia. Similarly the percentage of unoccupied beehives in the area of *A. m. woyi-gambella* was not statistically significantly different from any of the honeybee groups. These honeybees migrate during December to February. The main causes of migration include shortage of forage and water, drought and attack of pests and predators.

Like all other honeybee groups of the region *A. m. woyi-gambella* honeybees are aggressive to highly aggressive. Black honeybee colonies in the group were identified as being highly aggressive. The magnitude of aggression of these honeybees increases

during the flowering of honey plants, honey flow time, brood rearing, honey harvesting time (June to August), midday and by attacks of pests and predators.

Honey yield obtained from these honeybees is not statistically different from all other honeybee groups of the region. The honey flow period is biphasic and occurs during June to August and March to May.

6.2.2 *Apis mellifera jemenitica*

A. m. jemenitica occurs in the southeastern part of the country between 7° 3' 49" N to 9° 12' 21.6" N latitude and 41° 4' 4.5" E to 42° 57' 57" E longitude (Fig. 43) with an altitude ranging from 1149m to 1194m. Approximately 98.6% of this area is lowland with the temperature ranging from 14.7°C to 29°C. It receives a mean annual rainfall of 590mm. The predominant honey plants of the area are *Acacia spp.* *A. m. jemenitica* is found in Karre Tule (Rayito, Bale), Deriri Arba (Babile, East Haraghe) and Dudi Affi (Jijjiga, Somali). This constitutes the eastern escarpment of the country (Fig. 43).

A. m. jemenitica is the yellowest honeybee of all honeybee groups of the region, but possesses a dark scutellar plate and the population is yellow and black mixed. 87% of the population of *A. m. jemenitica* is yellow while 13% is black. The pigmentation of the scutellum, tergites 2, 3 and 4 are highly variable ranging from 3 to 7.5, 4 to 8.8, 3.8 to 9 and 2.5 to 7 respectively. All range from black to yellow. *A. m. jemenitica* is larger than *A. m. woyi-gambella* and smaller than *A. m. bandasii* and *A. m. scutellata*. It has a shorter hair cover (0.16mm) second to *A. m. woyi-gambella*. The mean widths of tergites 3 and 4 are 2.04mm and 1.98mm while that of longitudinal sternite 3 and transversal wax plate on sternite 3 are 2.44mm and 2.02mm respectively.

A. m. jementica shows lesser propensity for reproductive swarming than *A. m. scutellata* and *A. m. bandasii* but is not significantly different from *A. m. woyi-gambella*. The mean reproductive swarming rate in the population of *A. m. jementica* is 15.5% with the successive swarming ranging from 2 to 4 per colony per annum. Yellow and highly aggressive honeybee colonies in the group exhibited a high swarming tendency. The mean swarm catching rate in the area of *A. m. jementica* is 26.5% and this is statistically significantly less than in the areas of *A. m. bandasii*. Reproductive swarming is monophasic and occurs during December through February.

The tendency of this honeybee to migrate is higher than that of *A. m. scutellata* and *A. m. bandasii*. The mean migration rate of *A. m. jementica* is 58.8%. This is in agreement with the highest rate of unoccupied beehives (63.4%) in its area. Although the migration period varies from place to place in the area of *A. m. jementica*, it mainly occurs during March to May. Like in the area of *A. m. woyi-gambella*, the main causes of migration are the shortage of forage and water, drought and attack of pests and predators. The aggressive behaviour of these honeybees is pronounced during flowering, honey flow, honey harvesting, brood rearing (December to February) and the attack of pests and predators.

Honey yield obtained from this group of honeybees is significantly less than that from *A. m. bandasii* and *A. m. scutellata*. The honey flow period occurs in two seasons: the major honey flow during December to February and a minor honey flow during June to August.

6.2.3 *Apis mellifera bandasii*

A. m. bandasii occupies the central and eastern highlands located between 6° 51' 58.2" N to 8° 43' 40.5" N latitude and 36° 30' 23" E to 40° 38' 33.4" E longitude with an altitude ranging from 1574m to 2958m (Fig. 43). More than 40% of the area falls in a high altitude zone. This area includes Alage (Zuway, East Shoa), Hosaina, Boter Bacho (Limu Kosa, Jimma), Boke Tiko (Boke, West Hararghe), Effen Yachi (Agraro, Jimma) Gado Lama (Robe, Arisi), Roge (Woliso, West Showa), Serofta (Dodola, Bale) and Mararo (Limuna Bilbilo, Arisi) localities. It has annual temperatures ranging from 9.5 °C to 23.7 °C and a mean annual rainfall of 1184mm. About 25% of the area is covered by forest and bush comprising a wide range of honey plants.

A. m. bandasii is the darkest and largest of all honeybee groups in the region. It has the longest body hair. Although it is predominantly dark, a few yellow honeybees are found in the population. The population of *A. m. bandasii* is composed of 93% dark and 7% yellow honeybees. Pigmentation values of the scutellum and scutellar plate vary from 0 to 5.5 and 0 to 2 respectively, while that of tergites 2, 3 and 4 range from 0 to 8, 0 to 7.5 and 0.1 to 5 respectively.

Mean length of hair on the fifth abdominal segment is 0.19mm, mean width of tergites 3 and 4 are 2.10mm and 2.04mm in that order while mean longitudinal of sternite 3 and transversal of wax plate on sternite 3 are 2.55mm and 2.08mm respectively.

A. m. bandasii shows a high propensity for reproductive swarming. The reproductive swarming rate of this honeybee group is higher than that of *A. m. jemenitica*. 33.5% of the population swarm every year. Successive reproductive swarming is also common among the population of *A. m. bandasii* and ranges from 3 to 7 per colony per

annum. The successive reproductive swarming in this group of honeybees is higher than that of *A. m. woyi-gambella* and *A. m. jementica*. Thus, *A. m. bandasii* generally shows higher tendency to reproductively swarm than *A. m. jementica* and *A. m. woyi-gambella* honeybees. Black and highly aggressive honeybee colonies in the group are highly disposed to reproductive swarming. The swarm catching rate (57%) in the area of *A. m. bandasii* is also higher than in the area of *A. m. jementica* and *A. m. woyi-gambella*. Reproductive swarming is biphasic and corresponds to flowering periods of honey plants in the area. It occurs during September through November and March to May.

A. m. bandasii is also prone to migration and 25.5 percent of the population migrates every year. However, the migration tendency of this honeybee group is less than that of *A. m. jementica* and is not statistically different from that of *A. m. woyi-gambella* and *A. m. scutellata*. Similarly the unoccupied beehives (47.7%) in the area of this honeybee are less than in the area of *A. m. jementica* but not statistically significantly different from that of the *A. m. scutellata* and *A. m. woyi-gambella* areas. *A. m. bandasii* predominantly migrate during June through August and December to February. The main causes of migration in this group of honeybees are the shortage of food and attacks by pests and predators. *A. m. bandasii* shares the same aggressive behaviour like other honeybee groups and those factors initiating aggressive behaviour in honeybee groups mentioned above also provoke *A. m. bandasii* into aggression. It becomes more aggressive than usual during September to November.

The honey flow period in the area of this honeybee group is biphasic and occurs during September to November and March to May. Honey yield from these honeybees is

significantly higher than that of from *A. m. jemenitica* but not significantly different from that of *A. m. woyi-gambella* and *A. m. scutellata*.

6.2.4 *Apis mellifera scutellata*

A. m. scutellata occupies wet tropical forestlands located between 4° 49' 54.3" N to 8° 21' 2" N latitude and 35° 28' 13.3" E to 39° 23' 30.5" E longitude. The main localities included within these geographical co-ordinates are Gechi (Yayo, Illuababor), Masha, Woshi (Chana), Waka (Marka Gena), Sodo, Arero (Borena), Har Kalo (Liben, Borena), Eshido Aliyo (Bore) and Sawla (Gofa) (Fig. 43). Altitude ranges from 1427m to 2157m. Approximately 36.5% of the area falls in the midlands and constitutes the largest forest area of the country. It receives the highest rainfall with a mean annual rainfall of 1288mm. The mean annual temperatures range from 12.3°C to 26.0°C. The area is rich in a variety of honey plants. Both traditional and improved beekeeping are practiced, the former in forests and the latter in backyards of farmer beekeepers.

A. m. scutellata is the second darkest and largest honeybee after *A. m. bandasii*. Pigmentation variability among the populations of *A. m. scutellata* is lower than *A. m. bandasii*. The pigmentation values of the scutellum and scutellar plate vary from 0 to 3 and 0 to 2.5 respectively while that of abdominal tergites 2, 3 and 4 range from 0 to 5.5, 0.1 to 5 and 0 to 4 respectively. The colony comprises both black and yellow honeybees in the proportion of 13:1, that is, 7% of the population is yellowish in colour. Hair on the fifth abdominal segment measures 0.17mm while the width of tergites 3 and 4 measure 1.99mm and 1.93mm respectively. The mean longitudinal sternite 3 and width of wax plate on sternite 3 are 2.45mm and 2.02mm respectively.

Like *A. m. bandasii*, *A. m. scutellata* shows a higher tendency for reproductive swarming than *A. m. jementica* and *A. m. woyi-gambella* honeybees. 36.6% of the *A. m. scutellata* population swarms every year. Multiple reproductive swarming is also common in this honeybee group, ranging from 3 to 6 per colony per annum. Yellow and highly aggressive honeybee colonies in the group have a high tendency for swarming. The swarm catching rate (54%) in the area of *A. m. scutellata* is also higher than in the areas of *A. m. woyi-gambella* but is not statistically different from *A. m. bandasii* and *A. m. jementica*. Like *A. m. bandasii*, the swarming period in *A. m. scutellata* is biphasic and corresponds to the flowering times of major honey plants occurring during September to November and March to May.

32% of the population of *A. m. scutellata* migrate every year and the migration tendency of this honeybee group is not different from that of *A. m. jementica*. But the rate of unoccupied beehives (49%) in the area of *A. m. scutellata* is significantly less than in the area of *A. m. jementica*. Migration occurs during June to August and December to February. The main causes of migration in the area of this honeybee group are shortage of food and the attacks of pests and predators.

Like all other honeybee groups this honeybee group is also aggressive to highly aggressive and the aggression is pronounced during flowering, honey flow, honey harvesting, brood rearing (September - November), midday and by the attack of pests and predators.

The honey flow period is biphasic and occurs during September to November and March to May. The honey yield is significantly higher than the yield from *A. m.*

jementica and is not significantly different from that of *A. m. woyi-gambella* and *A. m. bandasii*.

Fig. 43. Physiography, sampling localities and distribution of the four morphoclusters of honeybees in the southern Ethiopian region.

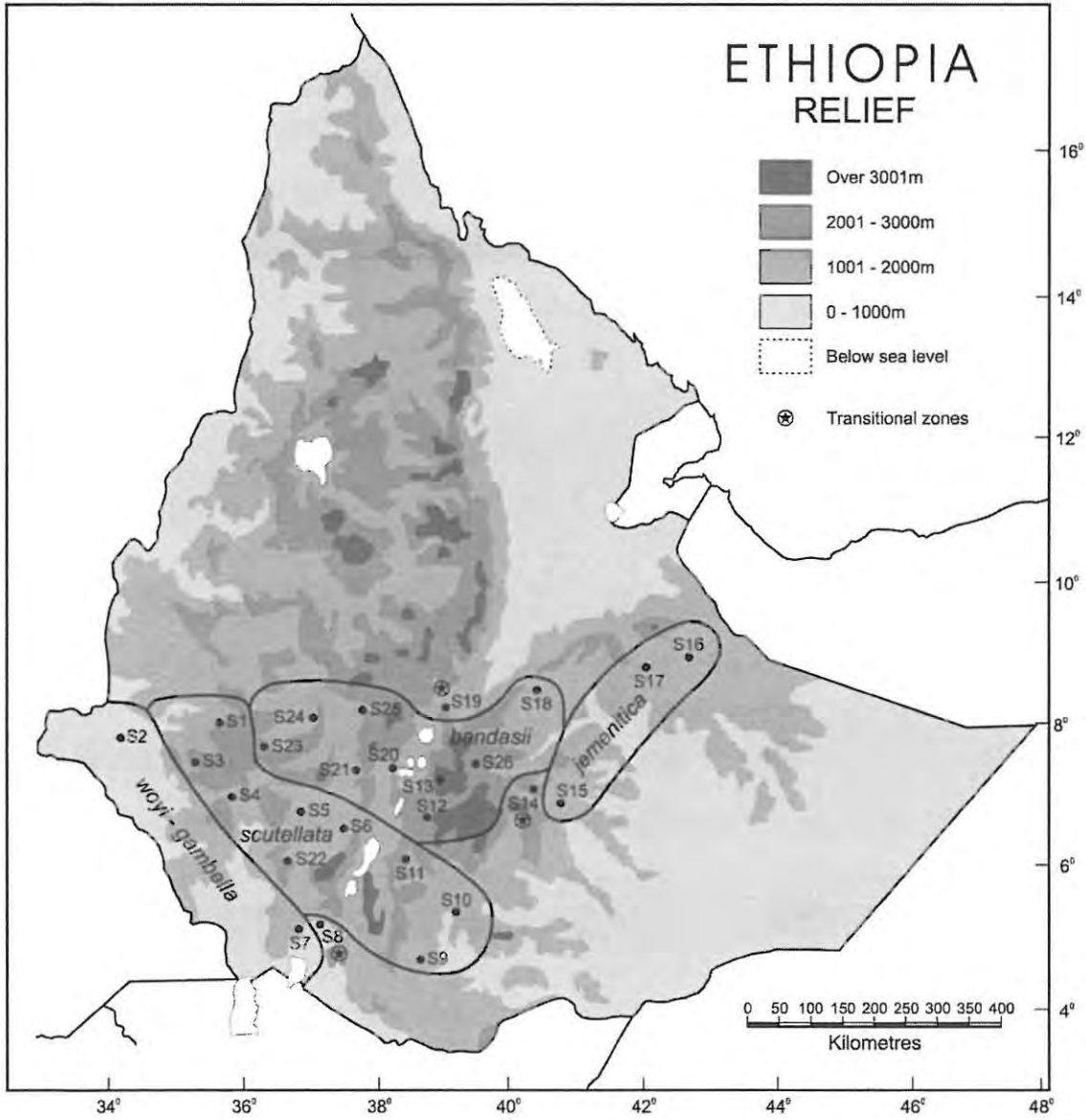


Fig. 44. Physiography, sampling localities, distribution of the four morphoclusters (broken lines) and reproductive swarming phenology (solid lines) of honeybees of southern Ethiopia.

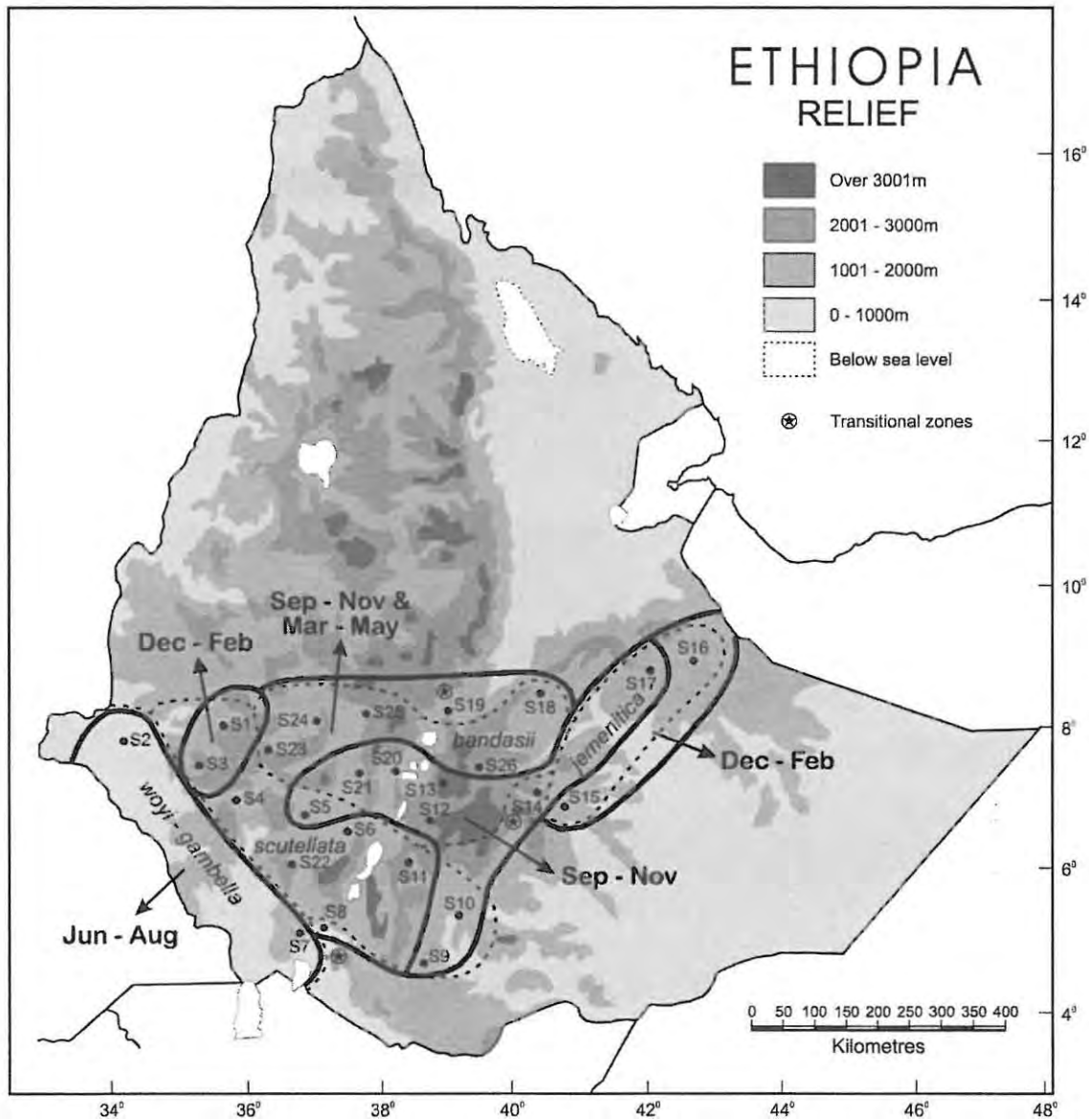
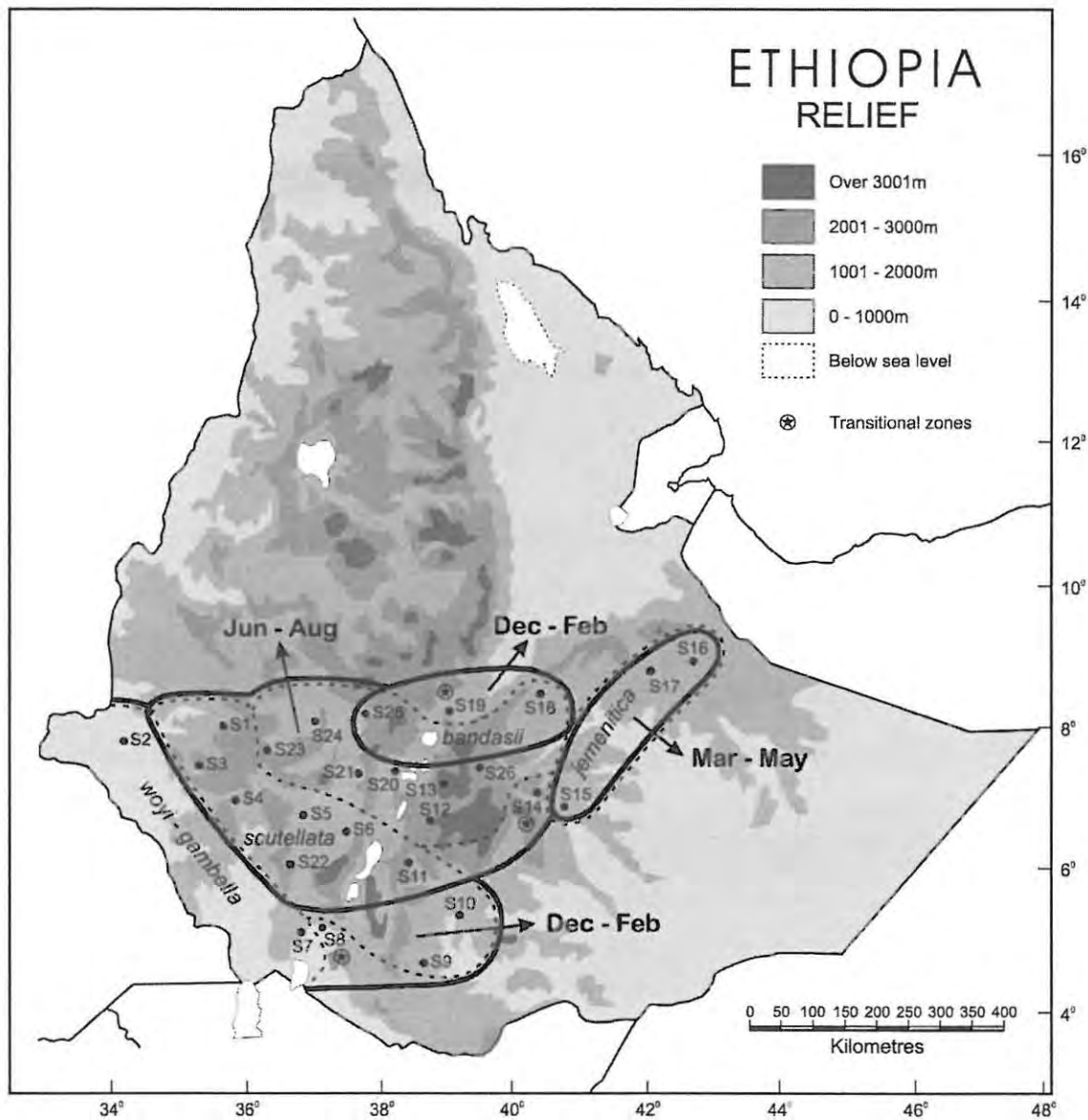


Fig 45. Physiography, sampling localities, distribution of the four morphoclusters (broken lines) and migration phenology (solid lines) of honeybees of southern Ethiopia.



6.3 Conclusions

Ethiopia is physiographically and climatologically diverse and complex. It comprises 18 major and 48 sub-agro-ecological zones varying within short distances. This complexity is reflected in a considerably diverse flora and fauna, including honeybees. Therefore it seems reasonable that different honeybee groups are found which have adapted to the diverse ecology in this physio-geographically complex country in general and southern parts of the country in particular. The occurrence of *A. m. bandasii*, *A. m. scutellata* and *A. m. jemenitica* in the southern regions of Ethiopia partially confirms the reports of Ruttner (1975), Kassaye (1990) and Radloff and Hepburn (1997). The 4th group is significantly smallest of all African honeybees. For this reason the name *A. m. woyi-gambella* is suggested in the present study. The discovery of *A. m. woyi-gambella* honeybees, which are different from other African honeybees identified so far, in the western and southern lowlands of the region revealed that the region is rich in honeybee resources and moreover supports the possibility that northeastern Africa in general and Ethiopia in particular is the centre of origin of *Apis mellifera* honeybees.

The absence of physical barriers among different ecological zones of different groups of honeybees, ecological changes within short distances (ecolines), mobile behaviour (swarming and migration) of honeybees of the region and transhumance may be some of the factors responsible for the occurrence of high intra and intercolonial variances as these factors might have notable contribution for the flow of gene among statistically defined morphoclusters. This may also explain why high variation in pigmentation and size were exhibited in Ethiopian honeybees in general and honeybees of southern Ethiopian region in particular. Areas consisting of statistically heterogeneous

honeybee populations are considered as transitional or introgression/natural hybridisation zones. Generally high variances in the population of honeybees are associated with ecological instability (Radloff, 1996), the mobile behaviour of honeybees and transhumance.

Wing venation angles: B4, N23 and O26 which were considered as some of important morphometric characters in discrimination of honeybees, failed to enter into the discriminant functions and lack discriminatory power for Ethiopian honeybees because they showed no geographical variability in Ethiopian conditions. Honeybees of Ethiopia were successfully discriminated using nine morphometric characters associated with pigmentation and size without including wing venation angles.

Therefore even though using several morphometric characters in morphometric analyses of honeybees are important to obtain better results, the same results could be achieved using fewer but very important morphological characters relevant to the region under investigation.

Generally Ethiopian honeybees have a high propensity to reproductive swarming, and migration and are aggressive. Reproductive swarming, successive reproductive swarming and swarm catching probabilities are higher in resource rich areas: central and eastern highlands and wet tropical forests as these areas are the wettest parts of the country receiving relatively higher rainfall than the eastern escarpments and western and southern lowland areas. Where there is high rainfall there will be high forage resources, which in turn initiate high reproductive swarming. Therefore reproductive swarming is associated mainly with rainfall. Reproductive swarming occurs in the region during the honey plants flowering periods and is biphasic in resource rich regions.

Unlike swarming, migration is higher in resource poor areas (eastern escarpments). It occurs mainly during dry and rainy seasons. Shortage of forage, water, high temperature, drought and attack of pests and predators are the main causes of migration in the region. Migration is mainly affected by temperature and altitude. Thus these behaviours of honeybees are the reflection of the their environment under which they exist.

The information generated based on survey studies about behaviour of these honeybee groups has a substantial contribution to bridge the information gap we have at present. However because these behaviours are complex and affected by several factors, the detailed experimental work is very important to understand and investigate more about these behaviours.

Table 48. Distribution of colour in the honeybee populations of southern Ethiopia region.

Honeybee group	Number of yellow honeybees	Number of black honeybees	Total honeybees (n)
<i>A. m. woyi-gambella</i>	444	191	635
<i>A. m. jemenitica</i>	910	188	1098
<i>A. m. bandasi</i>	255	3346	3601
<i>A. m. scutellata</i>	210	2675	2885
Total	1819	6400	8219

Chapter Seven

Seasonal intensity of flowering and resource partitioning in foraging by honeybees, *Apis mellifera* L. in the central highlands of Ethiopia.

7.1 Summery

To determine honey plants in the central highlands of Ethiopia, survey work and case studies were conducted. For the survey work, honey plant species visited by foraging honeybees were collected, botanically identified and the necessary data about the honey plant species was recorded. While to identify the major pollen source honey plant species, two medium-sized honeybee colonies were placed 2 km apart at Holetta Bee Research Center. Pollen traps with 16% pollen-trapping efficiency were fitted to the entrances of these colonies to trap pollen loads from foragers. Accordingly 51 honey plant families comprising 144 honey plant species were identified in the region. Asteraceae, Leguminosae and Lamiaceae are the major honey plant families in the region comprising 35.7% of the honey plant species. Honey plants of the region are predominantly herbaceous in nature and grow mainly in open and cultivated lands.

Herbaceous and shrub honey plants mainly flower after the big rainy season (September – November), while tree species flower during the small rainy season (March – May). About 82.5% of the mean annual pollen was collected during these two seasons. Reproductive swarming and migration occur during both high and low intensity of flowering respectively. The bulk of pollen collected came from comparatively few honey plants. The predominant sources of pollen include *Plantago lanceolatum*, *Guizotia spp.*,

Bidens spp., *Brassica napus*, *Trifolium spp.*, *Vernonia spp.*, *Helminthotheca echioides*, *Eucalyptus spp.* and *Pinus spp.*

7.2 Introduction

Ethiopia has diverse climatic conditions and topography which favour the growth of a wide range, about 7000 species, of cultivated and uncultivated plants including trees, shrubs, herbs and undergrowth or climbers (Geremew et al., 1999). The wide variety of vegetation and other conducive environmental conditions make the country highly favourable for honeybees.

As honeybees do not visit all plants for nectar and/or pollen, identification of the plants which supply these resources, plant communities and the phonological relationship between honey plants and honeybees are of paramount importance for practical beekeeping and in assessing the potential of an area for beekeeping. However, such knowledge in Ethiopia in particular and in Africa in general is at an elementary stage. The present study focuses on the central highlands, where beekeeping is widely practiced, to determine honey plants, their habitat, nature, time of flowering and the relation of intensity of flowering and phenology of reproductive swarming and migration of honeybees.

7.3 Materials and methods

The study was conducted in the central highlands between 5⁰ 16' 40.4" N to 8⁰ 11' 30.1" N latitude and 34⁰ 16.07'E to 37⁰ 3' 33.3" E latitude. Plants visited by honeybees for nectar and/or pollen were collected, registered and botanically identified. Most of the

botanical identifications were done at the National Herbarium, Addis Ababa University, while others were identified in the field using reference texts (Fichtl and Adi, 1994; Woldemichael, 1987). Data about the nature and habitat of plants and as a source of forage as nectar and/or pollen were recorded during the survey work. The flowering times of the plants were recorded through interviewing farmers of the area.

To facilitate the comparisons rainfall, temperature and flowering data of each study site were standardised. Firstly all rainfall and temperature frequency distributions were plotted according to months of the year, giving 12 classes. Then the simple arithmetic means and standard deviations were calculated. The mean was subtracted from each monthly value. The remainder was divided by the standard deviation and the end product simply expressed a positive or negative percentage value for each month. The reproductive swarming and migration times of each locality were plotted against the months of the year and compared to the intensity of flowering time.

A case study was conducted to determine the major pollen source honey plants of the region at the Holetta Bee Research Centre, which is situated in the middle of the central highlands.

Two medium-sized honeybee colonies in langstroth hives were placed 2km apart at the Holetta Bee Research Centre. Pollen traps with a 16.5% pollen-trapping efficiency were fitted to the entrances of each colony for two years. The trapped pollen pellets were collected twice a day (at 12 am and 6 pm) throughout the study period and allowed to dry overnight at room temperature. The pollen pellets were sorted by colour and the fractions were weighed and recorded. Pollen grain samples were taken from representative pellets of each colour, washed with ether and mounted in glycerine jelly on microscope slides to

identify the pollen source honey plant species under a microscope. Some pollen grains were also mounted fresh to verify the homogeneity of the colour fraction. To verify identification, pollen samples were collected from the flowers of honey plant species in the area. These were also examined microscopically in a fresh state. Pollen that could not botanically identified were categorized as "unidentified".

7.4 Results

51 plant families comprising 144 plant species were identified as honey plants in the central highlands of the country. Asteraceae, Lamiaceae and Leguminosae were the dominant honey plant families comprising 17.4%, 9.8% and 9.1% of the total honey plant species identified in the region respectively (Table 49). Honey plant species of the region include trees, shrubs, herbs and undergrowth growing in different habitats: open land, forestlands, bush lands and wetlands. About 65% of the identified honey plant species were herbaceous, while trees accounted for 17.5% and shrubs 16.8% of the total honey plant species. Moreover 35.7% and 32.8% of the honey plant species grow on open land and cultivated lands respectively, while forestland, bush land and wetland habitats comprise 14%, 7.7% and 7.7% of the honey plant species and the balance grows on both open land and forestland (Table 52).

The herbaceous honey plant species accounted for 88.0% in Asteraceae, 78.6% in Lamiaceae and 76.9% in Leguminosae families. About 61.5% of Leguminosae honey plant species grow on cultivated land. Lamiaceae honey plant species, which grow in cultivated lands account for 35.7%, open land 28.6%, wetland 21% and forestland 14.3%. Honey plant species in the Asteraceae family are found growing in open land (50%) and

cultivated lands (20). These results suggest that honey plants of the region are predominantly herbaceous in nature and grow mainly in open and cultivated lands.

Honey plants of the region offer nectar and/or pollen to honeybees. About 88.8% of the species provide both nectar and pollen together, while 9.1% of the species supply only pollen and the balance supply nectar or exudates (Table 49).

The flowering time of honey plants varies from species to species depending on the climatic conditions of their habitat. 76.9% of Leguminosae, 71.4% of Lamiaceae and 83.3% of Asteraceae honey plant species flower during September to November. Approximately 61.8% of honey plant species flower during September through November, 5.5% during dry season (December to February), 12.5% during the rainy season (June to August), 12.6% during spring (March to May) and the remaining balance flower at different times of a year (Tables 49 and 50). The greater proportion of trees were in flower during March through May (39.1%) while 77.7% of herbaceous and 50% shrub honey plant species were in flower during September to November (Table 50).

Although the intensity varies, rainfall occurs year round. However rainfall increases from April until September. The peak times are during July through to August. There are two main rainy seasons: the big rainy season, which occurs during mid-June through mid-September characterized by a higher intensity of rainfall, and the small rainy season which varies in intensity and duration with intermittent showers occurring from mid-February through to April. For the most parts the small rainy season merges with the big rainy season. The intensity of the big rainy season varies and is correlated to longitude. The intensity of rainfall increases towards the west while no distinct association was noted between the intensity of rainfall during the big rainy season and

latitude (Table 53). With the exception of a few cases, areas, which receive a higher intensity of rainfall during the big rainy season, also receive a higher intensity during the small rainy season (Table 53). The intensity of rainfall during the small rainy season is also correlated more to longitude than latitude.

The flowering intensity of honey plants coincides with the intensity of rainfall (Table 53). About 58% of the intensity of flowering plants occurs during September to November right after the highest rainfall (June to August), while the second highest intensity of flowering (18%) occurs during the small rainy season (March to May). As was found with the intensity of rainfall, the intensity of flowering of the honey plants varies with longitude. Following the rainy season, two main periods of flowering was noted. There is an average gap of 2.5 months between these flowering periods (Table 53). The shift in flowering time coincides with the shift in the rainy seasons.

Reproductive swarming correspond well with the high intensity of flowering plants while migration coincides with low intensity (Table 53).

Even though the amount varied pollen was collected throughout all seasons of the year. About 82% of the mean annual pollen was collected during autumn (September to November) and spring (March to May): 40% during autumn and 42% during spring. 12.5% and 5.5% of the mean annual pollen was gathered during winter (December to February) and summer (June to August) (Table 51). During the course of the study pollen was collected from more than 29 honey plant genera. However the bulk of the pollen came from relatively few honey plant genera. Moreover about 74.1% of mean annual pollen collection came from herbaceous plants while 25.7% came from trees and shrubs

In autumn, honeybees collected pollen from more than 22 plant genera. However approximately 87% of the pollen collected in autumn season was contributed by *Guizotia* spp., *Brassica napus*, *Bidens* spp., *Plantago lanceolatum* and *Trifolium* spp. These genera provided about 29.0, 24.4, 17.0, 9.6 and 7.1 percents of the pollen collections of the season for about 41, 69, 53, 64 and 54 days respectively. The early autumn pollen (from the 4th week of August to the end of October) came mainly from *Brassica napus* and followed by *Bidens* spp. and *Trifolium* spp. (from the 2nd week of September to the end of October). While *Guizotia* spp. and *Plantago lanceolatum* supplied pollen from the 2nd week of September to the 3rd week of November and from the 4th week of September throughout the season respectively. Herbaceous honey plants are the principal source of pollen during the autumn season.

During the winter season, pollen was collected from 12 honey plant genera of which *Vernonia* spp., *Plantago lanceolatum* and *Helminthotheca echioides* are the major ones. They contributed more than 82% to the seasons' collection. *Vernonia* spp. supplied about 32.83% of pollen for the season for 40 days; *Plantago lanceolatum* contributed 29.5% for 75 days and *Helminthotheca echioides* provided 20.4% for 42 days. The early winter pollen came from *Plantago lanceolatum* and *Vernonia* spp. Pollen from *Vernonia* spp. was first observed in the pollen trap 3 days before the onset of the winter season and remained the principal source of pollen throughout the season until the first week in February. It is also a major source of nectar during this period. Pollen from *Helminthotheca echioides* was collected from the 4th week of December to the 1st week of February.

Even though the number of honey plant species flowering during spring (March – May) are 5 times less than that in autumn, the highest proportions of the mean annual pollen was collected during this season. *Plantago lanceolatum*, *Pinus spp.*, *Eucalyptus spp.* and *Datura arborae* were the dominant pollen sources of the season. These plants supplied 40.4%, 21.5%, 16.5% and 13.9% of the pollen collected in spring for 87, 73, 47 and 59 days respectively. The early spring pollen came from *Plantago lanceolatum* and *Pinus spp.* (needle tree). *Datura arborae* provided pollen from the 2nd week of March to the end of the season while *Eucalyptus spp.* supplied pollen from mid-April to the end of the season. These genera, apart from *Datura arborae*, remain important pollen sources in the summer season too (June – August).

The highest proportion of pollen (67.5%) was collected during the morning (6 – 12am) while the balance was collected during the afternoon (after 12am to 6pm). October (24.8%) and March (23.7%) are months of the year in which largest proportion (48.5%) of pollen was collected. *Plantago lanceolatum* contributed 27% of the mean annual pollen in the region for about 280 days of the year (Table 51).

7.5 Discussion

Due to its favourable climatic conditions and edaphic factors wide range of species of cultivated and uncultivated honey plants grow in Ethiopia from the smallest herbaceous plants to giant trees. However the proportion of species of herbaceous honey plants species greatly outnumber trees and bushes. This is attributed to the fact that the central highlands are densely populated both with people and livestock, a resulting in pressure on the forests, which over the last century have been degraded and replaced by

herbaceous plants. Most of the existing forests are cultivated and comprise of a few select species like *Pinus* and *Eucalyptus*. The habitat distribution of honey plant species of the region conform the abovementioned results, i.e. the greater proportion of honey plant species in the region grow in open and cultivated land habitat. The forest and bush land habitats comprise only 14% and 7.7% of the total honey plant species. Moreover the habitat distribution of the dominant families of the region (Asteraceae, Leguminosae and Lamiaceae) also support the findings that honey plants of the region are predominantly herbaceous and grow in open and cultivated lands. In the highlands of Ethiopia less tree species are found and they are mainly Asteraceae and Compositae (Leguminosae) family (Mammo, 1976). This may reflect the situation throughout the entire country because 40% of Ethiopia, which used to be forest before 3 decades ago, now has been reduced to 3.5% (Svensson, 1991). This would also substantiate the rapid replacement of forest trees by herbaceous plants in the country. This is in agreement with the results of Hepburn and Radloff (1998) who indicated that the principal bee trees are gradually replaced by shrubs and herbs both sides of the equator and these changes in ratio of trees to shrubs and herbs are also reflected throughout the whole African continent (White, 1983).

Honey plant species grown on cultivated land include weeds and crops. This indicates that weeds and crops are among the honey plants, which contribute to bee forage in the region. This is consistent with Amssalu (1997, 1999) who indicated that weeds and cultivated crops contribute considerably to the pollen and honey production around Holetta, which is at the centre of the central highland region. Cultivated plants constitute important competition for native flora where both occur (Amoako, 1997).

Trees or shrubs alone could not be considered as major honey plants. The combination of forest trees, shrubs, cultivated crops, undergrowth and herbs including weeds are very important for the colony build-up and honey production (Kassaye, 1989). Thus even though there is a great variation in number of species, the region maintain all types of honey plants.

Of the 51 honey plant families identified Asteraceae, Lamiaceae and Leguminosae are the major families of honey plants in the region comprising about 35.7% of the honey plant species identified (144). These families are the largest plant family: Astraceae consists of up to 22000 species with about 1100 genera; Lamiaceae comprises of up to 5000 species with about 170 genera, of which 41 genera and 159 species are found in Ethiopia; and Leguminosae consists of up to 17000 species and 590 genera and are distributed throughout the world. They are a very important source of pollen and nectar in Ethiopia (Fichtl and Adi, 1994). Of 354 families of plants in Africa (Bamps, 1994) four families Acanthaceae, Leguminosae (including sub-family Caesalpiniodeae and Mimosaceae), Euphorbiaceae and Rubiaceae account for about 40% genera of bee flora in Africa (Hepburn and Radloff, 1998).

A great proportion of honey plant species in the region yield both nectar and pollen and with less than 10% of yielding either only nectar or pollen. That is most of species of honey plants contribute inessential forage, pollen for brood rearing and nectar for honey production. These conditions may help foragers to conserve time and energy as they get both types of forage from the same plant.

Herbaceous plants and shrubs mainly flower during September through November while tree species bloom during March through May. That is the phenology of

honey plants corresponding to the intensity of rainfall and temperature. As mentioned above the region has two rainy seasons: the main rainy season which provides the larger proportion of rainfall occurring during mid-June to mid-September, and the small rainy season which occurs during mid-February to April. Towards the end of these rainy seasons the temperatures rise and induce flowering (Ethiopian Mapping Authority, 1988). This may explain why about 61% of honey plant species mainly herbaceous, flower after the big rainy season (September to November) and others during the small rainy season (March to May). That is honey plant flowering overlap during September to November and March to May. This is in agreement with the findings of Amssalu (1997) who noted that in the Holetta highland areas, the predominant source of honey during Autumn (September – November) are herbaceous honey plants while the main source of honey during May to June are tree species. Moreover reproductive swarming and migration of honeybees of the region is associated to the flowering intensity and phenology of honey plants. The former occurs during the higher intensity of flowering while the latter occurs during the low intensity of flowering when no sufficient forage is available. This supports the fact that the seasonal cycle of the honeybee is related to the phenology of honey plants and flowering phenology is sufficient to provide accurate predictions of honeybee activities (Hepburn and Jacot Guillarmod, 1991). The temporal correspondence between flowering bee flora and brood-rearing cycle is 88% for entire Africa continent (Hepburn and Radloff, 1995).

Even though the number of species of honey plants flowering during March to May are smaller than that of September to November, the mean amount of pollen collected during both seasons are not significantly different. This result indicates that the

yield of pollen is not only determined by the number of honey plant species in bloom at a particular time of the year but may also be due to the abundance of flowers and the amount of pollen an individual plant yields at a particular flowering time. A few number of honey plant species could supply larger forage than many honey plant species when they are densely populated, flower abundantly and have high potential for the production of forage.

Guizotia spp., *Brassica napus*, *Bidens spp.* and *Plantago lanceolatum* are the main source of pollen during Autumn (September – November), while *Vernonia spp.*, *Plantago lanceolatum* and *Helminthotheca echioides* are the major sources of pollen during the dry season (December – February) and *Plantago lanceolatum*, *Pinus spp.* and *Eucalyptus spp.* are the predominant pollen source during Spring (March – May) and Summer (June – August). As indicated above, *Plantago lanceolatum* is the main source of pollen throughout the year and it provided 27% of mean annual pollen collected and was visited by foragers for 280 days of the year. This plant grows in both open and cultivated lands as weeds and is in bloom year round but it is source of pollen only. These results reveal that the bulk of pollen collected came from comparatively few plant species. In spite of the presence of different types of floral community and structure, honeybees concentrate and forage on a few densely flowering plants (Damblon, 1987, 1988; Lobreau-Callen *et al.*, 1989). In his study of honeybee-plant relation Damblon (1987, 1988) found a broad pollen spectrum with a few species dominating the total pollen source. Differences in foraging are ascribable to flowering biology and phenology rather than to the genetic difference between honeybee groups (Damblon and Lobreau-callen, 1991; Lobreau-Callen and Damblon, 1994; Ramanonjisa, 1992; and Ramanonjisa

et al., 1996). A greater proportion of pollen was collected during the mornings than afternoons. This may be attributed to the availability of pollen and the weather (especially humidity). This is in agreement with the findings of Sygne (1947) who indicated that pollen collection is restricted to the mornings and the numbers of pollen gatherer drop off steadily throughout the day.

Table 49. Botanical name, family, nature, food source, flowering time and habitat distribution of honey plants in the central highlands of Ethiopia.

No.	Botanical name	Family	Plant form	Food source	Flowering time	Habitat
1	<i>Acacia abyssinica</i>	Leguminosae	Tree	Nectar and pollen	Jan - May	Open land & forestlands
2	<i>Achyranthes aspera</i>	Amaranthaceae	Herb	Nectar and pollen	Year round	Forestlands
3	<i>Adhatoda schimperiana</i>	Acanthaceae	Shrub	Nectar and pollen	Sept - Nov	Open land
4	<i>Agiatoche rangesia</i>	Lamiaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
5	<i>Ajuga integrifolia</i>	Lamiaceae	Herb	Nectar and pollen	Sept - Nov	Wetlands
6	<i>Albizia gummifera</i>	Leguminosae	Tree	Nectar and pollen	Feb - April	Forestlands
7	<i>Anagallis arvensis</i>	Primulaceae	Herb	Nectar and pollen	August - Jan	Open land
8	<i>Anchusa officinalis</i>	Boraginaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
9	<i>Aningeria altissima</i>	Sapotaceae	Tree	Nectar and pollen	April - May	Forestlands
10	<i>Antirrhinum majusa</i>	Scrophulariaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
11	<i>Apodytes dimidiata</i>	Icacinaceae	Tree	Nectar and pollen	January	Forestlands
12	<i>Angelica archangelica</i>	Apiaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
13	<i>Aspilia africana</i>	Asteraceae	Herb	Nectar and pollen	Sept - Nov	Wetland
14	<i>Aspilia mossambicensis</i>	Asteraceae	Herb	Nectar and pollen	Sept - Nov	Wetland
15	<i>Barleria ventricosa</i>	Acanthaceae	Herb	Nectar and pollen	Sept - Nov	Forestlands
16	<i>Berkheya spekeana</i>	Asteraceae	Herb	Nectar and pollen	Sept - Nov	Open land
17	<i>Bidens ghedoensis</i>	Asteraceae	Herb	Nectar and pollen	Sept - Nov	Open land
18	<i>Bidens macroptera</i>	Asteraceae	Herb	Nectar and pollen	Sept - Nov	Open land
19	<i>Bidens pachyloma</i>	Asteraceae	Herb	Nectar and pollen	Sept - Nov	Open land
20	<i>Bidens prestinaria</i>	Asteraceae	Herb	Nectar and pollen	Sept - Nov	Open land
21	<i>Bothriocline schimperi</i>	Asteraceae	Herb	Nectar and pollen	Sept - Nov	Open land
22	<i>Brassica napus</i>	Brassicaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
23	<i>Caesalpinia decapetala</i>	Leguminosae	Shrub	Nectar and pollen	Sept - Nov	Bush land
24	<i>Carissa edulis</i>	Apocynaceae	Shrub	Nectar and pollen	May - August	Bush land
25	<i>Carthamus tinctorius</i>	Asteraceae	Herb	Nectar and pollen	October	Open land
26	<i>Caylusea abyssinica</i>	Resedaceae	Shrub	Pollen	Sept - Nov	Open land

27	<i>Celosia argentea</i>	Amaranthaceae	Herb	Nectar and pollen	Sept - Nov	Open land
28	<i>Cirsium schimperi</i>	Asteraceae	Herb	Nectar and pollen	Sept - Nov	Wetland
29	<i>Citrus spp.</i>	Rutaceae	Shrub	Nectar and pollen	March - May	Cultivated land
30	<i>Clerodendrum myricoides</i>	Verbenaceae	Herb	Nectar and pollen	March - May	Open land
31	<i>Commelina benghalensis</i>	Commelinaceae	Herb	Pollen	Sept - Nov	Wetland
32	<i>Cordia africana</i>	Boraginaceae	Tree	Nectar and pollen	Sept - Nov	Open land & forestlands
33	<i>Coriandrum sativum</i>	Apiaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
34	<i>Crassocephalum vitellinum</i>	Asteraceae	Herb	Nectar and pollen	Sept - Nov	Bush land
35	<i>Croton machrostachyus</i>	Euphorbiaceae	Tree	Nectar and pollen	March - May	Open land & forestlands
36	<i>Cucurbita pepo</i>	Cucurbitaceae	Herb	Nectar and pollen	June - August	Cultivated land
37	<i>Cyanotis barbata</i>	Commelinaceae	Herb	Nectar and pollen	August - Sept	Open land
38	<i>Datura arborea</i>	Solanaceae	Shrub	Nectar and pollen	Sept - Nov	Open land
39	<i>Delphinium dasycaulon</i>	Ranunculaceae	Herb	Nectar and pollen	Sept - Nov	Open land
40	<i>Dianthus spp.</i>	Caryophyllaceae	Herb	Nectar and pollen	Feb - March	Cultivated land
41	<i>Digitaria spp.</i>	Poaceae	Herb	Pollen	Sept - Nov	Open land
42	<i>Dracocephalum moldavica</i>	Lamiaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
43	<i>Echinops spp.</i>	Asteraceae	Herb	Nectar and pollen	Oct - March	Open land
44	<i>Ekebergia capensis</i>	Meliaceae	Tree	Nectar and pollen	May - June	Forestlands
45	<i>Eleusine floccifolia</i>	Poaceae	Herb	Pollen	Sept - Nov	Open land
46	<i>Erica arborea</i>	Ericaceae	Shrub	Nectar and pollen	Sept - Feb	Bush land
47	<i>Eucalyptus camaldulensis</i>	Myrtaceae	Tree	Nectar and pollen	April - June	Cultivated land
48	<i>Eucalyptus citriodora</i>	Myrtaceae	Tree	Nectar and pollen	April - June	Cultivated land
49	<i>Eucalyptus globulus</i>	Myrtaceae	Tree	Nectar and pollen	April - June	Cultivated land
50	<i>Euphorbia abyssinica</i>	Euphorbiaceae	Shrub	Nectar and pollen	Sept - Nov	Open land
51	<i>Fagopyrum esculentum</i>	Polygonaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
52	<i>Ficus sur</i>	Moraceae	Tree	Exudates	Sept - Nov	Open land
53	<i>Galinsoga parviflora</i>	Asteraceae	Herb	Nectar and pollen	Sept - Nov	Open land
54	<i>Galium simense</i>	Rubiaceae	Herb	Nectar and pollen	Sept - Nov	Wetland
55	<i>Galium spurium</i>	Rubiaceae	Herb	Nectar and pollen	Sept - Nov	Forestlands
56	<i>Geranium spp.</i>	Geraniaceae	Herb	Nectar and pollen	Sept - Dec	Bush land

57	<i>Glycine wightii</i>	Leguminosaceae	Herb	Nectar and pollen	Sept - Nov	Open land
58	<i>Grevillea robusta</i>	Proteaceae	Tree	Nectar and pollen	April - June	Cultivated land
59	<i>Guizotia abyssinica</i>	Asteraceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
60	<i>Guizotia scabra scabra</i>	Asteraceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
61	<i>Guizotia scabra schimperi</i>	Asteraceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
62	<i>Hagenia abyssinica</i>	Rosaceae	Tree	Pollen	Sept - Nov	Forestlands
63	<i>Helianthus annuus</i>	Asteraceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
64	<i>Helinus mystacinus</i>	Rhamnaceae	Climber	Nectar and pollen	Feb - April	Open land
65	<i>Helminthotheca echioides</i>	Asteraceae	Herb	Nectar and pollen	Sept - Nov	Open land
66	<i>Hypericum peplidifolium</i>	Clusiaceae	Herb	Pollen	Sept - Nov	Wetland
67	<i>Hypericum revolutum</i>	Clusiaceae	Shrub	Nectar and pollen	April - May	Forestlands
68	<i>Hypoestes triflora</i>	Acanthaceae	Herb	Nectar and pollen	June - August	Open land
69	<i>Impatiens rothii</i>	Balsaminaceae	Herb	Nectar and pollen	June - August	Open land
70	<i>Jasminum abyssinicum</i>	Oleaceae	Shrub	Nectar and pollen	Sept - Nov	Bush land
71	<i>Kalanchoe petitiiana</i>	Crassulaceae	Herb	Nectar	Sept - Nov	Open land
72	<i>Lactuca inermis</i>	Asteraceae	Herb	Nectar and pollen	Sept - Nov	Open land
73	<i>Lathyrus sativus</i>	Leguminosaceae	Herb	Nectar and pollen	Dec - Jan	Cultivated land
74	<i>Leonotis ocyimifolia</i>	Lamiaceae	Herb	Nectar and pollen	Sept - Nov	Open land
75	<i>Lepidium sativum</i>	Brassicaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
76	<i>Leucas martinicensis</i>	Lamiaceae	Herb	Nectar and pollen	Sept - Nov	Open land
77	<i>Linum usitatissimum</i>	Linaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
78	<i>Lippia adoensis</i>	Verbenaceae	Shrub	Nectar and pollen	June - August	Bush land
79	<i>Maytenus arbutifolia</i>	Celastraceae	Shrub	Nectar and pollen	Sept - Nov	Forestlands
80	<i>Medicago polymorpha</i>	Leguminosaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
81	<i>Medicago sativa</i>	Leguminosaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
82	<i>Melilotus alba</i>	Leguminosaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
83	<i>Nicotiana tabacum</i>	Solanaceae	Herb	Nectar and pollen	June - August	Cultivated land
84	<i>Nigella sativa</i>	Ranunculaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
85	<i>Ocimum basilicum</i>	Lamiaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
86	<i>Ocimum urticifolium</i>	Lamiaceae	Shrub	Nectar and pollen	Sept - Nov	Open land

87	<i>Oenothera fruticosa</i>	Onagraceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
88	<i>Olea capensis</i>	Oleaceae	Tree	Nectar and pollen	April - June	Forestlands
89	<i>Olinia rochetiana</i>	Oliniaceae	Tree	Nectar and pollen	Jan - May	Forestlands
90	<i>Otostegia integrifolia</i>	Lamiaceae	Shrub	Nectar and pollen	Sept - Nov	Forestlands
91	<i>Oxygonum sinuatum</i>	Polygonaceae	Herb	Nectar and pollen	Sept - Nov	Open land
92	<i>Phacelia tanacetifolia</i>	Hydrophyllaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
93	<i>Phaulopsis imbricata</i>	Acanthaceae	Herb	Nectar and pollen	Sept - Nov	Open land
94	<i>Physalis peruviana</i>	Solanaceae	Herb	Nectar and pollen	June - August	Open land
95	<i>Phytolacca dodecandra</i>	Phytolaccaceae	Shrub	Nectar and pollen	Oct - March	Open land
96	<i>Pinus spp.</i>	Pinaceae	Tree	Nectar and pollen	Jan - April	Cultivated land
97	<i>Pisum sativum</i>	Leguminosae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
98	<i>Pittosporum viridiflorum</i>	Pittosporaceae	Tree	Nectar and pollen	Nov - April	Forestlands
99	<i>Plantago lanceolata</i>	Plantaginaceae	Herb	Pollen	Year round	Open land
100	<i>Plectranthus punctatus</i>	Lamiaceae	Herb	Nectar and pollen	Sept - Nov	Wetland
101	<i>Plectranthus spp.</i>	Lamiaceae	Herb	Nectar and pollen	June - August	Wetland
102	<i>Polyscias fluva</i>	Araliaceae	Tree	Nectar and pollen	Nov - April	Forestlands
103	<i>Prunus persica</i>	Rosaceae	Tree	Nectar and pollen	Sept - Nov	Cultivated land
104	<i>Pygeum africanum</i>	Rosaceae	Tree	Nectar and pollen	June - August	Forestlands
105	<i>Ranunculus multifidus</i>	Ranunculaceae	Herb	Nectar and pollen	Sept - Nov	Open land
106	<i>Raphanus raphanistrum</i>	Brassicaceae	Herb	Nectar and pollen	Sept - Nov	Open land
107	<i>Ricinus communis</i>	Euphorbiaceae	Tree	Nectar and pollen	Sept - Nov	Cultivated land
108	<i>Rhamnus prinoides</i>	Rhamnaceae	Shrub	Nectar and pollen	August - Sept	Cultivated land
109	<i>Rhus vulgaris</i>	Anacardiaceae	Tree	Nectar and pollen	June - August	Open land
110	<i>Rorippa nasturtium-aquaticum</i>	Brassicaceae	Herb	Nectar and pollen	Sept - Nov	Wetland
111	<i>Rosa abyssinica</i>	Rosaceae	Shrub	Pollen	June - August	Bush land
112	<i>Rosmarinus officinalis</i>	Lamiaceae	Shrub	Nectar and pollen	March - May	Cultivated land
113	<i>Rubus apetalus</i>	Rosaceae	Shrub	Nectar and pollen	March - May	Bush land
114	<i>Rubus rosifolius</i>	Rosaceae	Shrub	Nectar and pollen	Sept - Nov	Bush land
115	<i>Rubus steudneri</i>	Rosaceae	Shrub	Nectar and pollen	March - May	Bush land
116	<i>Rumex bequaertii</i>	Polygonaceae	Herb	Nectar and pollen	Sept - Feb	Open land

117	<i>Ruta chalepensis</i>	Rutaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
118	<i>Salvia leucantha</i>	Lamiaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
119	<i>Salvia nilotica</i>	Lamiaceae	Herb	Nectar and pollen	June - August	Open land
120	<i>Salvia splendens</i>	Lamiaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
121	<i>Sambucus canadensis</i>	Caprifoliaceae	Tree	Nectar and pollen	June - August	Forestlands
122	<i>Satureja paradoxa</i>	Lamiaceae	Herb	Nectar and pollen	June - August	Forestlands
123	<i>Schefflera abyssinica</i>	Araliaceae	Tree	Nectar and pollen	March - May	Forestlands
124	<i>Silybum marianum</i>	Asteraceae	Herb	Nectar and pollen	June - Dec	Open land
125	<i>Sinapis alba</i>	Brassicaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
126	<i>Solanum indicum</i>	Solanaceae	Herb	Pollen	Sept - Nov	Open land
127	<i>Solanum nigrum</i>	Solanaceae	Herb	Pollen	Sept - Nov	Open land
128	<i>Solanum tuberosum</i>	Solanaceae	Herb	Pollen	Sept - Nov	Cultivated land
129	<i>Sonchus asper</i>	Asteraceae	Herb	Nectar and pollen	Sept - Nov	Open land
130	<i>Syzygium guineense</i>	Myrtaceae	Tree	Nectar and pollen	Jan - March	Forestlands
131	<i>Tagetes patula</i>	Asteraceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
132	<i>Thunbergia abyssinica</i>	Acanthaceae	Herb	Pollen	Sept - Nov	Open land
133	<i>Thymus vulgaris</i>	Lamiaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
134	<i>Trifolium quartianum</i>	Leguminosae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
135	<i>Trifolium spp.</i>	Leguminosae	Herb	Nectar and pollen	Sept - Nov	Open land
136	<i>Tropaeolum majus</i>	Tropaeolaceae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
137	<i>Urtica simensis</i>	Urticaceae	Herb	Pollen	March - May	Open land
138	<i>Verbascum sinaiticum</i>	Scrophulariaceae	Herb	Nectar and pollen	Sept - Nov	Open land
139	<i>Vernonia adoensis</i>	Asteraceae	Shrub	Nectar and pollen	Sept - Nov	Open land
140	<i>Vernonia amygdalina</i>	Asteraceae	Shrub	Nectar and pollen	Dec - Feb	Open land
141	<i>Vernonia urticifolia</i>	Asteraceae	Shrub	Nectar and pollen	Sept - Nov	Wetland
142	<i>Veronica abyssinica</i>	Scrophulariaceae	Herb	Nectar and pollen	Sept - Nov	Open land
143	<i>Vicia faba</i>	Leguminosae	Herb	Nectar and pollen	Sept - Nov	Cultivated land
144	<i>Zea mays</i>	Poaceae	Herb	Exudates and Pollen	August - Sept	Cultivated land

Table 50. Plant nature and flowering period (numbers in brackets reflect percentages, while others represent the number of species)

Plant nature	Number of spp.	Percent	Sep-Nov	Dec-Feb	Mar-May	Jun-Aug	Other
Trees	25	17.3	4 (17.4)	4 (17.4)	9 (39.1)	4 (17.4)	4 (8.7)
Shrubs	24	16.7	12 (50)	2 (8.3)	5 (20.8)	4 (16.7)	1 (4.2)
Herbs	94	65.3	73 (77.7)	2 (2.1)	4 (4.3)	10 (10.6)	5 (5.3)
Other	1	0.7					1 (100)
Total	144	100	89 (61.8)	8 (5.5)	18 (12.5)	18 (12.5)	11 (7.6)

Table 51. The mean amount of pollen and the number of days pollen was collected in Holetta during each season

Plant species	Autumn (Sept - Nov)			Winter (Dec - Feb)			Spring (Mar - May)			Summer (June - Augt)		
	pollen (g)	Percent	Days	Pollen (g)	Percent	Days	pollen (g)	Percent	Days	Pollen (g)	Percent	Days
<i>Brassica napus</i>	69	24.4	69							1	2.8	4
<i>Bidens spp.</i>	48	17.0	53									
<i>Trifolium spp.</i>	20	7.1	54									
<i>Cyanotis barbata</i>	13	4.6	30							0.1	0.3	2
<i>Plantago lanceolatum</i>	27	9.6	64	26	29.5	75	122	40.4	87	21	58.8	54
<i>Ociumum basilicum</i>	0.5	0.18	20									
<i>Vicia faba</i>	3	1.1	23									
<i>Pisum sativum</i>	1	0.35	26									
<i>Rumex bequaertii</i>	1	0.35	33	1	1.1	14						
<i>Linum usitatissimum</i>	0.2	0.07	10									
<i>Helianthus annuus</i>	0.1	0.04	1									
<i>Rosa abyssinca</i>	0.1	0.04	3									
<i>Rhamnus prinoids</i>	0.3	0.11	7							0.2	0.56	2
<i>Eucalyptus spp.</i>	9	3.2	47	0.1	0.11	9	50	16.5	47	6	16.84	52
<i>Guizotia spp.</i>	82	29.0	41									
<i>Echinops spp.</i>	1	0.35	43	8	9.1	66	0.1	0.03	1			
<i>Acacia spp.</i>	4	1.4	34	0.2	0.23	6						
<i>Caylusea abyssinca</i>	1	0.35	19	0.1	0.11	3						
<i>Geranium spp.</i>	0.4	0.14	12	0.5	0.56	21						
<i>Vernonia spp.</i>	0.1	0.04	3	29	32.83	40	1	0.33	20			
<i>Hypoestes spp.</i>	0.3	0.11	14									
<i>Phytolacca dodecandra</i>				0.2	0.23	6						
<i>Pinus spp.</i>				4	4.5	5	65	21.5	73	4	11.2	15
<i>Urtica simensis</i>							5	1.7	50			
<i>Oenothera fruticosa</i>							3	1.0	26	0.4	1.1	19

<i>Datura arborea</i>							42	13.9	59	1	2.8	12
<i>Helminthotheca echioides</i>				18	20.4	42	1	0.33	15			
<i>Cordia africana</i>				0.2	0.23	13	0.1	0.03	2			
<i>Cucurbita pepo</i>	1	0.35	1									
Unidentified	0.4	0.14	13	1	1.1	8	13	4.3	59	2	5.6	24
Total pollen (g)	282.4	100		88.3	100		302.2	100		35.7	100	

Table 52. Family, nature and habitat distribution of honey plant species in the central highlands of Ethiopia.

Family	Spps.	%	Tree	Herb	Shrub	Climber	Forestland	Open land	Cultivated	Wetland	Bush land	Open la2
Leguminosae	13	9.10	15.38	76.92	7.69	0	7.69	15.38	61.54	0	7.69	7.69
Amaranthaceae	2	1.40	0	100	0	0	50	50	0	0	0	0
Acanthaceae	5	3.50	0	80	20	0	20	80	0	0	0	0
Lamiaceae	16	11.19	0	81.25	18.75	0	12.50	25.00	43.75	18.75	0	0
Primulaceae	1	0.70	0	100	0	0	0	100	0	0	0	0
Boraginaceae	2	1.40	50	50	0	0	0	0	50	0	0	50
Sapotaceae	1	0.70	100	0	0	0	100	0	0	0	0	0
Scrophulariaceae	3	2.10	0	100	0	0	0	66.67	33.33	0	0	0
Ilacaceae	1	0.70	100	0	0	0	100	0	0	0	0	0
Asteraceae	25	17.4	0	88.0	12.0	0	0	60.0	20.0	16.0	4.0	0
Brassicaceae	5	3.50	0	100	0	0	0	20	60	20	0	0
Apocynaceae	1	0.70	0	0	100	0	0	0	0	0	100	0
Resedaceae	2	1.40	0	0	50	50	0	100	0	0	0	0
Rutaceae	2	1.40	0	50	50	0	0	0	100	0	0	0
Verbenaceae	2	1.40	0	50	50	0	0	50	0	0	50	0
Commelinaceae	2	1.40	0	100	0	0	0	50	0	50	0	0
Apiaceae	1	0.70	0	100	0	0	0	0	100	0	0	0
Euphorbiaceae	3	2.10	66.67	0	33.33	0	0	0	33.33	0	0	66.67
Cucurbitaceae	1	0.70	0	100	0	0	0	0	100	0	0	0
Solanaceae	6	4.20	0	83.33	16.67	0	0	66.67	33.33	0	0	0
Ranunculaceae	3	2.10	0	100	0	0	0	66.67	33.33	0	0	0
Caryophyllae	1	0.70	0	100	0	0	0	0	100	0	0	0
Poaceae	3	2.10	0	100	0	0	0	66.67	33.33	0	0	0
Meliaceae	1	0.70	100	0	0	0	100	0	0	0	0	0
Ericaceae	1	0.70	0	0	100	0	0	0	0	0	100	0

Myrtaceae	4	2.80	100	0	0	0	25	0	75	0	0	0
Polygonaceae	3	2.10	0	100	0	0	0	66.67	33.33	0	0	0
Moraceae	1	0.70	100	0	0	0	0	100	0	0	0	0
Rubiaceae	2	1.40	0	100	0	0	50	0	0	50	0	0
Geraniaceae	1	0.70	0	100	0	0	0	0	0	0	100	0
Proteaceae	1	0.70	100	0	0	0	0	0	100	0	0	0
Rosaceae	7	4.90	42.86	0	57.14	0	28.57	0	14.29	0	57.14	0
Clusiaceae	2	1.40	0	50	50	0	50	0	0	50	0	0
Balsaminaceae	1	0.70	0	100	0	0	0	100	0	0	0	0
Oleaceae	2	1.40	50	0	50	0	50	0	0	0	50	0
Crassulaceae	1	0.70	0	100	0	0	0	100	0	0	0	0
Linaceae	1	0.70	0	100	0	0	0	0	100	0	0	0
Celastraceae	1	0.70	0	0	100	0	100	0	0	0	0	0
Oliniaceae	1	0.70	100	0	0	0	100	0	0	0	0	0
Hydrophyllaceae	1	0.70	0	100	0	0	0	0	100	0	0	0
Phytolaccaceae	1	0.70	0	0	100	0	0	100	0	0	0	0
Pittosporaceae	1	0.70	100	0	0	0	100	0	0	0	0	0
Plantaginaceae	1	0.70	0	100	0	0	0	100	0	0	0	0
Araliaceae	2	1.40	100	0	0	0	100	0	0	0	0	0
Rhamnaceae	1	0.70	0	0	100	0	0	0	100	0	0	0
Anacardiaceae	1	0.70	100	0	0	0	0	100	0	0	0	0
Caprifoliaceae	1	0.70	100	0	0	0	100	0	0	0	0	0
Tropaeolaceae	1	0.70	0	100	0	0	0	0	100	0	0	0
Urticaceae	1	0.70	0	100	0	0	0	100	0	0	0	0
Pinaceae	1	0.70	100	0	0	0	0	0	100	0	0	0
Onagraceae	1	0.70	0	100	0	0	0	0	100	0	0	0
Total	144	100	17.02	65.25	17.02	0.7092	14.184	34.7518	31.9149	7.80142	7.801418	0.70922

NB. Open lan2 = Forest lands and open land

Table 53. The standardised temperature, rainfall, flowering intensity and reproductive swarming and migration periods of honeybees in the central highlands of Ethiopia.

Localities and co-ordinates	N	Climate	Months of the year												Mean + Sd
			1	2	3	4	5	6	7	8	9	10	11	12	
Holetta, 9.1N, 38.6E		T	-92.3	38.5	107.7	130.8	130.8	53.8	0	7.7	-15.4	-69.2	-14.6	-176.9	14.1 ± 1.3
		R	-108.6	-79.2	-55.5	-36.3	-50.8	-0.7	150.5	173.6	23.4	129.1	-118.6	-119.8	113 ± 88
	100	F	-61.3	-61.3	-38.3	-38.3	-38.3	-65.1	-65.1	-65.1	164.8	164.8	164.8	-61.3	20 ± 26.1
Swarming and migration			M	M				M	M	M	S	S	S	M	
Serofta, 6.5N, 39.1E		T	-13.2	26.3	105.3	131.6	157.9	52.6	-39.5	-65.8	-78.9	-65.8	-131.6	-144.7	15 ± 0.76
		R	-85.5	-67.7	-0.4	63	-2.4	13.5	165.9	122.4	108.5	17.4	-89.5	-107.3	73.2 ± 50.5
	12	F	-21.4	-92.9	-92.9	-21.4	-92.9	-21.4	-92.9	-92.9	121.4	192.9	121.4	50	2.3 ± 1.4
Swarming and migration			M	M				M	M	M	S	S	S	M	
Mararo, 7.2N, 39.1E		T	0	98.8	148.1	135.8	98.8	24.7	-74.1	-11.1	-74.1	-74.1	-98.8	-98.8	12.4 ± 0.81
		R	-107.7	-71.1	-15.5	19.5	7.3	40.4	174.6	167.6	57.8	-46.7	-90.2	-137.3	93.8 ± 57.4
	13	F	-50	-85.7	-14.3	-50	-50	-50	-50	-50	200	164.3	128.6	-85.7	2.4 ± 2.8
Swarming and migration								M	M	M	S	S	S		
Boter Bacho, 8.2N, 37.1E		T	-210	100	140	140	70	-30	-70	-80	-50	-30	-20	-10	12.9 ± 1.0
		R	-134.6	-95.8	-40.1	-2.3	17.6	88.3	129.1	158.9	104.2	-40.1	-101	-113.7	137.3 ± 100.5
	7	F	180	-20	-20.5	80	80	80	80	-120	-120	-120	-120	-20	1.2 ± 1.0
Swarming and migration				S	S	S	M	M	M	S	S	S			
Roge, 8.3N, 37.6E		T	10	100	150	140	110	-20	-90	-120	-80	-60	-80	-90	16.9 ± 1.0
		R	-101.1	70.6	-29.8	2.3	4.6	96.3	166.4	160	59.4	-80.8	-99.8	-106.2	92.4 ± 78.5
	10	F	-69.2	-69.2	-69.2	-69.2	-69.2	7.7	7.7	-69.2	-30.8	200	200	46.2	1.8 ± 2.6
Swarming and migration			M	M	S	S	S				S	S	S	M	
Hossaina, 7.3N, 37.5E		T	11.4	136.4	193.2	125	56.8	-45.5	-90.9	-113.6	-68.2	-56.8	-45.5	-56.8	16.4 ± 0.88
		R	-113.7	-95.6	-1.6	72.5	34.6	56	120.3	145	90.6	-51.1	-126.8	-126.8	97 ± 60.7

	9	F	-30.6	-30.6	71.4	173.5	-132.7	-30.6	71.4	71.4	71.4	71.4	-30.6	-30.6	1.3 ± 0.98
Swarming and migration								M	M	M	S	S	S		
Effo Yachi, 7.6N, 36.3E		T	-23	92	160.9	160.9	69	-23	114.9	-126.4	-80.5	-46	-50	-46	19.1 ± 0.87
		R	-115	-99.7	-58.8	-25.1	41.3	113.8	132.2	135.2	102.6	-23.1	-84.4	-119.1	141.6 ± 97.9
	11	F	-35.7	-35.7	-35.7	107.1	178.6	35.7	107.1	-107.1	107.1	107.1	-107.1	-107.1	3.5 ± 1.4
Swarming and migration					S	S	S	M	M	M	S	S	S		
Gado Lama, 7.4N, 39.4E		T	140	-40	60	100	110	90	-10	-20	0	-50	-160	-190	17 ± 1.0
		R	-120.3	-96.5	-16.5	42	-10	18.2	152.4	163.2	98.3	-20.8	-77.1	-133.3	70.6 ± 46.2
	11	F	50.6	50.6	50.6	50.6	50.6	50.6	50.6	50.6	50.6	-75.9	-202.5	-202.5	3.6 ± 0.79
Swarming and migration					S	S	S	M	M	M	S	S	S		
Boke Toko, 8.4N, 40.4E		T	-126.7	-46.7	33.3	80	120	146.7	33.3	13.3	53.3	0	-113.3	-160	21.2 ± 1.5
		R	-114	-95.4	-35	54	5.5	31.8	173.5	137	96.6	-51.2	-77.5	-126.1	75.3 ± 49.4
	9	F	-23.1	-100	-100	-100	-23.1	-23.1	53.8	207.7	53.8	130.8	53.8	-100	2.3 ± 1.3
Swarming and migration					S	S	S	M	M	M	S	S	S		
Alage, 7.4N, 38.2E		T	-33.7	67.4	179.8	146.1	78.7	11.2	-67.4	-78.7	-56.2	-33.7	-101.1	-134.8	18.6 ± 0.89
		R	-104.8	-72.8	-6.6	27.6	45.9	41.3	171.5	121.2	96.1	-75.1	-11.6	-132.2	63.9 ± 43.8
	10	F	-132.7	-132.7	71.4	71.4	-30.6	173.5	-30.6	-30.6	71.4	71.4	71.4	-132.7	2.3 ± 0.98
Swarming and migration								M	M	M	S	S	S		
Total mean		T	-59.5	47.6	142.9	142.9	119	35.7	-39.5	-71.4	-47.6	-59.5	-119	-142.9	16.4 ± 0.84
		R	-113.4	-88.3	-32.5	13.8	9.3	59.4	157.4	157	85	-20.2	-103.1	-126.1	95.8 ± 64.3
	194	F	-57.4	-72.5	-39.3	-27.2	-30.2	-45.3	-60.4	-120.8	178.2	178.2	139	-78.5	40 ± 33.1

Chapter Eight

8. References

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Chapter Nine

Appendices

9.1 Traditional beekeeping practise in the southern Ethiopia region

9.1.1 General

Traditional beekeeping is a deep-rooted cultural practise in Ethiopia. It is one of the oldest agricultural activities. Farmer beekeepers use their indigenous knowledge and locally available materials to keep honeybees. More than 95% of the honeybee colonies in Ethiopia are managed in the traditional method. Traditional beekeeping management may vary from one part of the country to the other due to different cultures and local material available in the area.

9.1.2 Traditional beekeeping practises in area of *A. m. scutellata*.

Both traditional and improved beekeeping are practised in the region, with traditional beekeeping being more predominant. Traditional beekeeping mainly takes place in the forest. In the southwest part of the region (eg. Mosha) farmer beekeepers share the existing natural forest amongst them selves exclusively for beekeeping purposes. This portion of forest is not used by other beekeepers without permission of the owner, which the ownership passes from generation to generation within a family. It is common to observe 20 to 30 beehives hung on a single big-branched tree in the region.

Beekeepers use mainly log hives, bark hives and bamboo hives for keeping honeybees. Log hives and bark hives are made from mainly from *Ficus sycomorus*, *Albizia shimpera*, *Acacia abyssiniaca*, and *Ficus vast*. While bamboo hives are made

from the stems and leaves of bamboo. Log hives are preferred to bamboo hives for a number of reasons: a log hive is more durable (can be passed down from generation to generation), easier and requiring less time to make (according to beekeepers 10 log hives and 1 bamboo hives can be made in a day) and as it has a split it is easy to open and harvest the honey. Moreover the cost of a log hives is cheaper than a bamboo hive (according to the farmer beekeepers one log hive costs US\$ 0.25 while a bamboo hive costs US\$ 0.50 to 0.75). However some farmer beekeepers complain that honeybee colonies in log hives abscond more frequently than those in bamboo hives. Log hives also become heavier and more difficult hang in a tree when it has been in use for long period of time..

The colony holding size in the region ranges from 10 to 200. Farmer beekeepers acquire their colonies mainly by trapping swarms. To attract swarm bait hives, smoked either with leaves from *Clausena anisata*, or *Olea europaea* or the bark from *Syzygium guineense*, are hung mainly on *Syzygium guineense*. Local beekeepers believe that this specific tree together with the smoking of the bait hives attracts swarm.

Regarding honeybee management, no attention is given to the colonies. Beekeepers only visit colonies during honey flow period. During honey harvesting beekeepers climb up the tree and send the hive to the ground either by means of a rope tied around the centre of the hive or by throwing the hive down, thereby destroying the colonies. When the first method is used, smoking materials such as Teff straw, a bundle of sticks and sometimes, though rarely cow dung is used to calm and chase bees away. Beekeepers remove all the contents from the hive and mix the pollen, brood and honey for sale or for making “Teji” for their own consumption.

The colour of honey in the region varies from season to season and place to place on the basis of which honey plants are available and flowering at that particular time of year. White honey is cropped during April to May when *Schefflera abyssinica* flowers abundantly, while yellow or amber honey is harvested during September to November from *Bidens spp.*, *Vernonia spp.*, *Syzygium guineense*, *Albizia gummifera* and other honey plants. White honey fetches a higher price than other types of honey. Honey is one of the main sources of income for farmers. However marketing of honey has not been well developed except some honey dealers found in a few towns. The market value of beeswax is unknown to most beekeepers and thus is not separated from the honey. Teji makers are the only ones who benefit from beeswax: they buy crude honey cheaply from beekeepers and make Teji. After fermentation they sieve the Teji and collect beeswax (Sefef) which is then sold to beeswax collectors who channel this product to beeswax refineries in Addis Ababa.

Besides traditional beekeeping classical honey-hunting and commercial beekeeping on are practised in the region.

9.1.3 Traditional beekeeping practises in the area of *A. m. bandasii*

In the central and eastern highlands honeybees are kept in beekeepers backyards and in the forests. However backyard beekeeping is the more widely practised method. The main types of hives used in the area include the pot hive (made of clay), bamboo hive (made from the split stems and leaves of bamboo) and the wicker (made of twigs from different shrubs and trees). Beekeeping management is practised here more than in the wet tropical forest areas. Farmer beekeepers are more conscientious and pay regular

visits to their colonies, providing water and supplementary food during dearth periods and protection from pests and predators. Hives are placed either under the roof overhang of the dwelling house or in the backyard on stone or pole supports. Moreover some beekeepers practise migratory beekeeping, moving their colonies to places where ample forage is available to secure bee and honey production. Beekeepers use queen cages made of locally available material, mainly bamboo and *Arundo donax*, and clip the queen's wings to prevent absconding and migration. Unlike beekeepers in the *A. m. scutellata* region (wet tropical forestlands), farmer beekeepers in this area leave some honey, pollen and brood to ensure that colonies stay after the honey harvest. Some beekeepers in this area separate the beeswax from the crude honey before selling the honey. To attract swarms they smoke the bait hives with the bark of *Ekeberia capensis* or rub the inside part of the hive with fresh leaves from *Ocimum basilicum* or *Ocimum sanctum* or use refined-beeswax.

On other hand like that of wet tropical forest in places where forest beekeeping is taking place no attention is given to honeybee colonies. They are visited only during honey flow period.

Channels for marketing honey and beeswax in this area are better than in the wet tropical forestlands as the area is closer to the central honey and beeswax markets (Addis Ababa). Farmer beekeepers in this region are more aware of the market value their products than the beekeepers from the *A. m. secutellata* area and therefore get a better price.

9.1.4 Traditional beekeeping in the areas of *A. m. woyi-gambella*

Forest beekeeping and honey hunting are the main types of beekeeping practised in the area of *A. m. woyi-gambella*. Log hives, made of *Cordia africana* is the dominant traditional hive used in the area, made either in a split or hollowed form. Even though bamboo hives are abundantly available in the area, they are not favoured by farmer beekeepers because the time and labour required is more extensive than for making a log hive.

Beekeepers smoke the hives using the bark from *Syzygium guineense* and leaves and chips from *Cordia africana* to attract swarms. The bait hives are hung mainly in *Cordia Africana* trees. Beekeepers can own up to about 600 colonies. The number of colonies owned by beekeepers is part of criteria used in the social standing of that beekeeper in the community.

Honey is harvested either by lowering or throwing the log hives to the ground, similar to the ways used in the *A. m. scutellata* area or by climbing the tree and removing the honey from the hive in situ. During the honey harvest beekeepers leave some honey, pollen and brood to sustain their colonies in the event of a dearth period. Brood is second only to honey as being the main product from the harvest. Beekeepers harvest brood from colonies which do not produce a lot of honey. The Mazanger tribe however only harvest the brood of wild honeybee colonies. Bee brood is the main source of protein for farmer beekeepers and children are fed bee brood as a substitute for milk. A bundle of sticks and other dry material from the forest is used for smoking during honey harvest and no protective clothing is worn.

Most Agnuwak tribe do not keep honeybees, as they are nomadic. They are however honey-hunters and the honey is used only for their own consumption and is not sold unlike other tribes of the area. Like Mazanger people, they also eat bee brood.

Honey hunters roam through the forest and mountainous areas searching for feral bee nests. They look for holes in trees, bee activity or use honey guide birds (*Indicator indicator*). Honey-hunters call honey guide birds by whistling. The honey guide directs the hunters to the honeybee nest by flying back and forth between the hunters and the nest. The honey guide can lead the hunters to beehives hung in a tree or wild bee nests situated in a tree hole, termite mound or cliff. Honey-hunters never rob beehives as honey stealing in Agnuwak and Mazenger is culturally unacceptable. Thus hunters encourage honey guide birds to lead them to other honeybee nests. When bees are situated in a hole in a tree excessive smoke and fire are used to force the bees out. If the nest is inaccessible to the hunters, the tree is cut down and the nest contents are collected. Honey and brood are given to the honey guide birds as a reward for their services. A honey-hunter could harvest honey from 3 – 4 wild honeybee nests per day. Honey-hunters are blamed for causing forest fires and for the decline of swarms. In Woyito, in the southern lowlands, forest beekeeping is practised and there is notable absence of honey-hunting in this area.

9.1.5 Traditional beekeeping practise in the area of *A. m. jemenitica*

Farmer beekeepers of the area use hollowed-out log hives, twig hives and bamboo hives for keeping honeybees. Log hives are made from of *Acacia spp.* While twigs hives are made from various twigs which are woven together with climbers and plastered with cow dung on the inside.

Traditional beekeeping in the area is practised both in the forest and in beekeepers backyards. Backyard beekeeping is the dominant practise while forest beekeeping mainly takes place in the eastern Bale zone (Karre Tule). In backyard beekeeping hives are either hung on the exterior wall of dwelling house or in the backyard the poles erected for this purpose. Some beekeepers place their colonies under a bee shelter, which is covered with straw or leaves to protect colonies from the heat. Honeybee handling and honey harvesting is relatively better than in the areas where forest beekeeping takes place.

In the eastern Bale zone, beekeeping is practised more in Acacia forests than in beekeepers backyards. Beekeeping management and honey harvesting in this particular area is similar to that of the area of *A. m. scutellata* where forest beekeeping takes place.

9.2 Questionnaire

Rhodes University Department of Zoology and Entomology

The Southern Ethiopian Honeybees (*Apis mellifera* L.)

Survey Questionnaire

Remark: Use “ X” mark where necessary

Date of interview -----

1. Data about the Woreda

1.1 General information

1.1.1 Region: -----

1.1.2 Zone: -----

1.1.3 Woreda: -----Code of locality-----

1.1.4 Geographical Co-ordinants:-----

1.1.5 Altitude: -----m.a.s.l.

1.1.6 Temperature (°C): Max :----- Min: ----- Mean :-----

1.1.7 Rainfall (mm): Max: ----- Min :----- Mean :-----

1.1.8 Raining Season (mark X):

	Remark	
	Small	Big
1.1.8.1 September - November	-----	-----
1.1.8.2 December - February	-----	-----
1.1.8.3 March - May	-----	-----

1.1.8.4 June -August -----

1.1.8.5 Others, specify:

-----to-----

1.2 Land utilisation (Hectare)

1.2.1 Total area-----

1.2.2 Cultivated land: -----

1.2.3 Forest land: -----

1.2.4 Bush land: -----

1.2.5 Grazing land: -----

1.2.6 Open land: -----

1.2.7 Agro climatical zone (in percent): Highlands ----- Midlands ----- Lowlands ----

1.3 Beekeeping in Woreda

1.3.1 Number of farmer households-----

1.3.2 Number of beekeepers in Woreda: -----

1.3.3 Number of honeybee colonies in Woreda: -----

1.3.4 Number of bee colonies owned by farmer beekeepers:

1.3.4.1 Basket hive Min: ----- Max: -----

1.3.4.2 Movable hive Min:----- Max:-----

1.3.5 Annual honey production (kg.):

1.3.5.1 Basket hive Min:----- Max:-----

1.3.5.2 Movable frame hive Min:----- Max:-----

1.3.6 Where do beekeepers keep their bee colonies?

1.3.6.1 In backyard -----

1.3.6.2 Hang on tree near homestead -----

1.3.6.3 Hang on tree in forest -----

1.3.6.4 1 and 2 -----

1.3.6.5 1 and 3 -----

1.3.6.6 2 and 3 -----

1.4 What are the major honeybee plants in the Woreda:

1.4.1 Bee plants (common or Botanical names)	Flowering time
1.4.1.1 -----	-----
1.4.1.2 -----	-----
1.4.1.3 -----	-----
1.4.1.4 -----	-----
1.4.1.5 -----	-----
1.4.1.6 -----	-----
1.4.1.7 -----	-----
1.4.1.8 -----	-----
1.4.1.9 -----	-----
1.4.1.10 -----	-----
1.4.1.11 -----	-----
1.4.1.12 -----	-----

- 1.4.1.13 -----
- 1.4.1.14 -----
- 1.4.1.15 -----
- 1.4.1.16-----
- 1.4.1.17-----
- 1.4.1.18-----
- 1.4.1.19 -----
- 1.4.1.20 -----

2 Information on sample site

2.1 Information on beekeepers and locality

- 2.1.1 Locality: -----
- 2.1.2 Code of locality-----
- 2.1.3 Altitude ----- Geographical co-ordinants -----
- 2.1.4 Name of beekeeper:----- Experience(years) -----
- 2.1.5 Marital status Single: ----- Married :-----
- 2.1.6 If married, the size of his/ her family-----
- 2.1.7 Occupation: -----

2.2 Beekeeping practise

- 2.2.1 Types of bee hive used (mark “X”, one or more when necessary)
- 2.2.1.1 Log hive -----
- 2.2.1.2 Straw hive -----
- 2.2.1.3 Clay pot -----

- 2.2.1.4 Bamboo hive -----
- 2.2.1.5 Mud hive -----
- 2.2.1.6 False banana hive -----
- 2.2.1.7 Movable frame hive ----- Zander----- or TB.Hive-----
- 2.2.3 How many hives do you have? -----
- 2.2.4 Occupied hives -----
- 2.2.5 Non-occupied hives -----
- 2.2.6 How do you characterise your colony? (mark one from each category)
- 2.2.6.1 Colour: Black----- Red/yellow-----Grey-----
- 2.2.6.2 Size: Big ----- Medium----- Small-----
- 2.2.6.3 Defensive behaviour: High----- Medium----- Low -----
- 2.2.6.4 Others, specify-----
- 2.2.7 When do bees become more aggressive? (mark one or more)
- 2.2.7.1 During honey flow-----
- 2.2.7.2 During honey harvest-----
- 2.2.7.3 During dearth period-----
- 2.2.7.4 During rainy season -----
- 2.2.7.5 During attack by enemies-----
- 2.2.7.6 During high temperature -----
- 2.2.7.7 Other, specify-----
- 2.2.8 Where do you get your colonies? (mark one or more)
- 2.2.8.1 Catching Swarms-----
- 2.2.8.2 Buying -----

2.2.8.3 Other, specify -----

2.2.9 How many bee hives did you hang for catching swarms: this year-----last year--

2.2.10 How many of them were occupied by swarms: this year -----last year-----

2.2.11 When do you think most swarms are caught? (mark one or more)

2.2.11.1 September - November -----

2.2.11.2 December - February-----

2.2.11.3 March - May-----

2.2.11.4 June - August-----

2.2.11.5 Other, specify----- to -----

2.2.12 When is the honey flow season	Major	Minor
--------------------------------------	-------	-------

2.2.12.1 September - November	-----	-----
-------------------------------	-------	-------

2.2.12.2 December - February	-----	-----
------------------------------	-------	-------

2.2.12.3 March - May	-----	-----
----------------------	-------	-------

2.2.12.4 June - August	-----	-----
------------------------	-------	-------

2.2.12.5 Other, specify	-----	-----
-------------------------	-------	-------

2.2.13 What is honey yield/year/colony

2.2.13.1 Traditional hive -----/kg

2.2.13.2 Movable frame hive -----/kg

2.2.14 Which of your colonies give you more honey? (mark one from each)

2.2.14.1 Colour: black ----- red ----- grey -----

2.2.14.2 Behaviour: aggressive ----- - non-aggressive -----

2.2.14.3 Size: big----- medium-----small -----

2.2.15 What was the approximate average honey yield you get in kg/year from-

2.2.15.1 Colour: black ----- red ----- grey -----

2.2.15.2 Behaviour: aggressive ----- -non-aggressive -----

2.2.15.3 Size: big----- medium-----small -----

2.2.16 How do you harvest honey?

2.2.16.1 Do you remove all combs and brood yes----- no---

2.2.16.2 Do you remove all honey comb and leave brood yes----- no---

2.2.16.3 Do you leave some honey for your colony yes----- no-----

2.2.17 Do your bees evacuate immediately after honey harvest? yes----- no ----

3. Behaviour of honeybees

3.1 Swarming

3.1.1 Is there any swarm problem? yes----- no-----

3.1.2 If yes, when does this happen? (mark one or more)

3.1.2.1 September - November -----

3.1.2.2 December - February -----

3.1.2.3 March - May -----

3.1.2.4 June - August -----

3.1.2.5 Other, specify ----- to ----- -----

3.1.3 If swarming occurs in two seasons of the year, in which season is it more frequent -----to-----

3.1.4 How many of your colonies swarmed: this year----- last year-----

3.1.5 Number of swarms per colony per year: min ----- max-----

3.1.6 Does swarming occur

3.1.6.1 Every year? yes----- no -----

3.1.6.2 Once in two years? yes -----no-----

3.1.6.3 Once in three years? yes----- no-----

3.1.6.4 Other, specify? -----

3.1.6.5 Give reasons for your response above -----

3.1.7 Which type of your colonies swarm frequently? (mark one from each category)

3.1.7.1 Colour: black ----- red ----- grey -----

3.1.7.2 Behaviour: aggressive ones ----- non aggressive ones-----

3.1.7.3 Size: big----- medium ----- small -----

3.1.8 Do you think the swarming of your colonies is advantageous ----- or
disadvantageous -----

3.1.9 If advantageous why?

3.1.9.1 Is it to increase your number of colonies yes-----no-----

3.1.9.2 Is it to sell and get income yes-----no -----

3.1.9.3 Both 1 and 2 yes----- no-----

3.1.9.4 Other, specify-----

3.1.10 If your answer above is 2, is it more financially advantageous than honey?

Yes---- No---

3.1.11 If yes, how many swarms do you produce per annum? -----

3.1.12 How many swarms do you produce from a colony? -----

3.1.13 Which bee colonies do you use for production of swarms?(mark one from each category)

3.1.13.1 Colour: black ----- red ----- grey -----

3.1.13.2 Behaviour: aggressive -----non aggressive -----

3.1.13.3 Size: big----- medium----- small-----

3.1.14 What is the price of one swarm (in Birr)? -----

3.2 Migration

3.2.1 Is migration a problem for you? Yes----- No-----

3.2.2 If yes, when does it occur?

3.2.2.1 September - November yes-----no -----

3.2.2.2 December - February yes-----no -----

3.2.2.3 March - May yes-----no -----

3.2.2.4 June - August yes -----no -----

3.2.2.5 Other, specify----- to -----

3.2.3 Did all or part of your colony migrate? all -----part-----

3.2.4 How many of your bee colonies migrated this year?----- last year? -----

3.2.5 Does migration occur

3.2.5.1 Every year yes----- no-----

3.2.5.2 Once in two years yes ----- no-----

3.2.5.3 Once in three years yes----- no-----

3.2.5.4 Other, specify -----

3.2.5.5 Give reasons for your response above -----

3.2.6 To where did the bee colonies migrate?

3.2.6.1 To high land yes----- no-----

3.2.6.2 To mid-land yes----- no -----

3.2.6.3 To low land yes -----no-----

3.2.6.4 Other, Specify -----

3.2.7 Give reasons for your answer above -----

3.2.8 Do the migrated bee colonies come back again? yes----- no -----

3.2.9 If yes, when do they come back?

3.2.9.1 September - November yes----- -- no-----

3.2.9.2 December - February yes ----- no -----

3.2.9.3 March - May yes----- no -----

3.2.9.4 June - August yes ----- no -----

3.2.9.5 Other, specify -----to -----

3.2.9.6 Why do you think honeybee colonies come back?-----

3.2.10 Which types of your colonies migrate more frequently?(mark one from each)

3.2.10.1 Colour: black ----- red s ----- grey -----

3.2.10.2 Behaviour: aggressive ones----- non aggressive -----

3.2.10.3 Size: big ----- medium----- small-----

3.2.10.4 Other, specify-----

3.2.11 What do you think are the causes for migration?

3.2.11.1 Shortage of forage yes----- no -----

3.2.11.2 Shortage of water yes ----- no -----

3.2.11.3 High temperatures yes----- no-----

3.2.11.4 High winds yes----- no -----

3.2.11.5 High rainfall yes----- no -----

3.2.11.6 Drought yes----- no -----

3.2.11.7 Pests and predators yes ----- no -----

3.2.11.8 Pesticides yes ----- no-----

3.2.11.9 Unknown reasons -----

3.2.11.10 Other, specify -----

3.3 Defence

3.3.1 Are your honeybee colonies docile----- aggressive----- very aggressive -----

3.3.2 How many of your honeybee colonies are aggressive -----

3.3.3 Which of your honeybee colonies are very aggressive?

3.3.3.1 Size: big----- medium ----- large -----

3.3.3.2 Colour: red----- grey----- black-----

3.3.4 When do honeybees become more aggressive?

3.3.4.1 during honey harvest yes----- no -----

3.3.4.2 during honey flow yes ----- no -----

3.3.4.3 during dearth period yes ----- no -----

3.3.4.4 during rainy season yes ----- no -----

3.3.4.5 during attack by pests and predators yes ----- no -----

3.3.4.6 during swarming yes----- no -----

3.3.4.7 during migration yes ----- no -----

3.3.4.8 early morning (6-11am) ----- mid-day (11.05am - 2pm) ----- noon(2.05 - 6pm)-----

3.3.4.9 when bees are foraging yes----- no -----

3.3.4.10 when bees are at home yes----- no -----

3.3.4.11 during September - November yes ----- no -----

3.3.4.12 during December - February yes- ----- n0 -----

3.3.4.13 during March - May yes ----- no -----

3.3.4.14 during June - August yes----- no -----

3.3.5 If the answer in 3.3.4.5.is yes, what are the major pests and predators causing aggression of honeybees?

3.3.6 How many stings did you receive during honey harvest or during honeybee colony manipulation? -----

4. Pests and predators

4.1 What are the major pests and predators of honeybee colonies in the locality?

Pests and predators	Incidence time	Damage caused
1. Ants	1. -----	1-----
2. Birds	2.-----	2-----
3. Wax moth	3.-----	3-----
4. Honey badgers	4. -----	4-----
5. Bee lice	5.-----	5 -----
6. Spiders	6.-----	6 -----
7. Beetles	7.-----	7 -----
8. Other, specify	8.-----	8 -----
	9.-----	9 -----
	10.-----	10 -----
	11.-----	11-----
	12.-----	12-----

4.2 Put the abovementioned pests and predators in order of importance

1. -----
2. -----
3. -----
4. -----
5. -----
6. -----
7. -----
8. -----

5. Problems of beekeeping in the area

5.1 What are the major problems of beekeeping in the locality?

Put in order of importance	Rank (put No.)
1. Shortage of forage	-----
2. Shortage of water	-----
3. High temperatures	-----
4. High winds	-----
5. High rainfall	-----
6. Drought	-----
7. Pests and predators	-----
8. Pesticides	-----
9. Defensive behaviour of bees	-----
10. Migration	-----
11. Swarming	-----

- 12. Inadequate honeybee colonies -----
- 13. Marketing -----
- 14. Beekeeping equipment -----
- 15. Other, specify -----

9.3 Tables and figures

Table 54. Posterior probability for classification of colonies into the four groups of southern Ethiopian region (incorrect classification marked with *).

Locality	Colony	Observed Classification	Group 1_	Group 2_	Group 3	Group 4_
			p=.08696	p=.13043	p=.39130	p=.39130
S1	1	G_4:4	0.00000	0.00000	0.00216	0.99784
S1	2	G_4:4	0.00000	0.00000	0.00020	0.99980
S1	3	G_4:4	0.00000	0.00000	0.01728	0.98272
S1	4	G_4:4	0.00000	0.00000	0.03065	0.96935
S1	5	G_4:4	0.00000	0.00000	0.03639	0.96361
S2	6	G_1:1	1.00000	0.00000	0.00000	0.00000
S2	7	G_1:1	0.99997	0.00001	0.00000	0.00001
S2	8	G_1:1	0.99694	0.00011	0.00000	0.00295
S2	9	G_1:1	0.97126	0.00000	0.00002	0.02873
S2	10	G_1:1	0.99563	0.00092	0.00000	0.00345
S3	11	G_4:4	0.00000	0.00000	0.00229	0.99771
S3	12	G_4:4	0.00000	0.00000	0.00027	0.99973
S3	13	G_4:4	0.00000	0.00000	0.04890	0.95110
S3	14	G_4:4	0.00000	0.00000	0.18991	0.81009
S3	15	G_4:4	0.00000	0.00000	0.02244	0.97756
S4	* 16	G_4:4	0.00000	0.00000	0.93114	0.06886
S4	17	G_4:4	0.00000	0.00000	0.05673	0.94327
S4	18	G_4:4	0.00000	0.00000	0.01799	0.98201
S4	19	G_4:4	0.00000	0.00000	0.05025	0.94975
S4	20	G_4:4	0.00000	0.00000	0.00134	0.99866
S5	21	G_4:4	0.00000	0.00000	0.00000	1.00000
S5	22	G_4:4	0.00001	0.00000	0.00000	0.99998
S5	23	G_4:4	0.00056	0.00000	0.00000	0.99944
S5	24	G_4:4	0.00000	0.00000	0.00004	0.99996
S5	25	G_4:4	0.00000	0.00000	0.00690	0.99310
S6	26	G_4:4	0.00000	0.00000	0.00030	0.99970
S6	27	G_4:4	0.00000	0.00000	0.00254	0.99746
S6	28	G_4:4	0.00000	0.00000	0.00044	0.99956
S6	29	G_4:4	0.00007	0.00000	0.00025	0.99968
S6	30	G_4:4	0.00001	0.00000	0.00019	0.99980
S7	31	G_1:1	0.71423	0.28577	0.00000	0.00000
S7	32	G_1:1	1.00000	0.00000	0.00000	0.00000
S7	33	G_1:1	0.99997	0.00000	0.00000	0.00003
S7	34	G_1:1	0.97393	0.02607	0.00000	0.00000
S7	35	G_1:1	0.99973	0.00027	0.00000	0.00000
S8	36	---	0.14990	0.84994	0.00000	0.00016
S8	37	---	0.09665	0.00000	0.00004	0.90331
S8	38	---	0.00001	0.00000	0.00085	0.99914

S8	39	---	0.67766	0.32063	0.00000	0.00171
S8	40	---	0.00032	0.99968	0.00000	0.00000
S9	41	G_4:4	0.00000	0.00000	0.00053	0.99947
S9	42	G_4:4	0.00086	0.00000	0.00000	0.99914
S9	43	G_4:4	0.00000	0.00000	0.00019	0.99981
S9	44	G_4:4	0.00000	0.00000	0.19450	0.80550
S9	45	G_4:4	0.01236	0.01855	0.00584	0.96325
S10	* 46	G_4:4	0.00000	0.00000	0.73685	0.26315
S10	47	G_4:4	0.00000	0.00000	0.00096	0.99904
S10	48	G_4:4	0.00000	0.00000	0.01163	0.98837
S10	49	G_4:4	0.00000	0.00000	0.02043	0.97957
S10	50	G_4:4	0.00000	0.00000	0.42581	0.57419
S11	51	G_4:4	0.00000	0.00000	0.00432	0.99568
S11	52	G_4:4	0.00000	0.00000	0.00260	0.99740
S11	53	G_4:4	0.00000	0.00000	0.02919	0.97081
S11	54	G_4:4	0.00000	0.00000	0.23697	0.76303
S11	55	G_4:4	0.00000	0.00000	0.00201	0.99799
S12	56	G_3:3	0.00000	0.00000	0.99682	0.00318
S12	57	G_3:3	0.00000	0.00000	0.99989	0.00011
S12	58	G_3:3	0.00000	0.00000	0.99186	0.00814
S12	59	G_3:3	0.00000	0.00000	0.97012	0.02988
S12	60	G_3:3	0.00000	0.00000	0.98802	0.01198
S13	61	G_3:3	0.00000	0.00000	0.99999	0.00001
S13	62	G_3:3	0.00000	0.00000	0.99918	0.00082
S13	63	G_3:3	0.00000	0.00000	0.99999	0.00001
S13	64	G_3:3	0.00000	0.00000	0.99114	0.00886
S13	65	G_3:3	0.00000	0.00000	1.00000	0.00000
S14	66	---	0.00000	0.00000	0.99920	0.00080
S14	67	---	0.00000	0.00346	0.09522	0.90132
S14	68	---	0.00424	0.99099	0.00006	0.00471
S14	69	---	0.00003	0.00000	0.00093	0.99904
S14	70	---	0.00000	0.00000	0.92442	0.07558
S15	* 71	G_2:2	0.99613	0.00366	0.00000	0.00021
S15	72	G_2:2	0.00002	0.99998	0.00000	0.00000
S15	73	G_2:2	0.00061	0.95125	0.00057	0.04758
S15	74	G_2:2	0.00276	0.99723	0.00000	0.00001
S15	75	G_2:2	0.00012	0.99988	0.00000	0.00000
S16	76	G_2:2	0.00000	1.00000	0.00000	0.00000
S16	77	G_2:2	0.00001	0.99999	0.00000	0.00000
S16	78	G_2:2	0.00024	0.99976	0.00000	0.00000
S16	79	G_2:2	0.00000	1.00000	0.00000	0.00000
S16	80	G_2:2	0.00000	1.00000	0.00000	0.00000
S17	81	G_2:2	0.00000	1.00000	0.00000	0.00000
S17	82	G_2:2	0.00003	0.99997	0.00000	0.00000
S17	83	G_2:2	0.00000	1.00000	0.00000	0.00000
S17	84	G_2:2	0.00000	1.00000	0.00000	0.00000

S17	85	G_2:2	0.00000	1.00000	0.00000	0.00000
S18	86	G_3:3	0.00000	0.00000	0.99352	0.00648
S18	* 87	G_3:3	0.00000	0.00000	0.29717	0.70283
S18	88	G_3:3	0.00000	0.00000	0.99921	0.00079
S18	89	G_3:3	0.00000	0.00000	0.95902	0.04098
S18	* 90	G_3:3	0.00000	0.00000	0.43855	0.56145
S19	91	---	0.00000	1.00000	0.00000	0.00000
S19	92	---	0.00000	0.00002	0.37704	0.62294
S19	93	---	0.00000	1.00000	0.00000	0.00000
S19	94	---	0.00000	0.00000	0.11498	0.88502
S19	95	---	0.00564	0.91184	0.00007	0.08245
S20	96	G_3:3	0.00000	0.00000	0.99996	0.00004
S20	97	G_3:3	0.00000	0.00000	0.99994	0.00006
S20	98	G_3:3	0.00000	0.00000	0.99984	0.00016
S20	99	G_3:3	0.00000	0.00002	0.96800	0.03197
S20	100	G_3:3	0.00000	0.00000	0.99599	0.00401
S21	101	G_3:3	0.00000	0.00000	0.94698	0.05302
S21	102	G_3:3	0.00000	0.00000	0.92330	0.07670
S21	103	G_3:3	0.00000	0.00000	0.99968	0.00032
S21	104	G_3:3	0.00000	0.00000	0.99048	0.00952
S21	105	G_3:3	0.00000	0.00000	0.99841	0.00159
S22	106	G_4:4	0.00000	0.00000	0.13548	0.86452
S22	107	G_4:4	0.00000	0.00000	0.00189	0.99811
S22	108	G_4:4	0.00001	0.00001	0.00669	0.99329
S22	109	G_4:4	0.00000	0.00000	0.03290	0.96710
S22	110	G_4:4	0.01328	0.09883	0.01576	0.87212
S23	111	G_3:3	0.00000	0.00000	0.99867	0.00133
S23	112	G_3:3	0.00000	0.00000	0.99970	0.00030
S23	113	G_3:3	0.00000	0.00000	0.99981	0.00019
S23	114	G_3:3	0.00000	0.00000	0.97950	0.02050
S23	115	G_3:3	0.00000	0.00000	0.95700	0.04300
S24	116	G_3:3	0.00000	0.00000	0.99620	0.00380
S24	117	G_3:3	0.00000	0.00000	0.98396	0.01604
S24	118	G_3:3	0.00000	0.00000	0.98374	0.01626
S24	119	G_3:3	0.00000	0.00000	0.91391	0.08609
S24	120	G_3:3	0.00000	0.00000	0.99785	0.00215
S25	121	G_3:3	0.00000	0.00000	0.99914	0.00086
S25	122	G_3:3	0.00000	0.00000	0.99568	0.00432
S25	123	G_3:3	0.00000	0.00000	0.96190	0.03810
S25	124	G_3:3	0.00000	0.00000	0.99742	0.00258
S25	125	G_3:3	0.00000	0.00000	0.99925	0.00075
S26	126	G_3:3	0.00000	0.00000	0.95699	0.04301
S26	127	G_3:3	0.00000	0.00000	0.75133	0.24867
S26	128	G_3:3	0.00000	0.00000	0.99969	0.00031
S26	* 129	G_3:3	0.00000	0.00000	0.40663	0.59336
S26	130	G_3:3	0.00101	0.00000	0.93919	0.05980

Table 55. Mean comparisons of morphometric characters over sampling localities (P-values are shown).

Table 55.1. Pigmentation of scutellum.

Tukey HSD test; variable SCUTLLUM																											
Probabilities for Post Hoc Tests																											
MAIN EFFECT: LOCALITY																											
Locality	{1}	{2}	{3}	{4}	{5}	{6}	{7}	{8}	{9}	{10}	{11}	{12}	{13}	{14}	{15}	{16}	{17}	{18}	{19}	{20}	{21}	{22}	{23}	{24}	{25}	{26}	
Mean	.1600000	2.710000	.8100000	.0600000	.3400000	.4100000	5.720000	3.190000	.6400000	.7300000	1.000000	0.000000	0.000000	1.440000	4.710000	5.100000	6.590000	1.500000	4.220000	1.270000	0.600000	1.450000	.2100000	0.000000	0.000000	1.410000	
S1 {1}		0.09376	1.00000	1.00000	1.00000	1.00000	0.00018	0.01179	1.00000	1.00000	1.00000	1.00000	1.00000	0.98706	0.00018	0.00018	0.00018	1.00000	0.00021	0.99816	1.00000	0.98576	1.00000	1.00000	1.00000	0.99041	
S2 {2}	0.09376		0.59688	0.06334	0.17801	0.22288	0.01296	1.00000	0.41943	0.51202	0.07435	0.04952	0.04952	0.98826	0.49103	0.16651	0.00028	0.09026	0.92182	0.95088	0.06334	0.98938	0.11299	0.04952	0.04952	0.98435	
S3 {3}	1.00000	0.59688		1.00000	1.00000	1.00000	0.00018	0.17219	1.00000	1.00000	1.00000	0.99999	0.99999	1.00000	0.00027	0.00018	0.00018	1.00000	0.00180	1.00000	1.00000	1.00000	1.00000	0.99999	0.99999	1.00000	
S4 {4}	1.00000	0.06334	1.00000		1.00000	1.00000	0.00018	0.00725	1.00000	1.00000	1.00000	1.00000	1.00000	0.96875	0.00018	0.00018	0.00018	1.00000	0.00019	0.99374	1.00000	0.96617	1.00000	1.00000	1.00000	0.97559	
S5 {5}	1.00000	0.17801	1.00000	1.00000		1.00000	0.00018	0.02708	1.00000	1.00000	1.00000	1.00000	1.00000	0.99839	0.00018	0.00018	0.00018	1.00000	0.00028	0.99989	1.00000	0.99816	1.00000	1.00000	1.00000	0.99896	
S6 {6}	1.00000	0.22288	1.00000	1.00000	1.00000		0.00018	0.03680	1.00000	1.00000	1.00000	1.00000	1.00000	0.99942	0.00018	0.00018	0.00018	1.00000	0.00033	0.99997	1.00000	0.99933	1.00000	1.00000	1.00000	0.99964	
S7 {7}	0.00018	0.01296	0.00018	0.00018	0.00018	0.00018		0.10110	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.99958	1.00000	0.99997	0.00018	0.92655	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018
S8 {8}	0.01179	1.00000	0.17219	0.00725	0.02708	0.03680	0.10110		0.09376	0.13057	0.00882	0.00540	0.00540	0.74866	0.91689	0.58627	0.00189	0.01124	0.99942	0.57565	0.00725	0.75794	0.01494	0.00540	0.00540	0.72001	
S9 {9}	1.00000	0.41943	1.00000	1.00000	1.00000	1.00000	0.00018	0.09376		1.00000	1.00000	1.00000	1.00000	0.99999	0.00020	0.00018	0.00018	1.00000	0.00079	1.00000	1.00000	0.99999	1.00000	1.00000	1.00000	1.00000	
S10 {10}	1.00000	0.51202	1.00000	1.00000	1.00000	1.00000	0.00018	0.13057	1.00000		1.00000	1.00000	1.00000	1.00000	0.00023	0.00018	0.00018	1.00000	0.00122	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	
S11 {11}	1.00000	0.07435	1.00000	1.00000	1.00000	1.00000	0.00018	0.00882	1.00000	1.00000		1.00000	1.00000	0.97759	0.00018	0.00018	0.00018	1.00000	0.00020	0.99605	1.00000	0.97559	1.00000	1.00000	1.00000	0.98283	
S12 {12}	1.00000	0.04952	0.99999	1.00000	1.00000	1.00000	0.00018	0.00540	1.00000	1.00000	1.00000		1.00000	0.95088	0.00018	0.00018	0.00018	1.00000	0.00019	0.98826	1.00000	0.94729	1.00000	1.00000	1.00000	0.96055	
S13 {13}	1.00000	0.04952	0.99999	1.00000	1.00000	1.00000	0.00018	0.00540	1.00000	1.00000	1.00000	1.00000		0.95088	0.00018	0.00018	0.00018	1.00000	0.00019	0.98826	1.00000	0.94729	1.00000	1.00000	1.00000	0.96055	
S14 {14}	0.98706	0.98826	1.00000	0.96875	0.99839	0.99942	0.00018	0.74866	0.99999	1.00000	0.97759	0.95088	0.95088		0.00361	0.00058	0.00018	0.98576	0.03680	1.00000	0.96875	1.00000	0.99222	0.95088	0.95088	1.00000	
S15 {15}	0.00018	0.49103	0.00027	0.00018	0.00018	0.00018	0.99958	0.91689	0.00020	0.00023	0.00018	0.00018	0.00018	0.00361		1.00000	0.61801	0.00018	1.00000	0.00155	0.00018	0.00380	0.00018	0.00018	0.00018	0.00311	
S16 {16}	0.00018	0.16651	0.00018	0.00018	0.00018	0.00018	1.00000	0.58627	0.00018	0.00018	0.00018	0.00018	0.00018	0.00056	1.00000		0.93108	0.00018	0.99996	0.00032	0.00018	0.00058	0.00018	0.00018	0.00018	0.00050	
S17 {17}	0.00018	0.00028	0.00018	0.00018	0.00018	0.00018	0.99997	0.00189	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.61801	0.93108		0.00018	0.17801	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	
S18 {18}	1.00000	0.09026	1.00000	1.00000	1.00000	1.00000	0.00018	0.01124	1.00000	1.00000	1.00000	1.00000	1.00000	0.98576	0.00018	0.00018	0.00018		0.00020	0.99790	1.00000	0.98435	1.00000	1.00000	1.00000	0.98938	
S19 {19}	0.00021	0.92182	0.00180	0.00019	0.00028	0.00033	0.92655	0.99942	0.00079	0.00122	0.00020	0.00019	0.00019	0.03680	1.00000	0.99996	0.17801	0.00020		0.01717	0.00019	0.03842	0.00022	0.00019	0.00019	0.03231	
S20 {20}	0.99816	0.95088	1.00000	0.99374	0.99989	0.99997	0.00018	0.57565	1.00000	1.00000	0.99605	0.98826	0.98826	1.00000	0.00155	0.00032	0.00018	0.99790	0.01717		0.99374	1.00000	0.99910	0.98826	0.98826	1.00000	
S21 {21}	1.00000	0.06334	1.00000	1.00000	1.00000	1.00000	0.00018	0.00725	1.00000	1.00000	1.00000	1.00000	1.00000	0.96875	0.00018	0.00018	0.00018	1.00000	0.00019	0.99374		0.96617	1.00000	1.00000	1.00000	0.97559	
S22 {22}	0.98576	0.98938	1.00000	0.96617	0.99816	0.99933	0.00018	0.75794	0.99999	1.00000	0.97559	0.94729	0.94729	1.00000	0.00380	0.00058	0.00018	0.98435	0.03842	1.00000	0.96617		0.99136	0.94729	0.94729	1.00000	
S23 {23}	1.00000	0.11299	1.00000	1.00000	1.00000	1.00000	0.00018	0.01494	1.00000	1.00000	1.00000	1.00000	1.00000	0.99222	0.00018	0.00018	0.00018	1.00000	0.00022	0.99910	1.00000	0.99136		1.00000	1.00000	0.99440	
S24 {24}	1.00000	0.04952	0.99999	1.00000	1.00000	1.00000	0.00018	0.00540	1.00000	1.00000	1.00000	1.00000	1.00000	0.95088	0.00018	0.00018	0.00018	1.00000	0.00019	0.98826	1.00000	0.94729	1.00000		1.00000	0.96055	
S25 {25}	1.00000	0.04952	0.99999	1.00000	1.00000	1.00000	0.00018	0.00540	1.00000	1.00000	1.00000	1.00000	1.00000	0.95088	0.00018	0.00018	0.00018	1.00000	0.00019	0.98826	1.00000	0.94729	1.00000	1.00000		0.96055	
S26 {26}	0.99041	0.98435	1.00000	0.97559	0.99896	0.99964	0.00018	0.72001	1.00000	1.00000	0.98283	0.96055	0.96055	1.00000	0.00311	0.00050	0.00018	0.98938	0.03231	1.00000	0.97559	1.00000	0.99440	0.96055	0.96055		

Table 55.2. Pigmentation of plate.

Tukey HSD test; variable PLATE																											
Probabilities for Post Hoc Tests																											
MAIN EFFECT: LOCALITY																											
Locality	{1}	{2}	{3}	{4}	{5}	{6}	{7}	{8}	{9}	{10}	{11}	{12}	{13}	{14}	{15}	{16}	{17}	{18}	{19}	{20}	{21}	{22}	{23}	{24}	{25}	{26}	
Mean	.6200000	.0800000	1.460000	2.900000	1.310000	5.600000	0.000000	.9400000	6.000000	1.190000	.6000000	.1300000	.0200000	2.400000	.1400000	.0200000	.1700000	.7700000	5.000000	.3900000	1.330000	6.880000	0.000000	4.700000	.2600000	.3000000	
S1 {1}		0.96755	0.33963	0.99998	0.73028	1.00000	0.87672	0.99999	1.00000	0.94289	1.00000	0.98976	0.90718	0.99977	0.99215	0.90718	0.99676	1.00000	1.00000	1.00000	0.67953	1.00000	0.87672	1.00000	0.99991	0.99999	
S2 {2}	0.96755		0.00097	1.00000	0.00644	0.99215	1.00000	0.29521	0.97883	0.02752	0.97883	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.73028	0.99885	0.99999	0.00499	0.90718	1.00000	0.99964	1.00000	1.00000	
S3 {3}	0.33963	0.00097		0.01357	1.00000	0.21747	0.00041	0.97883	0.29521	1.00000	0.29521	0.00179	0.00049	0.00731	0.00203	0.00049	0.00298	0.73028	0.12976	0.04296	1.00000	0.49086	0.00041	0.09786	0.00939	0.01532	
S4 {4}	0.99998	1.00000	0.01357		0.07273	1.00000	1.00000	0.82102	0.99999	0.21747	0.99999	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99215	1.00000	1.00000	0.05915	0.99964	1.00000	1.00000	1.00000	1.00000	
S5 {5}	0.73028	0.00644	1.00000	0.07273		0.57221	0.00231	0.99985	0.67953	1.00000	0.67953	0.01202	0.00298	0.04296	0.01357	0.00298	0.01944	0.96755	0.41240	0.18449	1.00000	0.85946	0.00231	0.33963	0.05325	0.08042	
S6 {6}	1.00000	0.99215	0.21747	1.00000	0.57221		0.95225	0.99977	1.00000	0.85946	1.00000	0.99833	0.96755	0.99999	0.99885	0.96755	0.99964	1.00000	1.00000	1.00000	0.51780	1.00000	0.95225	1.00000	1.00000	1.00000	
S7 {7}	0.87672	1.00000	0.00041	1.00000	0.00231	0.95225		0.15534	0.90718	0.01064	0.90718	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.51780	0.98679	0.99964	0.00179	0.75449	1.00000	0.99406	1.00000	1.00000	
S8 {8}	0.99999	0.29521	0.97883	0.82102	0.99985	0.99977	0.15534		0.99997	1.00000	0.99997	0.41240	0.18449	0.70526	0.43812	0.18449	0.51780	1.00000	0.99786	0.96044	0.99964	1.00000	0.15534	0.99406	0.75449	0.84087	
S9 {9}	1.00000	0.97883	0.29521	0.99999	0.67953	1.00000	0.90718	0.99997		0.92039	1.00000	0.99406	0.93228	0.99991	0.99557	0.93228	0.99833	1.00000	1.00000	1.00000	0.62648	1.00000	0.90718	1.00000	0.99997	1.00000	
S10 {10}	0.94289	0.02752	1.00000	0.21747	1.00000	0.85946	0.01064	1.00000	0.92039		0.92039	0.04786	0.01357	0.14208	0.05325	0.01357	0.07273	0.99885	0.73028	0.43812	1.00000	0.98318	0.01064	0.65323	0.16944	0.23543	
S11 {11}	1.00000	0.97883	0.29521	0.99999	0.67953	1.00000	0.90718	0.99997	1.00000	0.92039		0.99406	0.93228	0.99991	0.99557	0.93228	0.99833	1.00000	1.00000	1.00000	0.62648	1.00000	0.90718	1.00000	0.99997	1.00000	
S12 {12}	0.98976	1.00000	0.00179	1.00000	0.01202	0.99833	1.00000	0.41240	0.99406	0.04786	0.99406		1.00000	1.00000	1.00000	1.00000	1.00000	0.84087	0.99985	1.00000	0.00939	0.96044	1.00000	0.99997	1.00000	1.00000	
S13 {13}	0.90718	1.00000	0.00049	1.00000	0.00298	0.96755	1.00000	0.18449	0.93228	0.01357	0.93228	1.00000		1.00000	1.00000	1.00000	1.00000	0.57221	0.99215	0.99985	0.00231	0.79995	1.00000	0.99676	1.00000	1.00000	
S14 {14}	0.99977	1.00000	0.00731	1.00000	0.04296	0.99999	1.00000	0.70526	0.99991	0.14208	0.99991	1.00000	1.00000		1.00000	1.00000	1.00000	0.97365	1.00000	1.00000	0.03447	0.99766	1.00000	1.00000	1.00000	1.00000	
S15 {15}	0.99215	1.00000	0.00203	1.00000	0.01357	0.99885	1.00000	0.43812	0.99557	0.05325	0.99557	1.00000	1.00000	1.00000		1.00000	1.00000	0.85946	0.99991	1.00000	0.01064	0.96755	1.00000	0.99998	1.00000	1.00000	
S16 {16}	0.90718	1.00000	0.00049	1.00000	0.00298	0.96755	1.00000	0.18449	0.93228	0.01357	0.93228	1.00000	1.00000	1.00000	1.00000		1.00000	0.57221	0.99215	0.99985	0.00231	0.79995	1.00000	0.99676	1.00000	1.00000	
S17 {17}	0.99676	1.00000	0.00298	1.00000	0.01944	0.99964	1.00000	0.51780	0.99833	0.07273	0.99833	1.00000	1.00000	1.00000	1.00000	1.00000		0.90718	0.99998	1.00000	0.01532	0.98318	1.00000	1.00000	1.00000	1.00000	
S18 {18}	1.00000	0.73028	0.73028	0.99215	0.96755	1.00000	0.51780	1.00000	1.00000	0.99885	1.00000	0.84087	0.57221	0.97365	0.85946	0.57221	0.90718		1.00000	0.99977	0.95225	1.00000	0.51780	1.00000	0.98318	0.99406	
S19 {19}	1.00000	0.99885	0.12976	1.00000	0.41240	1.00000	0.98679	0.99766	1.00000	0.73028	1.00000	0.99985	0.99215	1.00000	0.99991	0.99215	0.99998	1.00000		1.00000	0.36312	1.00000	0.98679	1.00000	1.00000	1.00000	
S20 {20}	1.00000	0.99999	0.04296	1.00000	0.18449	1.00000	0.99964	0.96044	1.00000	0.43812	1.00000	1.00000	0.99985	1.00000	1.00000	0.99985	1.00000	0.99977	1.00000		0.15534	1.00000	0.99964	1.00000	1.00000	1.00000	
S21 {21}	0.67953	0.00499	1.00000	0.05915	1.00000	0.51780	0.00179	0.99964	0.62648	1.00000	0.62648	0.00939	0.00231	0.03447	0.01064	0.00231	0.01532	0.95225	0.36312	0.15534		0.82102	0.00179	0.29521	0.04296	0.06563	
S22 {22}	1.00000	0.90718	0.49086	0.99964	0.85946	1.00000	0.75449	1.00000	1.00000	0.98318	1.00000	0.96044	0.79995	0.99766	0.96755	0.79995	0.98318	1.00000	1.00000	1.00000	0.82102		0.75449	1.00000	0.99885	0.99977	
S23 {23}	0.87672	1.00000	0.00041	1.00000	0.00231	0.95225	1.00000	0.15534	0.90718	0.01064	0.90718	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.51780	0.98679	0.99964	0.00179	0.75449		0.99406	1.00000	1.00000	
S24 {24}	1.00000	0.99964	0.09786	1.00000	0.33963	1.00000	0.99406	0.99406	1.00000	0.65323	1.00000	0.99997	0.99676	1.00000	0.99998	0.99676	1.00000	1.00000	1.00000	1.00000	1.00000	0.29521	1.00000	0.99406		1.00000	1.00000
S25 {25}	0.99991	1.00000	0.00939	1.00000	0.05325	1.00000	1.00000	0.75449	0.99997	0.16944	0.99997	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.98318	1.00000	1.00000	0.04296	0.99885	1.00000	1.00000		1.00000	
S26 {26}	0.99999	1.00000	0.01532	1.00000	0.08042	1.00000	1.00000	0.84087	1.00000	0.23543	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99406	1.00000	1.00000	0.06563	0.99977	1.00000	1.00000	1.00000		

Table 55.3. Hair length.

Tukey HSD test; variable HAIR
 Probabilities for Post Hoc Tests
 MAIN EFFECT: LOCALITY

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	
	.1872000	.1404000	.1680000	.1788000	.1490000	.1516000	.1240000	.1496000	.1740000	.1685000	.1772000	.1998000	.2086000	.1780000	.1540000	.1600000	.1792000	.1918000	.1858000	.1982000	.1934000	.1764000	.1818000	.1976000	.1882000	.1762000	
S1 (1)		0.00019	0.78057	1.00000	0.00178	0.00568	0.00018	0.00232	0.99560	0.81827	0.99995	0.99774	0.58479	0.99999	0.01599	0.14542	1.00000	1.00000	1.00000	0.99973	1.00000	0.99980	1.00000	0.99990	1.00000	0.99973	
S2 (2)	0.00019		0.12819	0.00163	1.00000	0.99964	0.94165	0.99999	0.01352	0.10898	0.00332	0.00018	0.00018	0.00232	0.99340	0.74808	0.00137	0.00018	0.00021	0.00018	0.00018	0.00018	0.00474	0.00048	0.00018	0.00018	0.00519
S3 (3)	0.78057	0.12819		0.99980	0.79606	0.94165	0.00025	0.83916	1.00000	1.00000	0.99999	0.02827	0.00064	0.99995	0.99037	1.00000	0.99964	0.36557	0.87673	0.05219	0.24533	1.00000	0.99201	0.06496	0.69611	1.00000	
S4 (4)	1.00000	0.00163	0.99980		0.06042	0.14542	0.00018	0.07492	1.00000	0.99991	1.00000	0.62257	0.06042	1.00000	0.28717	0.81101	1.00000	0.99646	1.00000	0.76456	0.98376	1.00000	1.00000	0.81101	0.99998	1.00000	
S5 (5)	0.00178	1.00000	0.79606	0.06042		1.00000	0.27280	1.00000	0.27280	0.75638	0.10543	0.00018	0.00018	0.08034	1.00000	0.99973	0.05219	0.00032	0.00332	0.00018	0.00024	0.13659	0.01887	0.00018	0.00116	0.14542	
S6 (6)	0.00568	0.99964	0.94165	0.14542	1.00000		0.12819	1.00000	0.49029	0.92208	0.23236	0.00018	0.00018	0.18521	1.00000	1.00000	0.12819	0.00076	0.01048	0.00019	0.00042	0.28717	0.05219	0.00020	0.00363	0.30199	
S7 (7)	0.00018	0.94165	0.00025	0.00018	0.27280	0.12819		0.23236	0.00018	0.00024	0.00018	0.00018	0.00018	0.00018	0.05617	0.00474	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018
S8 (8)	0.00232	0.99999	0.83916	0.07492	1.00000	1.00000	0.23236		0.31725	0.80380	0.12819	0.00018	0.00018	0.09862	1.00000	0.99990	0.06496	0.00038	0.00434	0.00018	0.00026	0.16445	0.02411	0.00018	0.00149	0.17459	
S9 (9)	0.99560	0.01352	1.00000	1.00000	0.27280	0.49029	0.00018	0.31725		1.00000	1.00000	0.21986	0.00881	1.00000	0.71381	0.99037	1.00000	0.87673	0.99917	0.33295	0.76456	1.00000	1.00000	0.38247	0.98846	1.00000	
S10 (10)	0.81827	0.10898	1.00000	0.99991	0.75638	0.92208	0.00024	0.80380	1.00000		1.00000	0.03439	0.00079	0.99998	0.98506	1.00000	0.99983	0.40845	0.90356	0.06265	0.27992	1.00000	0.99512	0.07759	0.73967	1.00000	
S11 (11)	0.99995	0.00332	0.99999	1.00000	0.10543	0.23236	0.00018	0.12819	1.00000	1.00000		0.47173	0.03308	1.00000	0.41728	0.90843	1.00000	0.98376	1.00000	0.62257	0.94841	1.00000	1.00000	0.67810	0.99973	1.00000	
S12 (12)	0.99774	0.00018	0.02827	0.62257	0.00018	0.00018	0.00018	0.00018	0.21986	0.03439	0.47173		1.00000	0.54682	0.00020	0.00090	0.65981	1.00000	0.99037	1.00000	1.00000	0.39971	0.86485	1.00000	0.99937	0.38247	
S13 (13)	0.58479	0.00018	0.00064	0.06042	0.00018	0.00018	0.00018	0.00018	0.00881	0.00079	0.03308	1.00000		0.04495	0.00018	0.00018	0.06981	0.92631	0.45337	0.99990	0.97397	0.02411	0.16445	0.99973	0.67810	0.02223	
S14 (14)	0.99999	0.00232	0.99995	1.00000	0.08034	0.18521	0.00018	0.09862	1.00000	0.99998	1.00000	0.54682	0.04495		0.34906	0.86485	1.00000	0.99201	1.00000	0.69611	0.96986	1.00000	1.00000	0.74808	0.99993	1.00000	
S15 (15)	0.01599	0.99340	0.99037	0.28717	1.00000	1.00000	0.05617	1.00000	0.71381	0.98506	0.41728	0.00020	0.00018	0.34906		1.00000	0.25878	0.00212	0.02827	0.00025	0.00106	0.49029	0.12020	0.00027	0.01048	0.50902	
S16 (16)	0.14542	0.74808	1.00000	0.81101	0.99973	1.00000	0.00474	0.99990	0.99037	1.00000	0.90843	0.00090	0.00018	0.86485	1.00000		0.78057	0.02827	0.21986	0.00178	0.01470	0.94165	0.54682	0.00232	0.10543	0.94841	
S17 (17)	1.00000	0.00137	0.99964	1.00000	0.05219	0.12819	0.00018	0.06496	1.00000	0.99983	1.00000	0.65981	0.06981	1.00000	0.25878	0.78057		0.99774	1.00000	0.79606	0.98846	1.00000	1.00000	0.83916	0.99999	1.00000	
S18 (18)	1.00000	0.00018	0.36557	0.99646	0.00032	0.00076	0.00018	0.00038	0.87673	0.40845	0.98376	1.00000	0.92631	0.99201	0.00212	0.02827	0.99774		1.00000	1.00000	1.00000	0.96986	0.99995	1.00000	1.00000	0.96528	
S19 (19)	1.00000	0.00021	0.87673	1.00000	0.00332	0.01048	0.00018	0.00434	0.99917	0.90356	1.00000	0.99037	0.45337	1.00000	0.02827	0.21986	1.00000	1.00000		0.99822	1.00000	0.99998	1.00000	0.99917	1.00000	0.99997	
S20 (20)	0.99973	0.00018	0.05219	0.76456	0.00018	0.00019	0.00018	0.00018	0.00018	0.33295	0.06265	0.62257	1.00000	0.99990	0.69611	0.00025	0.00178	0.79606	1.00000	0.99822		1.00000	0.54682	0.94165	1.00000	0.99995	0.52788
S21 (21)	1.00000	0.00018	0.24533	0.98376	0.00024	0.00042	0.00018	0.00026	0.76456	0.27992	0.94841	1.00000	0.97397	0.96986	0.00106	0.01470	0.98846	1.00000	1.00000	1.00000		0.91769	0.99937	1.00000	1.00000	0.90843	
S22 (22)	0.99980	0.00474	1.00000	1.00000	0.13659	0.28717	0.00018	0.16445	1.00000	1.00000	1.00000	0.39971	0.02411	1.00000	0.49029	0.94165	1.00000	0.96986	0.99998	0.54682	0.91769		1.00000	0.60373	0.99917	1.00000	
S23 (23)	1.00000	0.00048	0.99201	1.00000	0.01887	0.05219	0.00018	0.02411	1.00000	0.99512	1.00000	0.86485	0.16445	1.00000	0.12020	0.54682	1.00000	0.99995	1.00000	0.94165	0.99937	1.00000		0.96019	1.00000	1.00000	
S24 (24)	0.99990	0.00018	0.06496	0.81101	0.00018	0.00020	0.00018	0.00018	0.38247	0.07759	0.67810	1.00000	0.99973	0.74808	0.00027	0.00232	0.83918	1.00000	0.99917	1.00000	1.00000	0.60373	0.96019		0.99998	0.58479	
S25 (25)	1.00000	0.00018	0.69611	0.99998	0.00116	0.00363	0.00018	0.00149	0.98846	0.73967	0.99973	0.99937	0.67810	0.99993	0.01048	0.10543	0.99999	1.00000	1.00000	0.99995	1.00000	0.99917	1.00000	0.99998		0.99893	
S26 (26)	0.99973	0.00519	1.00000	1.00000	0.14542	0.30199	0.00018	0.17459	1.00000	1.00000	1.00000	0.38247	0.02223	1.00000	0.50902	0.94841	1.00000	0.96528	0.99997	0.52788	0.90843	1.00000	1.00000	0.58479	0.99893		

Table 55.4. Pigmentation of tergite 2.

Tukey HSD test; variable TERG2PIG																										
Probabilities for Post Hoc Tests																										
MAIN EFFECT: LOCALITY																										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)
	1.370000	4.820000	1.520000	1.600000	6.100000	.8300000	8.059999	4.780000	1.420000	.9700000	2.800000	.0200000	0.000000	1.970000	5.870000	7.130000	8.840000	4.800000	5.400000	2.570000	2.100000	2.120000	2.500000	0.000000	0.000000	2.090000
S1 (1)		0.04111	1.00000	0.99980	1.00000	1.00000	0.00018	0.04705	1.00000	1.00000	0.99997	0.99883	0.99854	1.00000	0.00075	0.00018	0.00018	1.00000	0.00470	0.99982	0.99990	1.00000	0.99995	0.99854	0.99854	1.00000
S2 (2)	0.04111		0.06749	0.00045	0.00229	0.00552	0.08149	1.00000	0.04865	0.00956	0.00065	0.00031	0.00030	0.24053	0.99998	0.65550	0.00490	0.00138	1.00000	0.70408	0.00052	0.33834	0.00059	0.00030	0.00030	0.31720
S3 (3)	1.00000	0.06749		0.99869	1.00000	1.00000	0.00018	0.07657	1.00000	1.00000	0.99970	0.99455	0.99350	1.00000	0.00132	0.00018	0.00018	0.99999	0.00851	0.99998	0.99927	1.00000	0.99955	0.99350	0.99350	1.00000
S4 (4)	0.99980	0.00045	0.99869		1.00000	1.00000	0.00018	0.00050	0.99961	1.00000	1.00000	1.00000	1.00000	0.94913	0.00018	0.00018	0.00018	1.00000	0.00019	0.57146	1.00000	0.89235	1.00000	1.00000	1.00000	0.90600
S5 (5)	1.00000	0.00229	1.00000	1.00000		1.00000	0.00018	0.00269	1.00000	1.00000	1.00000	1.00000	1.00000	0.99869	0.00019	0.00018	0.00018	1.00000	0.00032	0.89235	1.00000	0.99404	1.00000	1.00000	1.00000	0.99547
S6 (6)	1.00000	0.00552	1.00000	1.00000	1.00000		0.00018	0.00647	1.00000	1.00000	1.00000	1.00000	1.00000	0.99993	0.00021	0.00018	0.00018	1.00000	0.00059	0.96642	1.00000	0.99943	1.00000	1.00000	1.00000	0.99961
S7 (7)	0.00018	0.08149	0.00018	0.00018	0.00018	0.00018		0.07191	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.75023	1.00000	1.00000	0.00018	0.36766	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018
S8 (8)	0.04705	1.00000	0.07657	0.00050	0.00269	0.00647	0.07191		0.05553	0.01116	0.00075	0.00034	0.00033	0.26459	0.99997	0.62218	0.00417	0.00161	1.00000	0.73517	0.00059	0.36766	0.00066	0.00033	0.00033	0.34555
S9 (9)	1.00000	0.04865	1.00000	0.99961	1.00000	1.00000	0.00018	0.05553		1.00000	0.99993	0.99796	0.99749	1.00000	0.00091	0.00018	0.00018	1.00000	0.00575	0.99992	0.99980	1.00000	0.99989	0.99749	0.99749	1.00000
S10 (10)	1.00000	0.00956	1.00000	1.00000	1.00000	1.00000	0.00018	0.01116	1.00000		1.00000	1.00000	1.00000	0.99999	0.00026	0.00018	0.00018	1.00000	0.00098	0.98739	1.00000	0.99992	1.00000	1.00000	1.00000	0.99995
S11 (11)	0.99997	0.00065	0.99970	1.00000	1.00000	1.00000	0.00018	0.00075	0.99993	1.00000		1.00000	1.00000	0.97577	0.00018	0.00018	0.00018	1.00000	0.00020	0.67191	1.00000	0.94002	1.00000	1.00000	1.00000	0.94913
S12 (12)	0.99883	0.00031	0.99455	1.00000	1.00000	1.00000	0.00018	0.00034	0.99796	1.00000	1.00000		1.00000	0.89703	0.00018	0.00018	0.00018	1.00000	0.00018	0.45412	1.00000	0.81322	1.00000	1.00000	1.00000	0.83223
S13 (13)	0.99854	0.00030	0.99350	1.00000	1.00000	1.00000	0.00018	0.00033	0.99749	1.00000	1.00000	1.00000		0.88753	0.00018	0.00018	0.00018	1.00000	0.00018	0.43790	1.00000	0.79996	1.00000	1.00000	1.00000	0.81967
S14 (14)	1.00000	0.24053	1.00000	0.94913	0.99869	0.99993	0.00018	0.26459	1.00000	0.99999	0.97577	0.89703	0.88753		0.00787	0.00020	0.00018	0.99503	0.04399	1.00000	0.96201	1.00000	0.97043	0.88753	0.88753	1.00000
S15 (15)	0.00075	0.99998	0.00132	0.00018	0.00019	0.00021	0.75023	0.99997	0.00091	0.00026	0.00018	0.00018	0.00018	0.00787		0.99961	0.17743	0.00018	1.00000	0.06749	0.00018	0.01400	0.00018	0.00018	0.00018	0.01250
S16 (16)	0.00018	0.65550	0.00018	0.00018	0.00018	0.00018	1.00000	0.62218	0.00018	0.00018	0.00018	0.00018	0.00018	0.00020	0.99961		0.97230	0.00018	0.96847	0.00061	0.00018	0.00023	0.00018	0.00018	0.00018	0.00021
S17 (17)	0.00018	0.00490	0.00018	0.00018	0.00018	0.00018	1.00000	0.00417	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.17743	0.97230		0.00018	0.04253	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018
S18 (18)	1.00000	0.00138	0.99999	1.00000	1.00000	1.00000	0.00018	0.00161	1.00000	1.00000	1.00000	1.00000	1.00000	0.99503	0.00018	0.00018	0.00018		0.00025	0.81967	1.00000	0.98295	1.00000	1.00000	1.00000	0.98638
S19 (19)	0.00470	1.00000	0.00851	0.00019	0.00032	0.00059	0.36766	1.00000	0.00575	0.00098	0.00020	0.00018	0.00018	0.04399	1.00000	0.96847	0.04253	0.00025		0.25237	0.00019	0.07191	0.00020	0.00018	0.00018	0.06531
S20 (20)	0.99982	0.70408	0.99998	0.57146	0.89235	0.96642	0.00018	0.73517	0.99992	0.98739	0.67191	0.45412	0.43790	1.00000	0.06749	0.00061	0.00018	0.81967	0.25237		0.61377	1.00000	0.64722	0.43790	0.43790	1.00000
S21 (21)	0.99990	0.00052	0.99927	1.00000	1.00000	1.00000	0.00018	0.00059	0.99980	1.00000	1.00000	1.00000	1.00000	0.96201	0.00018	0.00018	0.00018	1.00000	0.00019	0.61377		0.91445	1.00000	1.00000	1.00000	0.92617
S22 (22)	1.00000	0.33834	1.00000	0.89235	0.99404	0.99943	0.00018	0.36766	1.00000	0.99992	0.94002	0.81322	0.79996	1.00000	0.01400	0.00023	0.00018	0.98295	0.07191	1.00000	0.91445		0.92981	0.79996	0.79996	1.00000
S23 (23)	0.99995	0.00059	0.99955	1.00000	1.00000	1.00000	0.00018	0.00068	0.99989	1.00000	1.00000	1.00000	1.00000	0.97043	0.00018	0.00018	0.00018	1.00000	0.00020	0.64722	1.00000	0.92981		1.00000	1.00000	0.94002
S24 (24)	0.99854	0.00030	0.99350	1.00000	1.00000	1.00000	0.00018	0.00033	0.99749	1.00000	1.00000	1.00000	1.00000	0.88753	0.00018	0.00018	0.00018	1.00000	0.00018	0.43790	1.00000	0.79996	1.00000		1.00000	0.81967
S25 (25)	0.99854	0.00030	0.99350	1.00000	1.00000	1.00000	0.00018	0.00033	0.99749	1.00000	1.00000	1.00000	1.00000	0.88753	0.00018	0.00018	0.00018	1.00000	0.00018	0.43790	1.00000	0.79996	1.00000	1.00000		0.81967
S26 (26)	1.00000	0.31720	1.00000	0.90600	0.99547	0.99961	0.00018	0.34555	1.00000	0.99995	0.94913	0.83223	0.81967	1.00000	0.01250	0.00021	0.00018	0.98638	0.06531	1.00000	0.92617	1.00000	0.94002	0.81967	0.81967	

Table 55.5. Pigmentation of tergite 3.

Tukey HSD test; variable TERG3PIG

Probabilities for Post Hoc Tests

MAIN EFFECT: LOCALITY

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)
	2.550000	4.780000	2.300000	6.800000	1.410000	1.240000	8.070000	4.840000	1.680000	1.150000	5.900000	3.300000	0.000000	2.000000	5.820000	6.980000	8.690000	1.100000	5.570000	2.770000	8.800000	2.200000	2.400000	2.000000	2.400000	2.110000
S1 (1)		0.69476	1.00000	0.91983	0.99991	0.99909	0.00018	0.64509	1.00000	0.99750	0.87860	0.70283	0.42487	1.00000	0.06395	0.00074	0.00018	0.99585	0.13760	1.00000	0.97515	1.00000	0.62817	0.59399	0.62817	1.00000
S2 (2)	0.69476		0.48272	0.00282	0.04582	0.02519	0.05990	1.00000	0.10892	0.01806	0.00196	0.00072	0.00029	0.25872	0.99998	0.71084	0.00608	0.01497	1.00000	0.85097	0.00633	0.40076	0.00053	0.00046	0.00053	0.33265
S3 (3)	1.00000	0.48272		0.98257	1.00000	0.99997	0.00018	0.43298	1.00000	0.99989	0.96760	0.87334	0.63665	1.00000	0.02707	0.00035	0.00018	0.99978	0.06395	1.00000	0.99692	1.00000	0.82012	0.79326	0.82012	1.00000
S4 (4)	0.91983	0.00282	0.98257		1.00000	1.00000	0.00018	0.00221	0.99999	1.00000	1.00000	1.00000	1.00000	0.99898	0.00019	0.00018	0.00018	1.00000	0.00024	0.80015	1.00000	0.99217	1.00000	1.00000	1.00000	0.99660
S5 (5)	0.99991	0.04582	1.00000	1.00000		1.00000	0.00018	0.03725	1.00000	1.00000	1.00000	0.99996	0.99723	1.00000	0.00084	0.00018	0.00018	1.00000	0.00221	0.99837	1.00000	1.00000	0.99985	0.99974	0.99985	1.00000
S6 (6)	0.99909	0.02519	0.99997	1.00000	1.00000		0.00018	0.02021	1.00000	1.00000	1.00000	1.00000	0.99962	1.00000	0.00046	0.00018	0.00018	1.00000	0.00113	0.99147	1.00000	1.00000	0.99999	0.99998	0.99999	1.00000
S7 (7)	0.00018	0.05990	0.00018	0.00018	0.00018	0.00018		0.07283	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.67842	0.99996	1.00000	0.00018	0.46595	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018
S8 (8)	0.64509	1.00000	0.43298	0.00221	0.03725	0.02021	0.07283		0.09076	0.01440	0.00154	0.00058	0.00026	0.22326	0.99999	0.75721	0.00772	0.01189	1.00000	0.81358	0.00497	0.35465	0.00044	0.00039	0.00044	0.29100
S9 (9)	1.00000	0.10892	1.00000	0.99999	1.00000	1.00000	0.00018	0.09076		1.00000	0.99996	0.99855	0.97340	1.00000	0.00239	0.00018	0.00018	1.00000	0.00659	0.99996	1.00000	1.00000	0.99625	0.99450	0.99625	1.00000
S10 (10)	0.99750	0.01806	0.99989	1.00000	1.00000	1.00000	0.00018	0.01440	1.00000		1.00000	1.00000	0.99989	1.00000	0.00036	0.00018	0.00018	1.00000	0.00080	0.98257	1.00000	0.99998	1.00000	1.00000	1.00000	1.00000
S11 (11)	0.87860	0.00196	0.96760	1.00000	1.00000	1.00000	0.00018	0.00154	0.99996	1.00000		1.00000	1.00000	0.99723	0.00018	0.00018	0.00018	1.00000	0.00021	0.73440	1.00000	0.98383	1.00000	1.00000	1.00000	0.99217
S12 (12)	0.70283	0.00072	0.87334	1.00000	0.99996	1.00000	0.00018	0.00058	0.99855	1.00000	1.00000		1.00000	0.97515	0.00018	0.00018	0.00018	1.00000	0.00018	0.51666	1.00000	0.91983	1.00000	1.00000	1.00000	0.95045
S13 (13)	0.42487	0.00029	0.63665	1.00000	0.99723	0.99962	0.00018	0.00026	0.97340	0.99989	1.00000	1.00000		0.85676	0.00018	0.00018	0.00018	0.99995	0.00018	0.26497	1.00000	0.71877	1.00000	1.00000	1.00000	0.78626
S14 (14)	1.00000	0.25872	1.00000	0.99898	1.00000	1.00000	0.00018	0.22326	1.00000	1.00000	0.99723	0.97515	0.85676		0.00870	0.00021	0.00018	1.00000	0.02257	1.00000	0.99993	1.00000	0.95590	0.94452	0.95590	1.00000
S15 (15)	0.06395	0.99998	0.02707	0.00019	0.00084	0.00046	0.67842	0.99999	0.00239	0.00036	0.00018	0.00018	0.00018	0.00870		0.99985	0.20685	0.00032	1.00000	0.12621	0.00023	0.01875	0.00018	0.00018	0.00018	0.01334
S16 (16)	0.00074	0.71084	0.00035	0.00018	0.00018	0.00018	0.99996	0.75721	0.00018	0.00018	0.00018	0.00018	0.00018	0.00021	0.99985		0.96963	0.00018	0.99692	0.00174	0.00018	0.00028	0.00018	0.00018	0.00018	0.00024
S17 (17)	0.00018	0.00608	0.00018	0.00018	0.00018	0.00018	1.00000	0.00772	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.20685	0.96963		0.00018	0.10256	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018
S18 (18)	0.99585	0.01497	0.99978	1.00000	1.00000	1.00000	0.00018	0.01189	1.00000	1.00000	1.00000	1.00000	0.99995	1.00000	0.00032	0.00018	0.00018		0.00066	0.97515	1.00000	0.99995	1.00000	1.00000	1.00000	0.99999
S19 (19)	0.13760	1.00000	0.06395	0.00024	0.00221	0.00113	0.46595	1.00000	0.00659	0.00080	0.00021	0.00018	0.00018	0.02257	1.00000	0.99692	0.10256	0.00066		0.24651	0.00035	0.04582	0.00018	0.00018	0.00018	0.03353
S20 (20)	1.00000	0.85097	1.00000	0.80015	0.99837	0.99147	0.00018	0.81358	0.99996	0.98257	0.73440	0.51666	0.26497	1.00000	0.12621	0.00174	0.00018	0.97515	0.24651		0.91161	1.00000	0.44114	0.40889	0.44114	1.00000
S21 (21)	0.97515	0.00633	0.99692	1.00000	1.00000	1.00000	0.00018	0.00497	1.00000	1.00000	1.00000	1.00000	1.00000	0.99993	0.00023	0.00018	0.00018	1.00000	0.00035	0.91161		0.99898	1.00000	1.00000	1.00000	0.99967
S22 (22)	1.00000	0.40076	1.00000	0.99217	1.00000	1.00000	0.00018	0.35465	1.00000	0.99998	0.98383	0.91983	0.71877	1.00000	0.01875	0.00028	0.00018	0.99995	0.04582	1.00000	0.99898		0.87860	0.85676	0.87860	1.00000
S23 (23)	0.62817	0.00053	0.82012	1.00000	0.99985	0.99999	0.00018	0.00044	0.99625	1.00000	1.00000	1.00000	1.00000	0.95590	0.00018	0.00018	0.00018	1.00000	0.00018	0.44114	1.00000	0.87860		1.00000	1.00000	0.91983
S24 (24)	0.59399	0.00046	0.79326	1.00000	0.99974	0.99998	0.00018	0.00039	0.99450	1.00000	1.00000	1.00000	1.00000	0.94452	0.00018	0.00018	0.00018	1.00000	0.00018	0.40889	1.00000	0.85676	1.00000		1.00000	0.90285
S25 (25)	0.62817	0.00053	0.82012	1.00000	0.99985	0.99999	0.00018	0.00044	0.99625	1.00000	1.00000	1.00000	1.00000	0.95590	0.00018	0.00018	0.00018	1.00000	0.00018	0.44114	1.00000	0.87860	1.00000	1.00000		0.91983
S26 (26)	1.00000	0.33265	1.00000	0.99660	1.00000	1.00000	0.00018	0.29100	1.00000	1.00000	0.99217	0.95045	0.78626	1.00000	0.01334	0.00024	0.00018	0.99999	0.03353	1.00000	0.99967	1.00000	0.91983	0.90285	0.91983	

Table 55.6. Pigmentation of tergite 4.

Tukey HSD test; variable TERG4 PIG																										
Probabilities for Post Hoc Tests																										
MAIN EFFECT: LOCALITY																										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)
	2.250000	3.690000	1.390000	5.600000	1.080000	1.010000	6.200000	4.080000	1.390000	9.500000	5.600000	3.300000	0.000000	1.750000	5.080000	6.150000	7.850000	9.500000	4.890000	2.130000	8.400000	1.850000	1.400000	2.000000	1.800000	1.090000
S1 (1)		0.96185	0.99998	0.83448	0.99721	0.99371	0.00030	0.71391	0.99998	0.98839	0.83448	0.62423	0.30284	1.00000	0.03970	0.00034	0.00018	0.98839	0.08460	1.00000	0.96966	1.00000	0.42997	0.49000	0.46973	0.99754
S2 (2)	0.96185		0.26324	0.01045	0.09462	0.07264	0.13530	1.00000	0.26324	0.05734	0.01045	0.00344	0.00072	0.60364	0.97416	0.16033	0.00021	0.05734	0.99599	0.91552	0.03651	0.70428	0.00137	0.00183	0.00166	0.09817
S3 (3)	0.99998	0.26324		0.99999	1.00000	1.00000	0.00018	0.06988	1.00000	1.00000	0.99999	0.99938	0.97416	1.00000	0.00072	0.00018	0.00018	1.00000	0.00174	1.00000	1.00000	1.00000	0.99301	0.99644	0.99549	1.00000
S4 (4)	0.83448	0.01045	0.99999		1.00000	1.00000	0.00018	0.00158	0.99999	1.00000	1.00000	1.00000	1.00000	0.99644	0.00018	0.00018	0.00018	1.00000	0.00019	0.91046	1.00000	0.98948	1.00000	1.00000	1.00000	1.00000
S5 (5)	0.99721	0.09462	1.00000	1.00000		1.00000	0.00018	0.01898	1.00000	1.00000	1.00000	1.00000	0.99917	1.00000	0.00027	0.00018	0.00018	1.00000	0.00045	0.99947	1.00000	1.00000	0.99992	0.99997	0.99996	1.00000
S6 (6)	0.99371	0.07264	1.00000	1.00000	1.00000		0.00018	0.01381	1.00000	1.00000	1.00000	1.00000	0.99972	1.00000	0.00024	0.00018	0.00018	1.00000	0.00036	0.99855	1.00000	0.99999	0.99998	0.99999	0.99999	1.00000
S7 (7)	0.00030	0.13530	0.00018	0.00018	0.00018	0.00018		0.42011	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.99855	1.00000	0.86290	0.00018	0.98722	0.00024	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018
S8 (8)	0.71391	1.00000	0.06988	0.00158	0.01898	0.01381	0.42011		0.06988	0.01045	0.00158	0.00056	0.00023	0.24119	0.99976	0.46973	0.00052	0.01045	0.99999	0.59330	0.00618	0.31956	0.00030	0.00036	0.00034	0.01988
S9 (9)	0.99998	0.26324	1.00000	0.99999	1.00000	1.00000	0.00018	0.06988		1.00000	0.99999	0.99938	0.97416	1.00000	0.00072	0.00018	0.00018	1.00000	0.00174	1.00000	1.00000	1.00000	0.99301	0.99644	0.99549	1.00000
S10 (10)	0.98839	0.05734	1.00000	1.00000	1.00000	1.00000	0.00018	0.01045	1.00000		1.00000	1.00000	0.99990	1.00000	0.00021	0.00018	0.00018	1.00000	0.00030	0.99684	1.00000	0.99996	0.99999	1.00000	1.00000	1.00000
S11 (11)	0.83448	0.01045	0.99999	1.00000	1.00000	1.00000	0.00018	0.00158	0.99999	1.00000		1.00000	1.00000	0.99644	0.00018	0.00018	0.00018	1.00000	0.00019	0.91046	1.00000	0.98948	1.00000	1.00000	1.00000	1.00000
S12 (12)	0.62423	0.00344	0.99938	1.00000	1.00000	1.00000	0.00018	0.00056	0.99938	1.00000	1.00000		1.00000	0.96721	0.00018	0.00018	0.00018	1.00000	0.00018	0.74211	1.00000	0.93386	1.00000	1.00000	1.00000	1.00000
S13 (13)	0.30284	0.00072	0.97416	1.00000	0.99917	0.99972	0.00018	0.00023	0.97416	0.99990	1.00000	1.00000		0.78647	0.00018	0.00018	0.00018	0.99990	0.00018	0.41044	0.99999	0.69455	1.00000	1.00000	1.00000	0.99904
S14 (14)	1.00000	0.60364	1.00000	0.99644	1.00000	1.00000	0.00018	0.24119	1.00000	1.00000	0.99644	0.96721	0.78647		0.00398	0.00018	0.00018	1.00000	0.00996	1.00000	0.99995	1.00000	0.88825	0.92039	0.91046	1.00000
S15 (15)	0.03970	0.97416	0.00072	0.00018	0.00027	0.00024	0.99855	0.99976	0.00072	0.00021	0.00018	0.00018	0.00018	0.00398		0.99928	0.05082	0.00021	1.00000	0.02373	0.00019	0.00648	0.00018	0.00018	0.00018	0.00027
S16 (16)	0.00034	0.16033	0.00018	0.00018	0.00018	0.00018	1.00000	0.46973	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.99928		0.82691	0.00018	0.99224	0.00026	0.00018	0.00019	0.00018	0.00018	0.00018	0.00018
S17 (17)	0.00018	0.00021	0.00018	0.00018	0.00018	0.00018	0.86290	0.00052	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.05082	0.82691		0.00018	0.02271	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018
S18 (18)	0.98839	0.05734	1.00000	1.00000	1.00000	1.00000	0.00018	0.01045	1.00000	1.00000	1.00000	1.00000	0.99990	1.00000	0.00021	0.00018	0.00018		0.00030	0.99684	1.00000	0.99996	0.99999	1.00000	1.00000	1.00000
S19 (19)	0.08460	0.99599	0.00174	0.00019	0.00045	0.00036	0.98722	0.99999	0.00174	0.00030	0.00019	0.00018	0.00018	0.00996	1.00000	0.99224	0.02271	0.00030		0.05292	0.00024	0.01585	0.00018	0.00018	0.00018	0.00046
S20 (20)	1.00000	0.91552	1.00000	0.91046	0.99947	0.99855	0.00024	0.59330	1.00000	0.99684	0.91046	0.74211	0.41044	1.00000	0.02373	0.00026	0.00018	0.99684	0.05292		0.98948	1.00000	0.55181	0.61395	0.59330	0.99954
S21 (21)	0.96966	0.03651	1.00000	1.00000	1.00000	1.00000	0.00018	0.00618	1.00000	1.00000	1.00000	1.00000	0.99999	0.99995	0.00019	0.00018	0.00018	1.00000	0.00024	0.98948		0.99972	1.00000	1.00000	1.00000	1.00000
S22 (22)	1.00000	0.70428	1.00000	0.98948	1.00000	0.99999	0.00018	0.31956	1.00000	0.99996	0.98948	0.93386	0.69455	1.00000	0.00648	0.00019	0.00018	0.99996	0.01585	1.00000	0.99972		0.81916	0.86290	0.84906	1.00000
S23 (23)	0.42997	0.00137	0.99301	1.00000	0.99992	0.99998	0.00018	0.00030	0.99301	0.99999	1.00000	1.00000	1.00000	0.88825	0.00018	0.00018	0.00018	0.99999	0.00018	0.55181	1.00000	0.81916		1.00000	1.00000	0.99990
S24 (24)	0.49000	0.00183	0.99644	1.00000	0.99997	0.99999	0.00018	0.00036	0.99644	1.00000	1.00000	1.00000	1.00000	0.92039	0.00018	0.00018	0.00018	1.00000	0.00018	0.61395	1.00000	0.86290	1.00000		1.00000	0.99997
S25 (25)	0.46973	0.00166	0.99549	1.00000	0.99996	0.99999	0.00018	0.00034	0.99549	1.00000	1.00000	1.00000	1.00000	0.91046	0.00018	0.00018	0.00018	1.00000	0.00018	0.59330	1.00000	0.84906	1.00000	1.00000		0.99995
S26 (26)	0.99754	0.09817	1.00000	1.00000	1.00000	1.00000	0.00018	0.01988	1.00000	1.00000	1.00000	1.00000	0.99904	1.00000	0.00027	0.00018	0.00018	1.00000	0.00046	0.99954	1.00000	1.00000	0.99990	0.99997	0.99995	

Table 55.7. Width of tergite 3.

Tukey HSD test; variable TER3 LOG																											
Probabilities for Post Hoc Tests																											
MAIN EFFECT: LOCALITY																											
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	
	1.982800	1.922000	1.984800	1.996000	1.928400	1.974800	1.912800	1.965600	1.976000	2.028400	2.023200	2.105600	2.152400	2.061600	2.002800	2.071400	2.009600	2.062800	2.019600	2.127200	2.100800	2.006000	2.116800	2.066800	2.102400	2.079600	
S1 (1)		0.39077	1.00000	1.00000	0.61983	1.00000	0.15194	1.00000	1.00000	0.88646	0.96486	0.00018	0.00018	0.04735	1.00000	0.01025	0.99990	0.03973	0.98819	0.00018	0.00020	0.99999	0.00018	0.02160	0.00019	0.00251	
S2 (2)	0.39077		0.32691	0.07033	1.00000	0.67713	1.00000	0.92403	0.63433	0.00053	0.00120	0.00018	0.00018	0.00018	0.03528	0.00018	0.01210	0.00018	0.00219	0.00018	0.00018	0.02160	0.00018	0.00018	0.00018	0.00018	
S3 (3)	1.00000	0.32691		1.00000	0.54660	1.00000	0.11893	1.00000	1.00000	0.92403	0.98021	0.00019	0.00018	0.06292	1.00000	0.01424	0.99998	0.05312	0.99430	0.00018	0.00023	1.00000	0.00018	0.02943	0.00021	0.00355	
S4 (4)	1.00000	0.07033	1.00000		0.15930	0.99999	0.01785	0.99793	1.00000	0.99922	0.99997	0.00045	0.00018	0.30308	1.00000	0.09949	1.00000	0.26922	1.00000	0.00018	0.00093	1.00000	0.00020	0.17482	0.00071	0.03128	
S5 (5)	0.61983	1.00000	0.54660	0.15930		0.86868	1.00000	0.98650	0.83912	0.00146	0.00355	0.00018	0.00018	0.00018	0.08727	0.00018	0.03322	0.00018	0.00661	0.00018	0.00018	0.05623	0.00018	0.00018	0.00018	0.00018	
S6 (6)	1.00000	0.67713	1.00000	0.99999	0.86868		0.35175	1.00000	1.00000	0.64872	0.81756	0.00018	0.00018	0.01378	0.99980	0.00260	0.99430	0.01133	0.90266	0.00018	0.00018	0.99884	0.00018	0.00577	0.00018	0.00067	
S7 (7)	0.15194	1.00000	0.11893	0.01785	1.00000	0.35175		0.67713	0.31486	0.00023	0.00033	0.00018	0.00018	0.00018	0.00811	0.00018	0.00251	0.00018	0.00050	0.00018	0.00018	0.00469	0.00018	0.00018	0.00018	0.00018	
S8 (8)	1.00000	0.92403	1.00000	0.99793	0.98650	1.00000	0.67713		1.00000	0.32691	0.50281	0.00018	0.00018	0.00289	0.98650	0.00058	0.91730	0.00235	0.63433	0.00018	0.00018	0.96486	0.00018	0.00120	0.00018	0.00025	
S9 (9)	1.00000	0.63433	1.00000	1.00000	0.83912	1.00000	0.31486	1.00000		0.69109	0.84935	0.00018	0.00018	0.01674	0.99990	0.00320	0.99650	0.01378	0.92403	0.00018	0.00018	0.99937	0.00018	0.00708	0.00018	0.00080	
S10 (10)	0.88646	0.00053	0.92403	0.99922	0.00146	0.64872	0.00023	0.32691	0.69109		1.00000	0.05949	0.00018	0.99705	0.99996	0.93343	1.00000	0.99513	1.00000	0.00178	0.11309	1.00000	0.01060	0.98021	0.09200	0.73181	
S11 (11)	0.96486	0.00120	0.98021	0.99997	0.00355	0.81756	0.00033	0.50281	0.84935	1.00000		0.02768	0.00018	0.98020	1.00000	0.82308	1.00000	0.97180	1.00000	0.00076	0.05623	1.00000	0.00437	0.92403	0.04468	0.54660	
S12 (12)	0.00018	0.00018	0.00019	0.00045	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.05949	0.02768		0.85921	0.91730	0.00093	0.99550	0.00289	0.93638	0.01570	1.00000	1.00000	0.00156	1.00000	0.97766	1.00000	0.99994
S13 (13)	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.85921		0.00708	0.00018	0.03424	0.00018	0.00867	0.00018	0.99997	0.71845	0.00018	0.99229	0.01674	0.77036
S14 (14)	0.04735	0.00018	0.06292	0.30308	0.00018	0.01378	0.00018	0.00289	0.01674	0.99705	0.98020	0.91730	0.00708		0.45977	1.00000	0.70487	1.00000	0.94724	0.24807	0.97487	0.57596	0.59063	1.00000	0.96094	1.00000	
S15 (15)	1.00000	0.03528	1.00000	1.00000	0.08727	0.99980	0.00811	0.98650	0.99990	0.99996	1.00000	0.00093	0.00018	0.45977		0.17887	1.00000	0.41782	1.00000	0.00018	0.00205	1.00000	0.00025	0.29155	0.00156	0.06292	
S16 (16)	0.01025	0.00018	0.01424	0.09949	0.00018	0.00260	0.00018	0.00058	0.00320	0.93343	0.82308	0.99550	0.03424	1.00000	0.17887		0.35811	1.00000	0.71169	0.56862	0.99954	0.25325	0.89066	1.00000	0.99895	1.00000	
S17 (17)	0.99990	0.01210	0.99998	1.00000	0.03322	0.99430	0.00251	0.91730	0.99650	1.00000	1.00000	0.00289	0.00018	0.70487	1.00000	0.35811		0.66299	1.00000	0.00021	0.00661	1.00000	0.00048	0.51734	0.00502	0.15194	
S18 (18)	0.03973	0.00018	0.05312	0.26922	0.00018	0.01133	0.00018	0.00235	0.01378	0.99513	0.97180	0.93638	0.00867	1.00000	0.41782	1.00000	0.66299		0.93039	0.28029	0.98251	0.53195	0.63433	1.00000	0.97180	1.00000	
S19 (19)	0.98819	0.00219	0.99430	1.00000	0.00661	0.90266	0.00050	0.63433	0.92403	1.00000	1.00000	0.01570	0.00018	0.94724	1.00000	0.71169	1.00000	0.93039		0.00045	0.03322	1.00000	0.00235	0.84935	0.02603	0.41782	
S20 (20)	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00178	0.00076	1.00000	0.99997	0.24807	0.00018	0.56862	0.00021	0.28029	0.00045		0.99993	0.00019	1.00000	0.40419	0.99998	0.83912	
S21 (21)	0.00020	0.00018	0.00023	0.00093	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.11309	0.05623	1.00000	0.71845	0.97487	0.00205	0.99954	0.00661	0.98251	0.03322	0.99993		0.00355	1.00000	0.99586	1.00000	
S22 (22)	0.99999	0.02160	1.00000	1.00000	0.05623	0.99884	0.00469	0.96486	0.99937	1.00000	1.00000	0.00156	0.00018	0.57596	1.00000	0.25325	1.00000	0.53195	1.00000	0.00019	0.00355		0.00032	0.39077	0.00269	0.09694	
S23 (23)	0.00018	0.00018	0.00018	0.00020	0.00018	0.00018	0.00018	0.00018	0.00018	0.01060	0.00437	1.00000	0.99229	0.59063	0.00025	0.89066	0.00048	0.63433	0.00235	1.00000	1.00000	0.00032		0.77036	1.00000	0.98650	
S24 (24)	0.02160	0.00018	0.02943	0.17482	0.00018	0.00577	0.00018	0.00120	0.00708	0.98021	0.92403	0.97766	0.01674	1.00000	0.29155	1.00000	0.51734	1.00000	0.84935	0.40419	0.99586	0.39077	0.77036		0.99229	1.00000	
S25 (25)	0.00019	0.00018	0.00021	0.00071	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.09200	0.04468	1.00000	0.77036	0.96094	0.00156	0.99895	0.00502	0.97180	0.02603	0.99998	1.00000	0.00269	1.00000	0.99229		
S26 (26)	0.00251	0.00018	0.00355	0.03128	0.00018	0.00067	0.00018	0.00025	0.00080	0.73181	0.54660	0.99994	0.10748	1.00000	0.06292	1.00000	0.15194	1.00000	0.41782	0.83912	1.00000	0.09694	0.98650	1.00000	0.99999		

Table 55.8. Width of tergite 4.

Tukey HSD test; variable TERG4LOG																										
Probabilities for Post Hoc Tests																										
MAIN EFFECT: LOCALITY																										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)
	1.905600	1.845600	1.912400	1.939200	1.856800	1.936400	1.838000	1.895200	1.917700	1.972800	1.950400	2.036400	2.073200	1.994800	1.937800	2.030000	1.965800	1.987600	1.968800	2.054400	2.042800	1.936000	2.060000	2.010800	2.045000	2.006800
S1 (1)		0.59239	1.00000	0.99901	0.90156	0.99975	0.34741	1.00000	1.00000	0.35907	0.95692	0.00019	0.00018	0.02947	0.99949	0.00024	0.58565	0.07659	0.48499	0.00018	0.00018	0.99980	0.00018	0.00256	0.00018	0.00483
S2 (2)	0.59239		0.37093	0.01561	1.00000	0.02349	1.00000	0.88662	0.23113	0.00021	0.00273	0.00018	0.00018	0.00018	0.01917	0.00018	0.00033	0.00018	0.00026	0.00018	0.00018	0.02487	0.00018	0.00018	0.00018	0.00018
S3 (3)	1.00000	0.37093		0.99998	0.73487	1.00000	0.18323	1.00000	1.00000	0.57892	0.99401	0.00025	0.00018	0.07286	0.99999	0.00043	0.79799	0.16841	0.71024	0.00018	0.00019	1.00000	0.00018	0.00751	0.00019	0.01384
S4 (4)	0.99901	0.01561	0.99998		0.07286	1.00000	0.00483	0.96444	1.00000	0.99901	1.00000	0.00904	0.00018	0.73487	1.00000	0.02349	0.99998	0.90853	0.99987	0.00057	0.00330	1.00000	0.00031	0.24259	0.00233	0.34741
S5 (5)	0.90156	1.00000	0.73487	0.07286		0.10251	1.00000	0.99311	0.56204	0.00051	0.01561	0.00018	0.00018	0.00018	0.08863	0.00018	0.00141	0.00019	0.00091	0.00018	0.00018	0.10747	0.00018	0.00018	0.00018	0.00018
S6 (6)	0.99975	0.02349	1.00000	1.00000	0.10251		0.00751	0.98321	1.00000	0.99671	1.00000	0.00585	0.00018	0.64581	1.00000	0.01561	0.99989	0.85277	0.99944	0.00041	0.00212	1.00000	0.00026	0.18323	0.00150	0.27172
S7 (7)	0.34741	1.00000	0.18323	0.00483	1.00000	0.00751		0.68489	0.10131	0.00018	0.00085	0.00018	0.00018	0.00018	0.00603	0.00018	0.00021	0.00018	0.00019	0.00018	0.00018	0.00800	0.00018	0.00018	0.00018	0.00018
S8 (8)	1.00000	0.88662	1.00000	0.96444	0.99311	0.98321	0.68489		1.00000	0.12927	0.74688	0.00018	0.00018	0.00623	0.97518	0.00018	0.26663	0.01862	0.19899	0.00018	0.00018	0.98509	0.00018	0.00054	0.00018	0.00096
S9 (9)	1.00000	0.23113	1.00000	1.00000	0.56204	1.00000	0.10131	1.00000		0.74985	0.99935	0.00038	0.00018	0.13676	1.00000	0.00086	0.91354	0.28443	0.85503	0.00018	0.00024	1.00000	0.00018	0.01680	0.00021	0.02988
S10 (10)	0.35907	0.00021	0.57892	0.99901	0.00051	0.99671	0.00018	0.12927	0.74985		1.00000	0.47182	0.00549	1.00000	0.99814	0.68489	1.00000	1.00000	1.00000	0.08048	0.28185	0.99616	0.03883	0.99401	0.22888	0.99881
S11 (11)	0.95692	0.00273	0.99401	1.00000	0.01561	1.00000	0.00085	0.74688	0.99935	1.00000		0.04566	0.00027	0.96081	1.00000	0.10251	1.00000	0.99552	1.00000	0.00310	0.01862	1.00000	0.00129	0.57891	0.01344	0.71024
S12 (12)	0.00019	0.00018	0.00025	0.00904	0.00018	0.00585	0.00018	0.00018	0.00038	0.47182	0.04566		0.99616	0.98116	0.00728	1.00000	0.26663	0.90156	0.34741	1.00000	1.00000	0.00549	1.00000	0.99999	1.00000	0.99987
S13 (13)	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00549	0.00027	0.99616		0.11797	0.00018	0.97092	0.00181	0.04816	0.00291	1.00000	0.99980	0.00018	1.00000	0.51159	0.99995	0.38298
S14 (14)	0.02947	0.00018	0.07286	0.73487	0.00018	0.64581	0.00018	0.00623	0.13676	1.00000	0.96081	0.98116	0.11797		0.69129	0.99797	0.99991	1.00000	0.99999	0.60583	0.91517	0.63256	0.42015	1.00000	0.87455	1.00000
S15 (15)	0.99949	0.01917	0.99999	1.00000	0.08663	1.00000	0.00603	0.97518	1.00000	0.99814	1.00000	0.00728	0.00018	0.89129		0.01917	0.99995	0.88268	0.99973	0.00048	0.00264	1.00000	0.00028	0.21144	0.00187	0.30821
S16 (16)	0.00024	0.00018	0.00043	0.02349	0.00018	0.01561	0.00018	0.00018	0.00086	0.68489	0.10251	1.00000	0.97092	0.99797	0.01917		0.45226	0.97648	0.55192	1.00000	1.00000	0.01470	0.99984	1.00000	1.00000	1.00000
S17 (17)	0.58565	0.00033	0.79799	0.99998	0.00141	0.99989	0.00021	0.26663	0.91354	1.00000	1.00000	0.26663	0.00181	0.99991	0.99995	0.45226		1.00000	1.00000	0.03204	0.13830	0.99986	0.01426	0.95488	0.10747	0.88417
S18 (18)	0.07659	0.00018	0.16841	0.90853	0.00019	0.85277	0.00018	0.01862	0.28443	1.00000	0.99552	0.90156	0.04816	1.00000	0.88268	0.97648	1.00000		1.00000	0.37093	0.74688	0.84350	0.22443	1.00000	0.67846	1.00000
S19 (19)	0.48499	0.00026	0.71024	0.99987	0.00091	0.99944	0.00019	0.19899	0.85503	1.00000	1.00000	0.34741	0.00291	0.99999	0.99973	0.55192	1.00000	1.00000		0.04816	0.19099	0.99932	0.02218	0.97892	0.15117	0.99401
S20 (20)	0.00018	0.00018	0.00018	0.00057	0.00018	0.00041	0.00018	0.00018	0.00018	0.08048	0.00310	1.00000	1.00000	0.60583	0.00048	1.00000	0.03204	0.37093	0.04816		1.00000	0.00039	1.00000	0.96780	1.00000	0.92149
S21 (21)	0.00018	0.00018	0.00019	0.00330	0.00018	0.00212	0.00018	0.00018	0.00024	0.28185	0.01862	1.00000	0.99980	0.91517	0.00264	1.00000	0.13830	0.74688	0.19099	1.00000		0.00199	1.00000	0.99954	1.00000	0.99718
S22 (22)	0.99980	0.02487	1.00000	1.00000	0.10747	1.00000	0.00800	0.98509	1.00000	0.99616	1.00000	0.00549	0.00018	0.63256	1.00000	0.01470	0.99986	0.84350	0.99932	0.00039	0.00199		0.00025	0.17570	0.00141	0.26171
S23 (23)	0.00018	0.00018	0.00018	0.00031	0.00018	0.00026	0.00018	0.00018	0.00018	0.03883	0.00129	1.00000	1.00000	0.42015	0.00028	0.99984	0.01426	0.22443	0.02218	1.00000	1.00000	0.00025		0.89426	1.00000	0.80333
S24 (24)	0.00256	0.00018	0.00751	0.24259	0.00018	0.18323	0.00018	0.00054	0.01680	0.99401	0.57891	0.99999	0.51159	1.00000	0.21144	1.00000	0.95488	1.00000	0.97892	0.96780	0.99954	0.17570	0.89426		0.99869	1.00000
S25 (25)	0.00018	0.00018	0.00019	0.00233	0.00018	0.00150	0.00018	0.00018	0.00021	0.22888	0.01344	1.00000	0.99995	0.87455	0.00187	1.00000	0.10747	0.67846	0.15117	1.00000	1.00000	0.00141	1.00000	0.99869		0.99357
S26 (26)	0.00483	0.00018	0.01384	0.34741	0.00018	0.27172	0.00018	0.00096	0.02988	0.99881	0.71024	0.99987	0.38298	1.00000	0.30821	1.00000	0.98417	1.00000	0.99401	0.92149	0.99718	0.26171	0.80333	1.00000	0.99357	

Table 55.9. Sternite 3 longitudinal.

Tukey HSD test; variable SRT3 LOG																										
Probabilities for Post Hoc Tests																										
MAIN EFFECT: LOCALITY																										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)
	2.546400	2.386400	2.462200	2.472000	2.396800	2.434400	2.319600	2.428000	2.401800	2.469200	2.458400	2.578400	2.578800	2.511600	2.420000	2.475200	2.419200	2.508800	2.426800	2.580800	2.541200	2.398000	2.588400	2.518400	2.557600	2.506400
S1 (1)		0.00018	0.15530	0.36164	0.00019	0.00497	0.00018	0.00199	0.00019	0.29123	0.10521	0.99992	0.99990	0.99966	0.00067	0.45141	0.00060	0.99886	0.00168	0.99972	1.00000	0.00018	0.99424	0.99999	1.00000	0.99709
S2 (2)	0.00018		0.32537	0.13500	1.00000	0.97018	0.58373	0.99494	1.00000	0.17775	0.42826	0.00018	0.00018	0.00078	0.99981	0.09656	0.99987	0.00114	0.99665	0.00018	0.00018	1.00000	0.00018	0.00037	0.00018	0.00159
S3 (3)	0.15530	0.32537		1.00000	0.68521	0.99999	0.00020	0.99975	0.76782	1.00000	1.00000	0.00272	0.00257	0.95928	0.99387	1.00000	0.99214	0.97871	0.99956	0.00193	0.25055	0.66185	0.00069	0.86402	0.04532	0.98879
S4 (4)	0.36164	0.13500	1.00000		0.39428	0.99986	0.00018	0.98943	0.48090	1.00000	1.00000	0.01092	0.01034	0.99749	0.93167	1.00000	0.92105	0.99918	0.98521	0.00782	0.51086	0.37238	0.00264	0.97976	0.13500	0.99972
S5 (5)	0.00019	1.00000	0.68521	0.39428		0.99951	0.24628	0.99998	1.00000	0.47496	0.78812	0.00018	0.00018	0.00443	1.00000	0.31047	1.00000	0.00660	0.99999	0.00018	0.00020	1.00000	0.00018	0.00168	0.00018	0.00925
S6 (6)	0.00497	0.97018	0.99999	0.99886	0.99951		0.00332	1.00000	0.99989	0.99966	1.00000	0.00020	0.00019	0.29123	1.00000	0.99615	1.00000	0.36164	1.00000	0.00019	0.01034	0.99931	0.00018	0.15837	0.00103	0.42826
S7 (7)	0.00018	0.58373	0.00020	0.00018	0.24628	0.00332		0.00827	0.18808	0.00018	0.00024	0.00018	0.00018	0.00018	0.02429	0.00018	0.02691	0.00018	0.00977	0.00018	0.00018	0.26365	0.00018	0.00018	0.00018	0.00018
S8 (8)	0.00199	0.99494	0.99975	0.98943	0.99998	1.00000	0.00827		1.00000	0.99558	0.99997	0.00018	0.00018	0.16464	1.00000	0.97533	1.00000	0.21387	1.00000	0.00018	0.00418	0.99997	0.00018	0.08103	0.00046	0.26365
S9 (9)	0.00019	1.00000	0.76782	0.48090	1.00000	0.99989	0.18808	1.00000		0.56548	0.85602	0.00018	0.00018	0.00679	1.00000	0.38875	1.00000	0.01004	1.00000	0.00018	0.00023	1.00000	0.00018	0.00257	0.00018	0.01394
S10 (10)	0.29123	0.17775	1.00000	1.00000	0.47496	0.99966	0.00018	0.99558	0.56548		1.00000	0.00739	0.00699	0.99347	0.96099	1.00000	0.95380	0.99749	0.99347	0.00526	0.42826	0.45141	0.00177	0.96099	0.10081	0.99903
S11 (11)	0.10521	0.42826	1.00000	1.00000	0.78812	1.00000	0.00024	0.99997	0.85602	1.00000		0.00159	0.00150	0.91535	0.99841	1.00000	0.99783	0.94986	0.99993	0.00114	0.17775	0.76782	0.00044	0.77808	0.02831	0.97018
S12 (12)	0.99992	0.00018	0.00272	0.01092	0.00018	0.00020	0.00018	0.00018	0.00018	0.00739	0.00159		1.00000	0.58373	0.00018	0.01682	0.00018	0.49883	0.00018	1.00000	0.99903	0.00018	1.00000	0.77808	1.00000	0.42826
S13 (13)	0.99990	0.00018	0.00257	0.01034	0.00018	0.00019	0.00018	0.00018	0.00018	0.00699	0.00150	1.00000		0.57156	0.00018	0.01595	0.00018	0.48686	0.00018	1.00000	0.99886	0.00018	1.00000	0.76782	1.00000	0.41673
S14 (14)	0.99966	0.00078	0.95928	0.99749	0.00443	0.29123	0.00018	0.16464	0.00679	0.99347	0.91535	0.58373	0.57156		0.07080	0.99931	0.06457	1.00000	0.14629	0.51086	0.99998	0.00395	0.30076	1.00000	0.98172	1.00000
S15 (15)	0.00067	0.99981	0.99387	0.93167	1.00000	1.00000	0.02429	1.00000	1.00000	0.96099	0.99841	0.00018	0.00018	0.07080		0.88281	1.00000	0.09656	1.00000	0.00018	0.00134	1.00000	0.00018	0.03132	0.00025	0.12440
S16 (16)	0.45141	0.09656	1.00000	1.00000	0.31047	0.99615	0.00018	0.97533	0.38875	1.00000	1.00000	0.01682	0.01595	0.99931	0.88281		0.86791	0.99981	0.96732	0.01218	0.60800	0.29123	0.00418	0.99165	0.18459	0.99995
S17 (17)	0.00060	0.99987	0.99214	0.92105	1.00000	1.00000	0.02691	1.00000	1.00000	0.95380	0.99783	0.00018	0.00018	0.06457	1.00000	0.86791		0.08851	1.00000	0.00018	0.00120	1.00000	0.00018	0.02831	0.00024	0.11448
S18 (18)	0.99886	0.00114	0.97871	0.99918	0.00660	0.36164	0.00018	0.21387	0.01004	0.99749	0.94986	0.49883	0.48686	1.00000	0.09656	0.99981	0.08851		0.19162	0.42827	0.99990	0.00590	0.23789	1.00000	0.96426	1.00000
S19 (19)	0.00168	0.99665	0.99956	0.98521	0.99999	1.00000	0.00977	1.00000	1.00000	0.99347	0.99993	0.00018	0.00018	0.14629	1.00000	0.96732	1.00000	0.19162		0.00018	0.00352	0.99999	0.00018	0.07080	0.00041	0.23788
S20 (20)	0.99972	0.00018	0.00193	0.00782	0.00018	0.00019	0.00018	0.00018	0.00018	0.00526	0.00114	1.00000	1.00000	0.51086	0.00018	0.01218	0.00018	0.42827	0.00018		0.99749	0.00018	1.00000	0.71373	1.00000	0.36165
S21 (21)	1.00000	0.00018	0.25055	0.51086	0.00020	0.01034	0.00018	0.00418	0.00023	0.42826	0.17775	0.99903	0.99886	0.99998	0.00134	0.60800	0.00120	0.99990	0.00352	0.99749		0.00020	0.97533	1.00000	1.00000	0.99966
S22 (22)	0.00018	1.00000	0.66185	0.37238	1.00000	0.99931	0.26365	0.99997	1.00000	0.45141	0.76782	0.00018	0.00018	0.00395	1.00000	0.29123	1.00000	0.00590	0.99999	0.00018	0.00020		0.00018	0.00150	0.00018	0.00827
S23 (23)	0.99424	0.00018	0.00069	0.00264	0.00018	0.00018	0.00018	0.00018	0.00018	0.00177	0.00044	1.00000	1.00000	0.30076	0.00018	0.00418	0.00018	0.23789	0.00018	1.00000	0.97533	0.00018		0.48686	0.99996	0.19162
S24 (24)	0.99999	0.00037	0.86402	0.97976	0.00168	0.15837	0.00018	0.08103	0.00257	0.96099	0.77808	0.77808	0.76782	1.00000	0.03132	0.99165	0.02831	1.00000	0.07080	0.71373	1.00000	0.00150	0.48686		0.99783	1.00000
S25 (25)	1.00000	0.00018	0.04532	0.13500	0.00018	0.00103	0.00018	0.00046	0.00018	0.10081	0.02831	1.00000	1.00000	0.98172	0.00025	0.18459	0.00024	0.96426	0.00041	1.00000	1.00000	0.00018	0.99996	0.99783		0.94127
S26 (26)	0.99709	0.00159	0.98879	0.99972	0.00925	0.42826	0.00018	0.26365	0.01394	0.99903	0.97018	0.42826	0.41673	1.00000	0.12440	0.99995	0.11448	1.00000	0.23788	0.36165	0.99966	0.00827	0.19162	1.00000	0.94127	

Table 55.10. Sternite 3 transversal.

Tukey HSD test; variable SRT3 TRS																										
Probabilities for Post Hoc Tests																										
MAIN EFFECT: LOCALITY																										
	{1}	{2}	{3}	{4}	{5}	{6}	{7}	{8}	{9}	{10}	{11}	{12}	{13}	{14}	{15}	{16}	{17}	{18}	{19}	{20}	{21}	{22}	{23}	{24}	{25}	{26}
	2.113400	1.968600	1.990800	2.026000	1.955200	2.012800	1.890000	1.988800	1.996800	2.024000	2.080000	2.139600	2.139600	2.092800	1.995200	2.081600	1.978800	2.034400	2.011600	2.091600	2.072400	1.963200	2.120800	2.032000	2.086000	2.044800
S1 {1}		0.00023	0.00212	0.15724	0.00018	0.03835	0.00018	0.00162	0.00485	0.12966	0.99991	1.00000	1.00000	1.00000	0.00389	0.99996	0.00047	0.32054	0.03324	1.00000	0.99763	0.00019	1.00000	0.26585	1.00000	0.60835
S2 {2}	0.00023		1.00000	0.88255	1.00000	0.99322	0.33023	1.00000	1.00000	0.91401	0.00983	0.00018	0.00018	0.00171	1.00000	0.00793	1.00000	0.68824	0.99533	0.00201	0.02607	1.00000	0.00019	0.75243	0.00434	0.39153
S3 {3}	0.00212	1.00000		0.99979	0.99974	1.00000	0.03746	1.00000	1.00000	0.99992	0.13222	0.00020	0.00020	0.03246	1.00000	0.11278	1.00000	0.99435	1.00000	0.03745	0.26158	1.00000	0.00079	0.99746	0.07100	0.93237
S4 {4}	0.15724	0.88255	0.99979		0.54404	1.00000	0.00041	0.99947	0.99999	1.00000	0.93237	0.00731	0.00731	0.66017	0.99998	0.91115	0.98438	1.00000	1.00000	0.69378	0.98733	0.76758	0.07416	1.00000	0.83238	1.00000
S5 {5}	0.00018	1.00000	0.99974	0.54404		0.87906	0.70476	0.99990	0.99707	0.60253	0.00157	0.00018	0.00018	0.00035	0.99836	0.00127	1.00000	0.31576	0.89906	0.00039	0.00447	1.00000	0.00018	0.37572	0.00072	0.12713
S6 {6}	0.03835	0.99322	1.00000	1.00000	0.87906		0.00206	1.00000	1.00000	1.00000	0.64877	0.00121	0.00121	0.29705	1.00000	0.60253	0.99988	1.00000	1.00000	0.32536	0.84076	0.97211	0.01535	1.00000	0.47457	0.99996
S7 {7}	0.00018	0.33023	0.03746	0.00041	0.70476	0.00206		0.04733	0.01789	0.00050	0.00018	0.00018	0.00018	0.00018	0.02191	0.00018	0.13749	0.00023	0.00243	0.00018	0.00018	0.47457	0.00018	0.00026	0.00018	0.00018
S8 {8}	0.00162	1.00000	1.00000	0.99947	0.99990	1.00000	0.04733		1.00000	0.99979	0.10829	0.00019	0.00019	0.02544	1.00000	0.09179	1.00000	0.98983	1.00000	0.02946	0.22134	1.00000	0.00062	0.99502	0.05681	0.90523
S9 {9}	0.00485	1.00000	1.00000	0.99999	0.99707	1.00000	0.01789	1.00000		1.00000	0.22903	0.00025	0.00025	0.06498	1.00000	0.19936	1.00000	0.99937	1.00000	0.07416	0.40764	0.99990	0.00175	0.99979	0.13223	0.98089
S10 {10}	0.12966	0.91401	0.99992	1.00000	0.60253	1.00000	0.00050	0.99979	1.00000		0.90523	0.00557	0.00557	0.60253	0.99999	0.87906	0.99092	1.00000	1.00000	0.63730	0.97893	0.81493	0.05943	1.00000	0.78713	1.00000
S11 {11}	0.99991	0.00983	0.13222	0.93237	0.00157	0.64877	0.00018	0.10829	0.22903	0.90523		0.84076	0.84076	1.00000	0.19936	1.00000	0.03572	0.98983	0.61416	1.00000	1.00000	0.00472	0.99780	0.98089	1.00000	0.99979
S12 {12}	1.00000	0.00018	0.00020	0.00731	0.00018	0.00121	0.00018	0.00019	0.00025	0.00557	0.84076		1.00000	0.98592	0.00023	0.87189	0.00018	0.02191	0.00104	0.98089	0.64877	0.00018	1.00000	0.01616	0.93708	0.07415
S13 {13}	1.00000	0.00018	0.00020	0.00731	0.00018	0.00121	0.00018	0.00019	0.00025	0.00557	0.84076	1.00000		0.98592	0.00023	0.87189	0.00018	0.02191	0.00104	0.98089	0.64877	0.00018	1.00000	0.01616	0.93708	0.07415
S14 {14}	1.00000	0.00171	0.03246	0.66017	0.00035	0.29705	0.00018	0.02544	0.06498	0.60253	1.00000	0.98592	0.98592		0.05430	1.00000	0.00693	0.86447	0.27026	1.00000	1.00000	0.00084	1.00000	0.81494	1.00000	0.98089
S15 {15}	0.00389	1.00000	1.00000	0.99998	0.99836	1.00000	0.02191	1.00000	1.00000	0.99999	0.19936	0.00023	0.00023	0.05430		0.17257	1.00000	0.99880	1.00000	0.06214	0.36535	0.99996	0.00141	0.99956	0.11278	0.97211
S16 {16}	0.99996	0.00793	0.11278	0.91115	0.00127	0.60253	0.00018	0.09179	0.19936	0.87906	1.00000	0.87189	0.87189	1.00000	0.17257		0.02946	0.98438	0.56745	1.00000	1.00000	0.00379	0.99880	0.97211	1.00000	0.99956
S17 {17}	0.00047	1.00000	1.00000	0.98438	1.00000	0.99988	0.13749	1.00000	1.00000	0.99092	0.03572	0.00018	0.00018	0.00693	1.00000	0.02946		0.91115	0.99994	0.00815	0.08436	1.00000	0.00026	0.94155	0.01700	0.68268
S18 {18}	0.32054	0.68824	0.99435	1.00000	0.31576	1.00000	0.00023	0.96983	0.99937	1.00000	0.98983	0.02191	0.02191	0.86447	0.99880	0.98438	0.91115		1.00000	0.88598	0.99926	0.53235	0.17257	1.00000	0.95719	1.00000
S19 {19}	0.03324	0.99533	1.00000	1.00000	0.89906	1.00000	0.00243	1.00000	1.00000	1.00000	0.61416	0.00104	0.00104	0.27026	1.00000	0.56745	0.99994	1.00000		0.29705	0.81493	0.97893	0.01313	1.00000	0.44072	0.99892
S20 {20}	1.00000	0.00201	0.03745	0.69378	0.00039	0.32536	0.00018	0.02946	0.07416	0.63730	1.00000	0.98089	0.98089	1.00000	0.06214	1.00000	0.00815	0.88598	0.29705		1.00000	0.00098	0.99999	0.84076	1.00000	0.98592
S21 {21}	0.99763	0.02607	0.26158	0.98733	0.00447	0.84076	0.00018	0.22134	0.40764	0.97893	1.00000	0.64877	0.64877	1.00000	0.36535	1.00000	0.08436	0.99926	0.81493	1.00000		0.01313	0.97893	0.99810	1.00000	1.00000
S22 {22}	0.00019	1.00000	1.00000	0.76758	1.00000	0.97211	0.47457	1.00000	0.99990	0.81493	0.00472	0.00018	0.00018	0.00084	0.99996	0.00379	1.00000	0.53235	0.97893	0.00098	0.01313		0.00018	0.60253	0.00206	0.26158
S23 {23}	1.00000	0.00019	0.00079	0.07416	0.00018	0.01535	0.00018	0.00082	0.00175	0.05943	0.99780	1.00000	1.00000	1.00000	0.00141	0.99880	0.00026	0.17257	0.01313	0.99999	0.97893	0.00018		0.13749	0.99982	0.39687
S24 {24}	0.26585	0.75243	0.99746	1.00000	0.37572	1.00000	0.00026	0.99502	0.99979	1.00000	0.98089	0.01616	0.01616	0.81494	0.99956	0.97211	0.94155	1.00000	1.00000	0.84076	0.99810	0.60253	0.13749		0.93237	1.00000
S25 {25}	1.00000	0.00434	0.07100	0.83238	0.00072	0.47457	0.00018	0.05681	0.13223	0.78713	1.00000	0.93708	0.93708	1.00000	0.11278	1.00000	0.01700	0.95719	0.44072	1.00000	1.00000	0.00206	0.99982	0.93237		0.99746
S26 {26}	0.60835	0.39153	0.93237	1.00000	0.12713	0.99996	0.00018	0.90523	0.98089	1.00000	0.99979	0.07415	0.07415	0.98089	0.97211	0.99956	0.88268	1.00000	0.99992	0.98592	1.00000	0.26158	0.39687	1.00000	0.99746	

Table 55.1.1. Forewing angle B4.

Tukey HSD test; variable ANGLE B4
 Probabilities for Post Hoc Tests
 MAIN EFFECT: LOCALITY

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	
S1 (1)	104.0106	1.00000	105.0242	101.0909	105.1640	105.2402	104.1326	105.3938	104.2099	104.9990	104.5963	104.1632	104.4580	105.7033	104.9788	105.5085	101.8757	106.0915	105.4708	105.3218	108.6395	103.0703	104.7048	101.6736	106.6293	102.7252	
S2 (2)	1.00000	1.00000	0.99860	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.78795	1.00000	1.00000	0.99997	0.99975	1.00000	
S3 (3)	1.00000	1.00000	1.00000	0.96108	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.96014	1.00000	1.00000	0.99496	1.00000	0.99999	
S4 (4)	0.99860	0.96108	0.93990	1.00000	0.91617	0.90094	0.99741	0.86516	0.99629	0.94504	0.99293	0.99700	0.98963	0.77349	0.94648	0.93409	1.00000	0.99575	0.63078	0.94470	0.88278	0.03098	1.00000	0.97561	1.00000	0.42067	1.00000
S5 (5)	1.00000	1.00000	1.00000	0.91617	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.98462	1.00000	1.00000	0.98380	1.00000	0.99993	
S6 (6)	1.00000	1.00000	1.00000	0.90094	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.98829	0.99999	1.00000	0.97906	1.00000	0.99987	
S7 (7)	1.00000	1.00000	1.00000	0.99741	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.80747	1.00000	1.00000	0.99991	1.00000	0.99989	
S8 (8)	1.00000	1.00000	1.00000	0.86516	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99357	0.99997	1.00000	0.96628	1.00000	0.99966	
S9 (9)	1.00000	1.00000	1.00000	0.99629	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.83063	1.00000	1.00000	0.99985	0.99994	1.00000	
S10 (10)	1.00000	1.00000	1.00000	0.94504	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.97266	1.00000	1.00000	0.99151	1.00000	0.99998	
S11 (11)	1.00000	1.00000	1.00000	0.98293	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.92170	1.00000	1.00000	0.99858	1.00000	1.00000	
S12 (12)	1.00000	1.00000	1.00000	0.99700	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.81682	1.00000	1.00000	0.99989	0.99991	1.00000	
S13 (13)	1.00000	1.00000	1.00000	0.98963	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.89400	1.00000	1.00000	0.99933	0.99989	1.00000	
S14 (14)	1.00000	1.00000	1.00000	0.77349	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99846	0.99973	1.00000	0.92412	1.00000	0.99810	
S15 (15)	1.00000	1.00000	1.00000	0.94646	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.97178	1.00000	1.00000	0.99164	1.00000	0.99998	
S16 (16)	1.00000	1.00000	1.00000	0.83409	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99608	0.99983	1.00000	0.95346	1.00000	0.99933	
S17 (17)	0.99999	0.99803	0.99575	1.00000	0.99237	0.98973	0.99988	0.98218	0.99997	0.99638	0.99954	0.99998	0.99980	0.95437	0.99654	0.97412	1.00000	0.88628	0.97703	0.97703	0.88613	1.0244	1.00000	0.99914	1.00000	0.72428	1.00000
S18 (18)	1.00000	1.00000	1.00000	0.63076	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99984	0.99765	1.00000	0.83401	1.00000	0.98966	
S19 (19)	1.00000	1.00000	1.00000	0.84470	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99536	0.99994	1.00000	0.95801	1.00000	0.99946	
S20 (20)	1.00000	1.00000	1.00000	0.88278	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99143	0.99998	1.00000	0.97285	1.00000	0.99978	
S21 (21)	0.78795	0.96014	0.97551	0.03098	0.98462	0.98829	0.80747	0.99357	0.83063	0.97266	0.92170	0.81682	0.89400	0.99846	0.97178	0.99608	0.10244	0.99984	0.99536	0.99143	0.99143	0.40928	0.93969	0.07674	1.00000	0.29203	
S22 (22)	1.00000	1.00000	1.00000	1.00000	1.00000	0.99999	1.00000	0.99997	1.00000	1.00000	1.00000	1.00000	1.00000	0.99973	1.00000	0.99993	1.00000	0.99765	0.99994	0.99998	0.40928	0.99998	1.00000	1.00000	0.97957	1.00000	
S23 (23)	1.00000	1.00000	1.00000	0.97561	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99959	1.00000	1.00000	0.99754	1.00000	1.00000	
S24 (24)	0.99997	0.98496	0.99026	1.00000	0.96380	0.97906	0.99991	0.96628	0.99985	0.99151	0.99858	0.99989	0.99933	0.92412	0.99164	0.95346	1.00000	0.83401	0.95801	0.97285	0.07674	1.00000	0.99754	0.64826	1.00000	0.94418	
S25 (25)	0.99975	1.00000	1.00000	0.42067	1.00000	1.00000	0.99999	1.00000	0.99999	1.00000	1.00000	1.00000	0.99999	0.99999	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.64826	1.00000	0.94418	
S26 (26)	1.00000	0.99999	0.99997	1.00000	0.99983	0.99987	1.00000	0.99966	1.00000	0.99998	1.00000	1.00000	1.00000	0.99810	0.99998	0.99993	1.00000	0.98966	0.99946	0.99978	0.29203	1.00000	1.00000	1.00000	0.94418	1.00000	

Table 55.12. Forewing angle N23.

Tukey HSD test; variable ANGLE N23
 Probabilities for Post Hoc Tests
 MAIN EFFECT: LOCALITY

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	
	86.82540	86.88210	87.60200	89.29481	88.86920	89.32300	87.05170	87.80200	87.64760	87.29050	87.98650	88.11360	87.00260	87.96450	88.03470	89.08280	85.92840	86.98210	87.66310	86.81820	86.57520	87.32810	85.99160	87.23400	87.72240	86.83120	
S1 (1)		1.00000	1.00000	0.85789	0.97780	0.84456	1.00000	1.00000	1.00000	1.00000	1.00000	0.99998	1.00000	1.00000	0.99999	0.93592	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
S2 (2)	1.00000		1.00000	0.88263	0.98409	0.87069	1.00000	1.00000	1.00000	1.00000	1.00000	0.99999	1.00000	1.00000	1.00000	0.95028	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
S3 (3)	1.00000	1.00000		0.99819	0.99999	0.99768	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99978	0.99847	1.00000	1.00000	1.00000	1.00000	1.00000	0.99916	1.00000	1.00000	1.00000	1.00000
S4 (4)	0.85789	0.88263	0.99819		1.00000	1.00000	0.93978	0.99975	0.99880	0.98235	0.99998	1.00000	0.92579	0.99997	0.99999	1.00000	0.29516	0.91934	0.99897	0.85455	0.71841	0.98597	0.33074	0.97558	0.99942	0.86056	
S5 (5)	0.97780	0.98409	0.99999	1.00000		1.00000	0.99496	1.00000	0.99999	0.99939	1.00000	1.00000	0.99280	1.00000	1.00000	1.00000	0.56869	0.99169	0.99999	0.97688	0.92524	0.99958	0.61259	0.99894	1.00000	0.97852	
S6 (6)	0.84456	0.87069	0.99768	1.00000	1.00000		0.93199	0.99966	0.99844	0.97919	0.99996	0.99999	0.91683	0.99995	0.99998	1.00000	0.28005	0.90988	0.99866	0.84105	0.70020	0.98332	0.31458	0.97151	0.99924	0.84736	
S7 (7)	1.00000	1.00000	1.00000	0.93978	0.99496	0.93199		1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.97935	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
S8 (8)	1.00000	1.00000	1.00000	0.99975	1.00000	0.99966	1.00000		1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99998	0.99244	1.00000	1.00000	1.00000	0.99999	1.00000	0.99522	1.00000	1.00000	1.00000	1.00000
S9 (9)	1.00000	1.00000	1.00000	0.99880	0.99999	0.99844	1.00000	1.00000		1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99987	0.99772	1.00000	1.00000	1.00000	1.00000	1.00000	0.99870	1.00000	1.00000	1.00000	1.00000
S10 (10)	1.00000	1.00000	1.00000	0.98235	0.99939	0.97919	1.00000	1.00000	1.00000		1.00000	1.00000	1.00000	1.00000	1.00000	0.99585	0.99995	1.00000	1.00000	1.00000	1.00000	1.00000	0.99998	1.00000	1.00000	1.00000	1.00000
S11 (11)	1.00000	1.00000	1.00000	0.99998	1.00000	0.99996	1.00000	1.00000	1.00000	1.00000		1.00000	1.00000	1.00000	1.00000	1.00000	0.97594	1.00000	1.00000	1.00000	0.99990	1.00000	0.98332	1.00000	1.00000	1.00000	1.00000
S12 (12)	0.99998	0.99999	1.00000	1.00000	1.00000	0.99999	1.00000	1.00000	1.00000	1.00000	1.00000		1.00000	1.00000	1.00000	1.00000	0.95376	1.00000	1.00000	0.99998	0.99959	1.00000	0.96614	1.00000	1.00000	0.99998	1.00000
S13 (13)	1.00000	1.00000	1.00000	0.92579	0.99280	0.91683	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000		1.00000	1.00000	0.97284	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
S14 (14)	1.00000	1.00000	1.00000	0.99997	1.00000	0.99995	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000		1.00000	1.00000	0.97875	1.00000	1.00000	1.00000	0.99993	1.00000	0.98542	1.00000	1.00000	1.00000	1.00000
S15 (15)	0.99999	1.00000	1.00000	0.99999	1.00000	0.99998	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000		1.00000	0.96878	1.00000	1.00000	0.99999	0.99983	1.00000	0.97789	1.00000	1.00000	0.99999	1.00000
S16 (16)	0.93592	0.95028	0.99978	1.00000	1.00000	1.00000	0.97935	0.99998	0.99987	0.99585	1.00000	1.00000	0.97284	1.00000	1.00000		0.42305	0.96969	0.99989	0.93390	0.83967	0.99693	0.46502	0.99366	0.99995	0.93751	
S17 (17)	1.00000	1.00000	0.99847	0.29516	0.56869	0.28005	1.00000	0.99244	0.99772	0.99995	0.97594	0.95376	1.00000	0.97875	0.96878	0.42305		1.00000	0.99740	1.00000	1.00000	0.99992	1.00000	0.99998	0.99579	1.00000	
S18 (18)	1.00000	1.00000	1.00000	0.91934	0.99169	0.90988	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.96969	1.00000		1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
S19 (19)	1.00000	1.00000	1.00000	0.99897	0.99999	0.99866	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99989	0.99740	1.00000		1.00000	1.00000	1.00000	0.99851	1.00000	1.00000	1.00000	1.00000
S20 (20)	1.00000	1.00000	1.00000	0.85455	0.97688	0.84105	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99998	1.00000	1.00000	0.99999	0.93390	1.00000	1.00000		1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
S21 (21)	1.00000	1.00000	1.00000	0.71841	0.92524	0.70020	1.00000	0.99999	1.00000	1.00000	0.99990	0.99959	1.00000	0.99993	0.99983	0.83967	1.00000	1.00000	1.00000	1.00000		1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
S22 (22)	1.00000	1.00000	1.00000	0.98597	0.99958	0.98332	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99693	0.99992	1.00000	1.00000	1.00000	1.00000		0.99996	1.00000	1.00000	1.00000	1.00000
S23 (23)	1.00000	1.00000	0.99916	0.33074	0.61259	0.31458	1.00000	0.99522	0.99870	0.99998	0.98332	0.96614	1.00000	0.98542	0.97789	0.46502	1.00000	1.00000	0.99851	1.00000	1.00000	1.00000	0.99996		0.99999	0.99749	1.00000
S24 (24)	1.00000	1.00000	1.00000	0.97558	0.99894	0.97151	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99366	0.99998	1.00000	1.00000	1.00000	1.00000	1.00000	0.99999		1.00000	1.00000	1.00000
S25 (25)	1.00000	1.00000	1.00000	0.99942	1.00000	0.99924	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99995	0.99579	1.00000	1.00000	1.00000	1.00000	1.00000	0.99749	1.00000		1.00000	
S26 (26)	1.00000	1.00000	1.00000	0.86056	0.97852	0.84736	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99998	1.00000	1.00000	0.99999	0.93751	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000

Table 55.13. Forewing angle O26.

Tukey HSD test; variable ANGLE O26																											
Probabilities for Post Hoc Tests																											
MAIN EFFECT: LOCALITY																											
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	
	36.92690	38.60620	37.25790	38.05810	39.50800	38.57860	37.73490	38.20380	37.75160	37.66450	37.58160	38.07280	38.08640	37.08320	37.09810	36.14760	36.11850	35.36610	35.36020	36.57580	36.18520	38.66530	36.27420	35.19980	37.27760	36.45450	
S1 (1)		0.99273	1.00000	0.99999	0.61719	0.99417	1.00000	0.99989	1.00000	1.00000	1.00000	0.99998	0.99998	1.00000	1.00000	1.00000	1.00000	0.99737	0.99723	1.00000	1.00000	0.98864	1.00000	0.98955	1.00000	1.00000	
S2 (2)	0.99273		0.99973	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99817	0.99842	0.70872	0.68757	0.18339	0.18082	0.93565	0.73532	1.00000	0.79415	0.12058	0.99979	0.89044	
S3 (3)	1.00000	0.99973		1.00000	0.84204	0.99981	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99999	0.99999	0.96912	0.96804	1.00000	1.00000	0.99946	1.00000	0.92670	1.00000	1.00000	
S4 (4)	0.99999	1.00000	1.00000		0.99914	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.96561	0.95955	0.53147	0.52692	0.99879	0.97238	1.00000	0.98437	0.40681	1.00000	0.99612	
S5 (5)	0.61719	1.00000	0.84204	0.99914		1.00000	0.98549	0.99985	0.98708	0.97694	0.96239	0.99927	0.99937	0.73267	0.74299	0.13595	0.12605	0.01247	0.01222	0.35549	0.14968	1.00000	0.18617	0.00693	0.85256	0.27911	
S6 (6)	0.99417	1.00000	0.99981	1.00000	1.00000		1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99862	0.99881	0.72833	0.70764	0.19581	0.19310	0.94376	0.75424	1.00000	0.81102	0.12962	0.99985	0.90212	
S7 (7)	1.00000	1.00000	1.00000	1.00000	0.98549	1.00000		1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99665	0.99566	0.77060	0.76672	0.99998	0.99763	1.00000	0.99904	0.65224	1.00000	0.99889	
S8 (8)	0.99989	1.00000	1.00000	1.00000	0.99985	1.00000	1.00000		1.00000	1.00000	1.00000	1.00000	1.00000	0.99999	0.99999	0.92734	0.91714	0.42166	0.41738	0.99521	0.93921	1.00000	0.96172	0.30900	1.00000	0.98771	
S9 (9)	1.00000	1.00000	1.00000	1.00000	0.98708	1.00000	1.00000	1.00000		1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99611	0.99500	0.75954	0.75559	0.99998	0.99724	1.00000	0.99886	0.63958	1.00000	0.99986	
S10 (10)	1.00000	1.00000	1.00000	1.00000	0.97694	1.00000	1.00000	1.00000	1.00000		1.00000	1.00000	1.00000	1.00000	1.00000	0.99827	0.99771	0.81459	0.81108	0.99999	0.99882	1.00000	0.99956	0.70433	1.00000	0.99996	
S11 (11)	1.00000	1.00000	1.00000	1.00000	0.96239	1.00000	1.00000	1.00000	1.00000	1.00000		1.00000	1.00000	1.00000	1.00000	0.99928	0.99901	0.86025	0.85723	1.00000	0.99953	0.99999	0.99984	0.76201	1.00000	0.99999	
S12 (12)	0.99998	1.00000	1.00000	1.00000	0.99927	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000		1.00000	1.00000	1.00000	0.96264	0.95622	0.52014	0.51560	0.99859	0.96987	1.00000	0.98274	0.39635	1.00000	0.99559	
S13 (13)	0.99998	1.00000	1.00000	1.00000	0.99937	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000		1.00000	1.00000	0.95973	0.95295	0.50969	0.50517	0.99838	0.96739	1.00000	0.98112	0.38678	1.00000	0.99505	
S14 (14)	1.00000	0.99817	1.00000	1.00000	0.73267	0.99862	1.00000	0.99999	1.00000	1.00000	1.00000	1.00000	1.00000		1.00000	1.00000	1.00000	0.99029	0.98986	1.00000	1.00000	0.99680	1.00000	0.97060	1.00000	1.00000	
S15 (15)	1.00000	0.99842	1.00000	1.00000	0.74299	0.99881	1.00000	0.99999	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000		1.00000	1.00000	0.98916	0.98868	1.00000	1.00000	0.99721	1.00000	0.96793	1.00000	1.00000	
S16 (16)	1.00000	0.70872	0.99999	0.96561	0.13595	0.72833	0.99665	0.92734	0.99611	0.99827	0.99928	0.96264	0.95973	1.00000	1.00000		1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.66532	1.00000	1.00000	0.99999
S17 (17)	1.00000	0.68757	0.99999	0.95955	0.12605	0.70764	0.99566	0.91714	0.99500	0.99771	0.99901	0.95622	0.95295	1.00000	1.00000	1.00000		1.00000	1.00000	1.00000	1.00000	1.00000	0.84338	1.00000	1.00000	0.99998	1.00000
S18 (18)	0.99737	0.18339	0.96912	0.53147	0.01247	0.19581	0.77060	0.42166	0.75954	0.81459	0.86025	0.52014	0.50969	0.99029	0.98916	1.00000	1.00000		1.00000	0.99996	1.00000	0.15878	1.00000	1.00000	0.96541	0.99999	
S19 (19)	0.99723	0.18082	0.96804	0.52692	0.01222	0.19310	0.76672	0.41738	0.75559	0.81108	0.85723	0.51560	0.50517	0.98986	0.98868	1.00000	1.00000	1.00000		0.99995	1.00000	0.15646	1.00000	1.00000	0.96424	0.99999	
S20 (20)	1.00000	0.93565	1.00000	0.99879	0.35549	0.94376	0.99998	0.99521	0.99998	0.99999	1.00000	0.99859	0.99838	1.00000	1.00000	1.00000	1.00000	0.99996	0.99995		1.00000	0.91559	1.00000	0.99963	1.00000	1.00000	
S21 (21)	1.00000	0.73532	1.00000	0.97238	0.14968	0.75424	0.99763	0.93921	0.99724	0.99882	0.99953	0.96987	0.96739	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000		0.69314	1.00000	1.00000	0.99999	1.00000	
S22 (22)	0.98864	1.00000	0.99946	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99999	1.00000	1.00000	0.99680	0.99721	0.66532	0.64338	0.15878	0.15646	0.91559	0.69314		0.75579	0.10292	0.99957	0.86263	
S23 (23)	1.00000	0.79415	1.00000	0.98437	0.18617	0.81102	0.99904	0.96172	0.99886	0.99956	0.99984	0.98274	0.98112	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.75579		1.00000	1.00000	1.00000
S24 (24)	0.98955	0.12058	0.92670	0.40681	0.00693	0.12962	0.65224	0.30900	0.63958	0.70433	0.76201	0.39635	0.38678	0.97060	0.96793	1.00000	1.00000	1.00000	1.00000	0.99963	1.00000	0.10292	1.00000		0.91985	0.99992	
S25 (25)	1.00000	0.99979	1.00000	1.00000	0.85256	0.99985	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99999	0.99998	0.96541	0.96424	1.00000	0.99999	0.99957	1.00000	0.91985		1.00000	
S26 (26)	1.00000	0.89044	1.00000	0.99612	0.27911	0.90212	0.99989	0.98771	0.99986	0.99996	0.99999	0.99559	0.99505	1.00000	1.00000	1.00000	1.00000	0.99999	0.99999	1.00000	1.00000	0.86263	1.00000	0.99992	1.00000		

Fig. 46. The effect of rainfall on reproductive swarming of honeybees of southern Ethiopia.

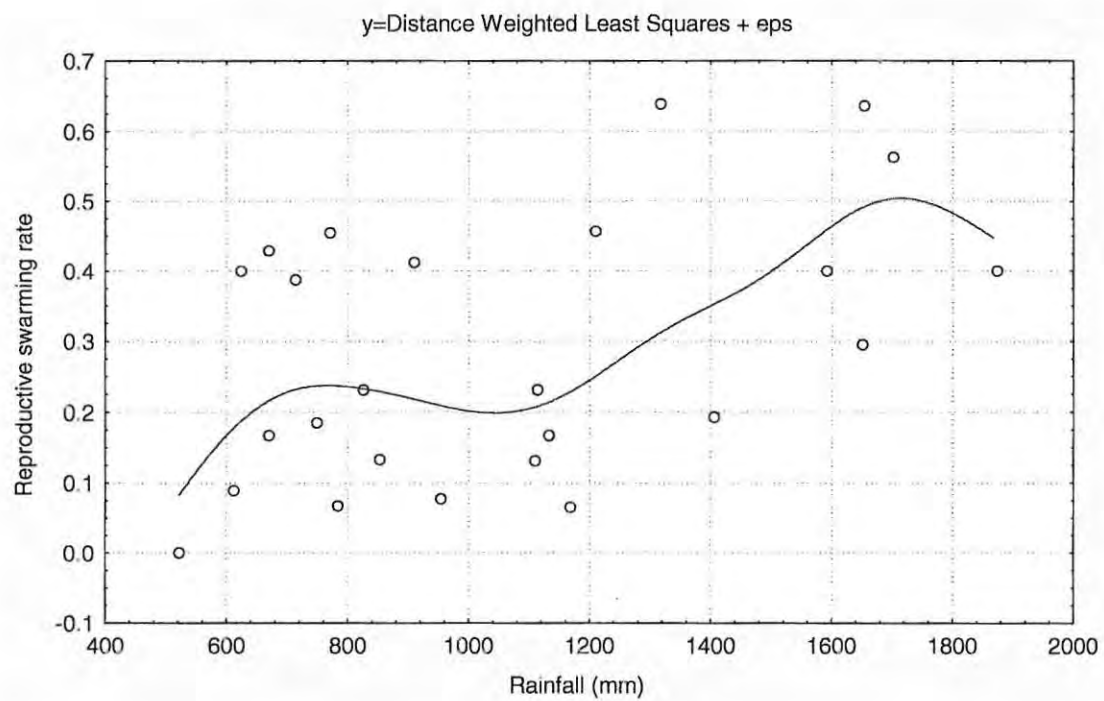


Table 56. Mean morphometric characters of honeybee colonies of the southern Ethiopian region (measurements in mm, angles in degree).

Number	Locality	Colony	SCUTLUM	PLATE	HAIR	T2 PIG	T3 PIG	T4 PIG	T3 LOG	T4 LOG	S3 LOG	S3 TRS	A B4	A N23	A O26
1	S1	1	0.2	0.85	0.207	2.85	4.3	4.2	1.988	1.92	2.536	2.134	108.54	87.2375	36.58
2	S1	2	0.15	0.2	0.182	1.95	3.7	3.3	1.942	1.86	2.51	2.093	103.29	86.883	36.141
3	S1	3	0.35	0.95	0.181	1.4	2.55	2.4	2	1.918	2.572	2.112	99.474	87.53	37.974
4	S1	4	0.1	0.2	0.182	0.6	1.5	1.05	1.976	1.904	2.55	2.086	108.51	86.877	35.079
5	S1	5	0	0.9	0.184	0.05	0.7	0.3	2.008	1.926	2.564	2.142	100.23	85.5995	38.86
6	S2	1	2.25	0.1	0.167	5.8	5.75	4.7	1.824	1.744	2.372	1.958	103.04	85.3995	39.609
7	S2	2	3.45	0	0.141	4.9	5	4.15	1.862	1.796	2.332	1.977	106.81	87.8535	39.529
8	S2	3	2.75	0.15	0.131	4.95	5	3.8	1.96	1.906	2.416	2.008	109.89	87.58	37.674
9	S2	4	2.6	0	0.129	4.4	4.3	2.6	1.984	1.886	2.412	1.948	100.84	86.2015	37.467
10	S2	5	2.5	0.15	0.134	4.05	3.85	3.2	1.98	1.896	2.4	1.952	103.73	87.376	38.752
11	S3	1	1.85	1.4	0.16	3.25	3.45	1.8	1.994	1.92	2.418	1.986	105.47	86.0275	38.946
12	S3	2	0.1	2.5	0.153	0.85	2.15	1.6	1.964	1.87	2.411	1.94	105.43	84.981	37.315
13	S3	3	0.05	0.35	0.172	0.3	1.4	1.05	1.996	1.942	2.462	2.018	104.38	88.5935	39.176
14	S3	4	2.05	1.85	0.18	3.15	3.95	2.35	1.978	1.904	2.498	1.946	104.07	90.4405	34.667
15	S3	5	0	1.2	0.175	0.05	0.55	0.15	1.992	1.926	2.522	2.064	105.78	87.9675	36.186
16	S4	1	0	0	0.19	0.25	0.7	0.6	2.056	1.974	2.52	2.054	103.33	89.9515	36.786
17	S4	2	0.1	0.1	0.166	0.1	0.3	0.1	1.98	1.948	2.452	1.964	96.578	91.6245	35.544
18	S4	3	0	0.6	0.191	0.3	1.1	0.85	1.972	1.9	2.43	1.992	101.06	88.4126	39.796
19	S4	4	0	0	0.171	0	0.2	0.15	2.012	1.95	2.472	2.044	98.683	89.8015	35.788
20	S4	5	0.2	0.75	0.176	0.15	1.1	1.1	1.97	1.924	2.486	2.076	105.81	86.684	42.376
21	S5	1	0.15	1.15	0.149	0.4	1.05	0.6	1.9	1.836	2.366	1.944	103.85	87.379	41.206
22	S5	2	1.2	1.6	0.163	1.45	1.9	1.3	1.888	1.826	2.414	1.966	108.64	90.963	40.53
23	S5	3	0	0.95	0.127	0.05	0.5	0.4	1.936	1.844	2.386	1.97	103.71	85.0735	37.25
24	S5	4	0	1.4	0.144	0.3	1.65	1.5	1.928	1.854	2.394	1.926	106.12	92.587	39.312

25	S5	5	0.35	1.45	0.162	0.85	1.95	1.6	1.99	1.924	2.434	1.97	103.5	88.3435	39.242
26	S6	1	0.35	0.65	0.146	0.6	1.4	1.3	1.956	1.922	2.454	1.998	100.15	90.7725	37.564
27	S6	2	0.85	0.55	0.158	0.95	1.3	1.1	2.002	1.938	2.434	2.024	109.28	90.0245	39.562
28	S6	3	0	1.35	0.169	0.1	0.5	0.7	1.974	1.95	2.466	2.052	108.9	88.916	38.531
29	S6	4	0.45	0.1	0.132	0.85	1.05	0.75	1.974	1.944	2.404	1.974	102.3	88.5475	39.707
30	S6	5	0.4	0.15	0.153	1.65	1.95	1.2	1.968	1.928	2.414	2.016	105.58	88.3545	37.53
31	S7	1	8.05	0	0.12	8.75	8.95	6.9	1.906	1.844	2.302	1.83	98.783	85.742	35.414
32	S7	2	3.55	0	0.116	8.7	8.7	7.2	1.936	1.872	2.33	1.94	106.1	87.799	39.089
33	S7	3	3.6	0	0.132	5.8	5.8	3.8	1.89	1.804	2.318	1.86	111.24	85.9545	37.903
34	S7	4	6.4	0	0.131	8.65	8.55	6.9	1.918	1.848	2.324	1.89	97.934	86.465	36.553
35	S7	5	7	0	0.121	8.4	8.35	6.2	1.914	1.822	2.324	1.93	106.61	89.298	39.716
36	S8	1	4.65	0.5	0.147	6.75	6.75	5.5	1.988	1.942	2.418	2.032	102.61	89.3245	39.061
37	S8	2	1.7	1.05	0.148	2.25	2.3	1.55	1.934	1.812	2.408	1.932	107.78	88.5685	37.57
38	S8	3	0.3	1.15	0.146	0.8	1.05	0.9	1.98	1.918	2.47	1.996	107.37	85.557	37.595
39	S8	4	2.65	0.4	0.155	5.2	5.2	4.75	1.97	1.911	2.464	1.996	104.48	87.536	38.044
40	S8	5	6.65	1.6	0.152	8.9	8.9	7.7	1.956	1.893	2.38	1.988	104.72	88.024	38.749
41	S9	1	0	0.85	0.169	0.15	0.55	0.45	1.962	1.89	2.356	1.942	103.67	90.1735	40.511
42	S9	2	0.8	0.25	0.157	1.25	1.25	0.95	1.912	1.86	2.356	1.968	103.79	90.188	39.468
43	S9	3	0.25	1.7	0.183	0.45	1.1	0.95	1.954	1.9085	2.422	2.024	100.51	89.6265	38.734
44	S9	4	0	0.1	0.18	0	0.25	0.25	2.006	1.942	2.432	1.972	108.99	83.9695	34.772
45	S9	5	2.15	0.1	0.181	5.25	5.25	4.35	2.046	1.988	2.443	2.078	104.09	84.2805	35.273
46	S10	1	1	0.3	0.17	1.3	1.4	1.05	2.062	2.01	2.502	2.04	104.39	87.0605	36.022
47	S10	2	0.4	1.5	0.162	0.85	1	0.85	1.996	1.938	2.444	2.022	105.97	86.0755	38.01
48	S10	3	1.6	1.6	0.175	1.8	1.9	1.55	2.006	1.956	2.484	2.034	104.84	87.6915	37.929
49	S10	4	0.2	0.8	0.155	0.45	0.85	0.75	2.008	1.946	2.416	1.952	102.56	90.715	38.311
50	S10	5	0.45	1.75	0.181	0.45	0.6	0.55	2.07	2.014	2.5	2.072	107.18	84.91	38.051
51	S11	1	0	0.3	0.175	0	0.25	0.25	2.044	1.988	2.454	2.152	103.29	88.542	37.026
52	S11	2	0	0.3	0.186	0.1	0.4	0.4	1.994	1.908	2.432	2.068	107.25	87.3035	37.904
53	S11	3	0.3	0.65	0.173	0.45	0.7	0.7	2.018	1.964	2.476	2.052	102.27	88.461	36.871
54	S11	4	0.2	0	0.174	0.45	0.45	0.3	2.056	1.982	2.466	2.068	105.33	87.46	38.766

55	S11	5	0	1.75	0.178	0.4	1.15	1.15	2.004	1.91	2.464	2.06	104.84	88.166	37.34
56	S12	1	0	0	0.201	0	0.2	0.2	2.132	2.072	2.6	2.208	107.37	86.649	36.877
57	S12	2	0	0.1	0.199	0.05	0.4	0.4	2.138	2.086	2.638	2.16	105.96	87.579	38.339
58	S12	3	0	0.4	0.193	0	0.4	0.4	2.1	2.02	2.57	2.118	102.21	89.1295	39.718
59	S12	4	0	0	0.194	0.05	0.45	0.45	2.078	2.018	2.516	2.082	101.91	86.849	38.846
60	S12	5	0	0.15	0.212	0	0.2	0.2	2.08	1.986	2.568	2.13	103.36	90.3615	36.584
61	S13	1	0	0	0.202	0	0	0	2.174	2.084	2.566	2.106	107.17	84.9335	36.467
62	S13	2	0	0	0.212	0	0	0	2.148	2.086	2.56	2.186	105.38	87.4285	38.36
63	S13	3	0	0.1	0.22	0	0	0	2.182	2.096	2.608	2.18	104	86.0085	36.446
64	S13	4	0	0	0.19	0	0	0	2.108	2.03	2.562	2.128	102.56	86.755	38.843
65	S13	5	0	0	0.219	0	0	0	2.15	2.07	2.598	2.098	103.17	89.8875	40.315
66	S14	1	0	0.1	0.191	0	0.05	0.05	2.136	2.066	2.594	2.146	112.48	87.679	36.253
67	S14	2	2.55	0.65	0.189	2.65	2.7	2.5	2.03	1.97	2.486	2.06	107.11	89.258	35.381
68	S14	3	4	0.25	0.167	5.85	5.9	4.9	2.038	1.98	2.502	2.076	103.69	88.436	38.94
69	S14	4	0.2	0	0.16	0.9	0.9	0.85	2.002	1.934	2.452	2.066	104.75	86.793	37.754
70	S14	5	0.45	0.2	0.183	0.45	0.45	0.45	2.102	2.024	2.524	2.116	100.5	87.6565	37.089
71	S15	1	3.35	0	0.143	5.8	5.75	4.75	1.98	1.898	2.358	1.928	98.978	89.3365	37.112
72	S15	2	6.1	0	0.177	7.65	7.65	6.6	2.002	1.944	2.406	1.99	104.23	90.0675	40.354
73	S15	3	2.9	0	0.171	3.55	3.55	3.55	2.006	1.957	2.412	1.964	105.61	85.627	36.724
74	S15	4	5.35	0.7	0.134	6.2	6.2	5.1	2.036	1.962	2.474	2.044	109.7	88.191	35.127
75	S15	5	5.85	0	0.145	6.15	5.95	5.4	1.99	1.928	2.45	2.05	106.37	86.9515	36.173
76	S16	1	4.15	0	0.168	7.95	7.75	7.25	2.094	2.06	2.528	2.122	103.82	88.8725	35.88
77	S16	2	5.25	0	0.147	6.3	5.95	5.05	2.08	2.034	2.478	2.098	104.93	89.745	36.477
78	S16	3	5.75	0	0.181	8.6	8.55	7.15	2.03	1.97	2.396	2.036	107.63	88.359	34.639
79	S16	4	5.05	0.1	0.153	6.25	6.15	5.6	2.054	2.022	2.444	2.078	107.18	89.9145	36.561
80	S16	5	5.3	0	0.151	6.55	6.55	5.7	2.099	2.064	2.53	2.074	103.98	88.523	37.181
81	S17	1	6.2	0	0.203	8.85	8.65	7.35	1.994	1.959	2.44	1.986	102.33	85.2315	37.591
82	S17	2	5.8	0.4	0.17	8.75	8.75	7.7	2.008	1.956	2.426	1.984	102.17	84.6555	37.423
83	S17	3	7.35	0	0.166	8.95	8.9	8.9	2.034	1.984	2.432	2.002	102.15	89.009	33.879
84	S17	4	6.3	0	0.177	8.95	8.6	7.7	1.998	1.962	2.4	1.97	101.74	85.296	35.467

85	S17	5	7.3	0.45	0.18	8.7	8.55	7.6	2.014	1.968	2.398	1.952	101	85.45	36.232
86	S18	1	0	0.7	0.192	0.35	0.45	0.45	2.1	1.976	2.53	2.042	101.88	87.329	37.348
87	S18	2	0.75	1.6	0.182	0.9	1.6	1.35	2.032	1.952	2.512	2.036	107.85	87.784	34.514
88	S18	3	0	0.2	0.199	0.35	0.35	0.15	2.1	2.046	2.558	2.064	103.23	86.4535	33.213
89	S18	4	0	1.05	0.2	0.55	1.75	1.55	2.07	2.018	2.486	2.04	107.4	86.7095	37.229
90	S18	5	0	0.3	0.186	0.25	1.35	1.25	2.012	1.946	2.458	1.99	110.1	86.6345	34.528
91	S19	1	7.5	0.75	0.175	8.7	8.55	6.95	2.028	1.98	2.438	2.056	105.73	89.8535	36.741
92	S19	2	1.9	0.6	0.191	2.7	3.15	2.85	2.046	2.004	2.438	2.01	105.8	86.555	32.43
93	S19	3	6.5	0	0.185	7.45	7.45	7.1	2.02	1.978	2.48	2.06	107.23	86.264	35.499
94	S19	4	2	0.7	0.188	3.3	3.9	3.1	2.002	1.958	2.392	1.928	102.01	87.343	37.949
95	S19	5	3.2	0.45	0.19	4.85	4.8	4.45	2.002	1.924	2.386	2.004	106.58	88.3	34.182
96	S20	1	2.05	0.1	0.23	3.8	4.3	3.75	2.136	2.058	2.6	2.104	106.15	85.825	35.82
97	S20	2	0.45	0.1	0.189	1.25	1.45	1.25	2.144	2.068	2.576	2.056	104.35	88.1495	35.765
98	S20	3	0.15	0.2	0.187	0.45	0.65	0.5	2.146	2.07	2.62	2.13	101.74	85.726	37.161
99	S20	4	2.3	0	0.166	3.85	4	3.05	2.108	2.032	2.544	2.068	107.73	87.4435	36.559
100	S20	5	1.4	1.55	0.219	3.5	3.45	2.1	2.102	2.044	2.564	2.1	106.64	86.947	37.573
101	S21	1	0.3	0.3	0.192	0.75	1.05	0.9	2.05	2.004	2.482	1.998	106.71	87.2425	37.748
102	S21	2	0	1.65	0.178	0	0.4	0.4	2.106	2.038	2.526	2.088	109.68	88.2765	38.263
103	S21	3	0	1.85	0.202	0.05	0.3	0.25	2.146	2.112	2.598	2.13	114.89	84.2915	35.992
104	S21	4	0	1.9	0.198	0.15	1.35	1.35	2.084	2.01	2.532	2.036	105.95	87.8015	32.95
105	S21	5	0	0.95	0.197	0.1	1.3	1.3	2.118	2.05	2.568	2.11	105.97	85.264	35.974
106	S22	1	0.75	0.7	0.178	1.35	1.65	1.15	2	1.938	2.396	1.916	104.71	88.571	39.08
107	S22	2	1.4	1.4	0.179	2.15	2.15	1.65	2.006	1.946	2.408	2.02	104.87	90.0065	38.842
108	S22	3	1.4	0.85	0.183	2.65	2.65	2.3	1.992	1.928	2.41	1.966	98.872	86.519	38.537
109	S22	4	0.8	0.4	0.177	0.9	0.95	0.95	2.01	1.932	2.376	1.948	103.46	84.127	38.423
110	S22	5	2.9	0.05	0.165	3.55	3.6	3.2	2.022	1.936	2.4	1.966	103.44	87.417	38.445
111	S23	1	0	0	0.189	0	0	0	2.112	2.078	2.598	2.126	105.69	84.669	36.209
112	S23	2	1.05	0	0.188	1.25	1.2	0.7	2.132	2.084	2.642	2.158	103.36	87.2865	36.565
113	S23	3	0	0	0.182	0	0	0	2.158	2.098	2.576	2.118	106.73	86.592	35.575
114	S23	4	0	0	0.169	0	0	0	2.102	2.016	2.612	2.138	103.5	86.892	37.745

115	S23	5	0	0	0.181	0	0	0	2.08	2.024	2.514	2.064	104.25	84.5185	35.277
116	S24	1	0	0.3	0.212	0	0	0	2.076	2.022	2.498	2.034	103.56	86.146	36.636
117	S24	2	0	0.7	0.191	0	0	0	2.062	1.992	2.548	2.032	106.4	85.652	35.667
118	S24	3	0	0.1	0.18	0	0.2	0.2	2.072	2	2.506	2.01	103.21	89.409	32.529
119	S24	4	0	1.25	0.204	0	0.3	0.3	2.05	2.004	2.494	2.03	99.208	86.6025	36.797
120	S24	5	0	0	0.201	0	0.5	0.5	2.074	2.036	2.546	2.054	96.001	88.3605	34.37
121	S25	1	0	0.7	0.18	0	0.3	0.3	2.138	2.082	2.552	2.082	107.31	90.285	38.672
122	S25	2	0	0.3	0.184	0	0.2	0.1	2.094	2.038	2.62	2.126	105.6	87.333	37.648
123	S25	3	0	0.1	0.178	0	0.4	0.4	2.094	2.043	2.562	2.126	107.49	86.2265	37.839
124	S25	4	0	0.15	0.192	0	0.2	0	2.092	2.032	2.526	2.05	106.76	86.7515	36.293
125	S25	5	0	0.05	0.207	0	0.1	0.1	2.094	2.03	2.528	2.046	105.98	88.016	35.936
126	S26	1	0	0.5	0.182	0	0.2	0.2	2.076	2.004	2.46	1.996	107.71	84.018	37.192
127	S26	2	1.3	0.1	0.189	1.4	1.4	0.65	2.04	1.98	2.398	1.966	103.22	88.426	36.243
128	S26	3	0	0.8	0.188	1.05	1.05	0.1	2.15	2.064	2.618	2.148	101.59	90.462	36.035
129	S26	4	0.4	0	0.141	0.35	0.35	0.15	2.06	2.014	2.492	2.024	98.652	85.2385	36.699
130	S26	5	5.35	0.1	0.181	7.65	7.55	4.35	2.072	1.972	2.564	2.09	102.45	86.0115	36.103

Table 57. Climatic data of honeybee colony sampling localities (1920 – 1980yrs).

Table 57.1. Monthly temperatures and rainfall for Colony sampling locality, Gechi (S1).

Geographical co-ordinate: 8°21'2"N 35°51'44" E

Altitude: 1515.7 m.a.s.l.

Annual mean T⁰: 13.5 - 27.7 °C

Annual mean Rf: 1592 mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	28.4	12.1	17
2	February	30	13.1	27
3	March	30.7	14.3	46
4	April	30.1	14.6	82
5	May	27.9	14.4	194
6	June	26.1	14.4	254
7	July	24.7	14	268
8	August	24.7	13.7	268
9	September	25.9	13.7	246
10	October	27.3	13.4	115
11	November	27.5	12.4	54
12	December	29	11.9	17

Table 57.2. Monthly temperatures and rainfall for colony sampling locality, Itang (S2).

Geographical co-ordinate: 8°11'30.1"N 34°16'07" E

Altitude: 455.5 m.a.s.l.

Annual mean T⁰: 19.4 – 34.7 °C

Annual mean Rf: 1027 mm.

No.	Months	Monthly mean temperature		Monthly mean rainfall
		Maximum	Minimum	
1	January	35.9	18.1	5
2	February	38.3	19.2	5
3	March	38.7	20.6	24
4	April	37.4	20.9	54
5	May	34.8	19.6	128
6	June	33.8	19.3	137
7	July	32.5	18.9	189
8	August	32.3	18.8	195
9	September	31.8	19.3	155
10	October	33	19.7	87
11	November	34	19.5	35
12	December	34.4	18.6	9

Table 57.3. Monthly temperatures and rainfall for colony sampling locality, Masha (S3).

Geographical co-ordinate: 7°46'4.5"N 35°28'13.3" E

Altitude: 2110.1 m.a.s.l.

Annual mean T⁰: 10.7 – 24.1°C

Annual mean Rf: 1874 mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	25.2	10.1	30
2	February	25.6	10.5	51
3	March	25.8	11.3	93
4	April	25.6	11.15	135
5	May	24.5	11.2	224
6	June	23	11	260
7	July	21.8	10.9	272
8	August	22	11.2	277
9	September	22.7	10.8	273
10	October	24	10.5	139
11	November	23.8	10.1	78
12	December	24.6	9.9	37

Table 57.4. Monthly temperatures and rainfall for colony sampling locality, Woshi (S4).

Geographical co-ordinate: 7°19'16.6"N 36°1'24.4" E

Altitude: 1750.7 m.a.s.l.

Annual mean T⁰: 11.8 – 26.7 °C

Annual mean Rf: 1651 mm:

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	28	10.5	33
2	February	28.4	11.3	56
3	March	28.5	12.2	100
4	April	27.9	12.8	144
5	May	27.4	12.8	197
6	June	26	12.5	215
7	July	24.5	12.5	217
8	August	24.7	12.6	227
9	September	25.4	12.1	216
10	October	26.4	11.4	124
11	November	26.6	10.6	79
12	December	27.1	10.2	38

Table 57.5. Monthly temperatures and rainfall for colony sampling locality, Waka (S5).

Geographical co-ordinate: 7^o4'47"N 37^o11'12" E

Altitude: 1719 m.a.s.l.

Annual mean T^o: 13.1 – 27.2 °C

Annual mean Rf: 1317 mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	29	12.1	31
2	February	29.6	13.3	43
3	March	29.5	13.8	94
4	April	28.2	14	137
5	May	27.3	13.8	150
6	June	25.7	13.8	166
7	July	24.1	13.7	188
8	August	24.3	13.6	183
9	September	25.6	13.4	142
10	October	26.9	12.6	104
11	November	27.8	12.4	47
12	December	28.3	11.4	26

Table 57. 6. Monthly temperatures and rainfall for colony sampling locality, Sodo (S6).

Geographical co-ordinate: 6^o49'22.6"N 37^o43'26. 2" E

Altitude: 1758.5

Annual mean T^o: 12.8 – 27.1°C

Annual mean Rf: 1210mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	29.3	11.9	30
2	February	29.7	13.2	40
3	March	29.4	13.4	89
4	April	28.1	13.5	141
5	May	27.2	13.2	144
6	June	25.4	13.3	132
7	July	23.7	13.3	176
8	August	23.9	13.1	162
9	September	25.6	13.2	122
10	October	26.9	12.4	106
11	November	28.1	12	40
12	December	28.5	11.2	22

Table 57.7. Monthly temperatures and rainfall for colony sampling locality, Woyito (S7).

Geographical co-ordinate: 5°16'40.4"N 37°3'33.4"E

Altitude: 921.1m.a.s.l.

Annual mean T⁰: 17.8 – 28.9 °C

Annual mean Rf: 610 mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	31.6	18.2	24
2	February	31.9	18.4	30
3	March	31.5	18.6	67
4	April	28.8	18	108
5	May	27.4	18.2	88
6	June	27.2	17.7	28
7	July	26.8	17.2	33
8	August	25.3	17.2	31
9	September	28.3	17.5	50
10	October	28.3	17.8	67
11	November	29.2	17.5	69
12	December	30.6	17.4	13

Table 57.8. Monthly temperatures and rainfall for colony sampling locality, Konso (S8).

Geographical co-ordinate: 5°20'17.7"N 37°25'34.8"E

Altitude: 1436.1 m.a.s.l.

Annual mean T⁰: 16.4 – 26.7 °C

Annual mean Rf: 749 mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	29.4	14.9	29
2	February	30.1	15	40
3	March	29.2	15.2	79
4	April	26.6	15.1	136
5	May	25	15.1	108
6	June	25	14.3	30
7	July	24.4	14	33
8	August	23.3	14	32
9	September	26.2	14.3	71
10	October	26.1	14.8	102
11	November	27.1	14.4	76
12	December	28.2	14.1	5

Table 57.9. Monthly temperatures and rainfall for colony sampling locality, Arero (S9).

Geographical co-ordinate: 4°49'54.3"N 38°52'49. 6" E
 Altitude: 1483.2 m.a.s.l.
 Annual mean T⁰: 14.8 – 26.7 °C
 Annual mean Rf: 670mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	29.7	15.1	19
2	February	30.5	15	32
3	March	29.3	15.8	61
4	April	27	15.7	168
5	May	25.5	15.5	120
6	June	24.7	14.4	19
7	July	24	13.9	8
8	August	24	14.1	6
9	September	26.3	14.2	28
10	October	25.6	14.8	119
11	November	26.4	14.2	64
12	December	27.9	14.2	21

Table 57.10. Monthly temperatures and rainfall for colony sampling locality, Har Kalo (S10).

Geographical co-ordinate: 5°33'7.1"N 39°23'30. 5" E
 Altitude: 1427.3 m.a.s.l.
 Annual mean T⁰: 13.7 – 27.5 °C
 Annual mean Rf: 714 mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	30	13.1	15
2	February	30.8	13.6	29
3	March	29.6	14.6	57
4	April	27.8	15	180
5	May	26.6	15	137
6	June	25.9	14	17
7	July	25	13.7	12
8	August	25.1	13.6	16
9	September	27.1	13.7	45
10	October	26.3	13.9	134
11	November	26.8	12.6	53
12	December	28.4	12.3	14

Table 57.11. Monthly temperatures and rainfall for colony sampling locality, Eshedo Aliyo (S11).

Geographical co-ordinate: 6°17'5.2"N 38°39'41.8"E

Altitude: 2157.8 m.a.s.l.

Annual mean T⁰: 8.8 – 23.6°C

Annual mean Rf: 1110mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	25.8	7.2	32
2	February	25.7	8	45
3	March	25.2	9.1	89
4	April	24.2	10	170
5	May	23.6	9.8	135
6	June	22.7	9.1	84
7	July	21.3	9.6	94
8	August	21.4	9.5	99
9	September	22.4	9.4	134
10	October	22.8	9.3	137
11	November	23.5	7.7	61
12	December	24.4	6.9	24

Table 57.12. Monthly temperatures and rainfall for colony sampling locality, Serofta (S12).

Geographical co-ordinate: 6°51'58.2"N 39°1'5. 1"E

Altitude: 2377.4 ma.s.l.

Annual mean T⁰: 6.9 - 23 °C

Annual mean Rf: 954mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	24.2	5.5	30
2	February	24.1	6.3	39
3	March	24.5	7	73
4	April	23.9	8.1	105
5	May	24.3	8.1	72
6	June	23.7	7.1	80
7	July	21.3	8	157
8	August	21.2	7.8	135
9	September	21.3	7.5	128
10	October	21.9	7.1	82
11	November	22.7	5.3	28
12	December	23.1	4.7	19

Table 57. 13. Monthly temperatures and rainfall for colony sampling locality, Mararo (S13).

Geographical co-ordinate: 7°24'37.5"N 39°14' 30.1"E
 Altitude: 2868.5 m.a.s.l.
 Annual mean T⁰: 5.9-18.8 °C
 Annual mean Rf: 1133 mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	20.2	4.6	34
2	February	20.5	5.8	53
3	March	20.6	6.6	85
4	April	19.7	7.3	105
5	May	19.5	7	98
6	June	18.7	6.4	117
7	July	16.9	6.7	194
8	August	16.7	6.3	190
9	September	17.4	6.2	127
10	October	17.9	5.7	67
11	November	18.6	4.5	42
12	December	19.5	3.7	15

Table 57.14. Monthly temperatures and rainfall for colony sampling locality, Wolta'e Atote (S14).

Geographical co-ordinate: 7°15'55.4"N 40°34' 25.1"E
 Altitude: 2050m.a.s.l.
 Annual mean T⁰: 10.5-24.4 °C
 Annual mean Rf: 784 mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	24.8	8.7	13
2	February	25.8	9.4	22
3	March	25.9	10.8	55
4	April	25	11.9	112
5	May	25	11.9	95
6	June	24.8	11.5	57
7	July	23.4	11.6	93
8	August	23.4	11.4	96
9	September	24.1	11.6	95
10	October	23.5	10.8	78
11	November	23.3	8.9	49
12	December	24.1	8.0	13

Table 57.15. Monthly temperatures and rainfall for colony sampling locality, Karre Tule (S15).

Geographical co-ordinate: 7°3'49.0"N 41°4'. 4.5"E
 Altitude: 1194.3 m.a.s.l.
 Annual mean T⁰: 16.2-30.1 °C
 Annual mean Rf: 522mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	30.6	14.1	9
2	February	31.6	15.2	15
3	March	31.7	16.7	37
4	April	30.7	17.4	98
5	May	30	17.5	90
6	June	29.7	17.1	30
7	July	28.7	17.4	42
8	August	28.7	17.1	41
9	September	30.2	17.5	53
10	October	29.6	16.3	64
11	November	29.3	14.3	32
12	December	29.9	13.2	7

Table 57.16. Monthly temperatures and rainfall for colony sampling locality, Dudi Affi (S16).

Geographical co-ordinate: 9°12'21.6"N 42°57'57. 1" E
 Altitude: 1559.3 m.a.s.l.
 Annual mean T⁰: 12.5-27.9 °C
 Annual mean Rf: 624mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	27.1	9.3	8
2	February	28.1	10.2	21
3	March	29.5	12.1	38
4	April	28.8	14	82
5	May	29	14.7	93
6	June	28	15.2	54
7	July	26.7	15	67
8	August	27	14.8	104
9	September	28.1	14.4	87
10	October	28.3	11.5	42
11	November	27.3	9.9	15
12	December	26.7	9.4	8

Table 57.17. Monthly temperatures and rainfall for colony sampling locality, Deriri Arba (S17).

Geographical co-ordinate: 9^o7'9.8"N 42^o23'15" E

Altitude: 1449.5 m.a.s.l.

Annual mean T^o: 14.4 –28.3 °C

Annual mean Rf: 670 mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	27.7	11.8	12
2	February	28.9	12.9	25
3	March	29.8	14.4	47
4	April	29.1	15.7	87
5	May	29.3	16.3	90
6	June	28.4	16.6	66
7	July	27.5	16.1	86
8	August	27.2	15.7	96
9	September	28.1	15.5	90
10	October	28.6	13.8	44
11	November	27.8	12.2	15
12	December	27.4	11.8	7

Table 57.18. Monthly temperatures and rainfall for colony sampling locality, Boke Tiko (S18).

Geographical co-ordinate: 8^o43'40.5"N 40^o38'33.4" E

Altitude: 1574.8 m.a.s.l.

Annual mean T^o: 14.3 –28.1 °C

Annual mean Rf: 910 mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	26.7	11.9	19
2	February	28	13	28
3	March	28.8	14.5	58
4	April	29.2	15.5	102
5	May	29.8	16.1	78
6	June	30.2	16.5	91
7	July	27.7	15.7	161
8	August	27.2	15.5	143
9	September	28.3	15.6	123
10	October	28.2	14.2	50
11	November	26.9	12.1	37
12	December	26.4	11.2	13

Table 57.19. Monthly temperatures and rainfall for colony sampling locality, Nazrieth (S19).

Geographical co-ordinate: 8°32'7.5"N 39°17'37.7" E

Altitude: 1699.3 m.a.s.l.

Annual mean T⁰: 12.9-27°C

Annual mean Rf: 826 mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	26.3	10.5	10
2	February	27.3	11.7	21
3	March	28.7	13.5	46
4	April	29.1	14.3	60
5	May	29.6	14.3	41
6	June	28.7	14.8	78
7	July	24.9	14.3	200
8	August	25.2	14.4	210
9	September	26.4	14.1	107
10	October	27	11.9	27
11	November	26	10.6	14
12	December	25.3	9.9	6

Table 57.20. Monthly temperatures and rainfall for colony sampling locality, Alage (S20).

Geographical co-ordinate: 7°36'14"N 38°24'27.4"E

Altitude: 1830.5 m.a.s.l.

Annual mean T⁰: 11.4 – 125.6 °C

Annual mean Rf: 771 mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	26.5	10	18
2	February	27.1	11.2	32
3	March	27.4	12	61
4	April	27	12.7	76
5	May	26.3	12.3	84
6	June	25	12.3	82
7	July	23.3	12.7	139
8	August	23.3	12.5	117
9	September	24	12.1	106
10	October	25.4	11.1	31
11	November	25.6	9.8	15
12	December	26.2	8.6	6

Table 57.21. Monthly temperatures and rainfall for colony sampling locality, Hosaina (S21).

Geographical co-ordinate: 7°33'8"N 37°53'27.3"E

Altitude: 2276.2 m.a.s.l.

Annual mean T⁰: 9.1–23.7 °C

Annual mean Rf: 1168 mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	25.3	7.6	28
2	February	26.1	9	39
3	March	26	10.1	94
4	April	24.3	10.7	141
5	May	23.8	10	118
6	June	22.2	9.8	131
7	July	21	10.1	170
8	August	20.9	9.9	185
9	September	22	9.6	152
10	October	23.4	8.3	66
11	November	24.2	7.7	20
12	December	25	6.7	20

Table 57.22. Monthly temperatures and rainfall for colony sampling locality, Sawla (S22).

Geographical co-ordinate: 6°18'4.1"N 36°52'54. 5"E

Altitude:

Annual mean T⁰: 12.2- 23.7°C

Annual mean Rf: 1406 mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	25.6	11.7	37
2	February	26.2	12.4	55
3	March	26.1	12.9	112
4	April	24.3	12.8	184
5	May	23.4	12.8	166
6	June	22	12.1	142
7	July	20.8	12	141
8	August	21.2	12	161
9	September	22.4	12	149
10	October	23.3	12.3	139
11	November	24.3	12	78
12	December	24.9	12.1	38

Table 57.23. Monthly temperatures and rainfall for colony sampling locality, Effo Yachi (S23).

Geographical co-ordinate: 7°57'40.0"N 36°30'23"E

Altitude: 1876.8 m.a.s.l.

Annual mean T⁰: 11.9-26.2°C

Annual mean Rf: 1702 mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	27.2	10.5	29
2	February	28.2	11.6	44
3	March	28.4	12.5	84
4	April	28	13	117
5	May	26.6	12.8	182
6	June	25	12.7	253
7	July	23.5	12.6	271
8	August	23.5	12.5	274
9	September	24.6	12.2	242
10	October	25.9	11.5	119
11	November	26.4	10.7	59
12	December	27.1	10.2	25

Table 57.24. Monthly temperatures and rainfall for colony sampling locality, Boter Bacho (S24).

Geographical co-ordinate: 8°21'57.3"N 37°16'24. 2" E

Altitude: 2957.9 m.a.s.l.

Annual mean T⁰: 6.6-19.5°C

Annual mean Rf: 1654 mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	21	5.9	27
2	February	21.1	6.7	41
3	March	21.3	7.2	97
4	April	20.9	7.6	135
5	May	19.9	7.3	155
6	June	18.2	6.9	226
7	July	17	7.3	276
8	August	17	7.1	294
9	September	18	6.8	242
10	October	19.2	5.9	96
11	November	19.9	5.5	36
12	December	20.5	5	23

Table 57.25. Monthly temperatures and rainfall for colony sampling locality, Roge (S25).

Geographical co-ordinate: 8°30'37.8"N 37°59'56.34" E
 Altitude: 2194.2 m.a.s.l.
 Annual mean T⁰: 9.6- 24.1°C
 Annual mean Rf: 1114 mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	25.3	8.6	13
2	February	25.9	9.8	37
3	March	26.2	10.5	69
4	April	25.5	11.1	94
5	May	25.1	10.8	96
6	June	23	10.3	168
7	July	21.1	10.9	223
8	August	21.2	10.1	218
9	September	22.4	9.7	139
10	October	24	8.5	29
11	November	24.4	7.8	14
12	December	24.7	7.3	9

Table 57.26. Monthly temperatures and rainfall for colony sampling locality, Gado Lama (S26).

Geographical co-ordinate: 7°40'34.2"N 39°46'20.7" E
 Altitude: 2121.1 m.a.s.l.
 Annual mean T⁰: 9.6-24 °C
 Annual mean Rf: 853 mm.

No.	Months	Monthly mean temperature (°C)		Monthly mean rainfall
		Maximum	Minimum	
1	January	24	7.8	15
2	February	24.8	8.4	26
3	March	25.4	9.7	63
4	April	25	11	90
5	May	25.3	10.9	66
6	June	25	10.8	79
7	July	22.8	11	141
8	August	22.7	10.9	146
9	September	23.2	10.8	116
10	October	23.2	9.7	61
11	November	23	7.8	35
12	December	23.4	6.8	9

Source: Hutchinson *et al.*, (1996).

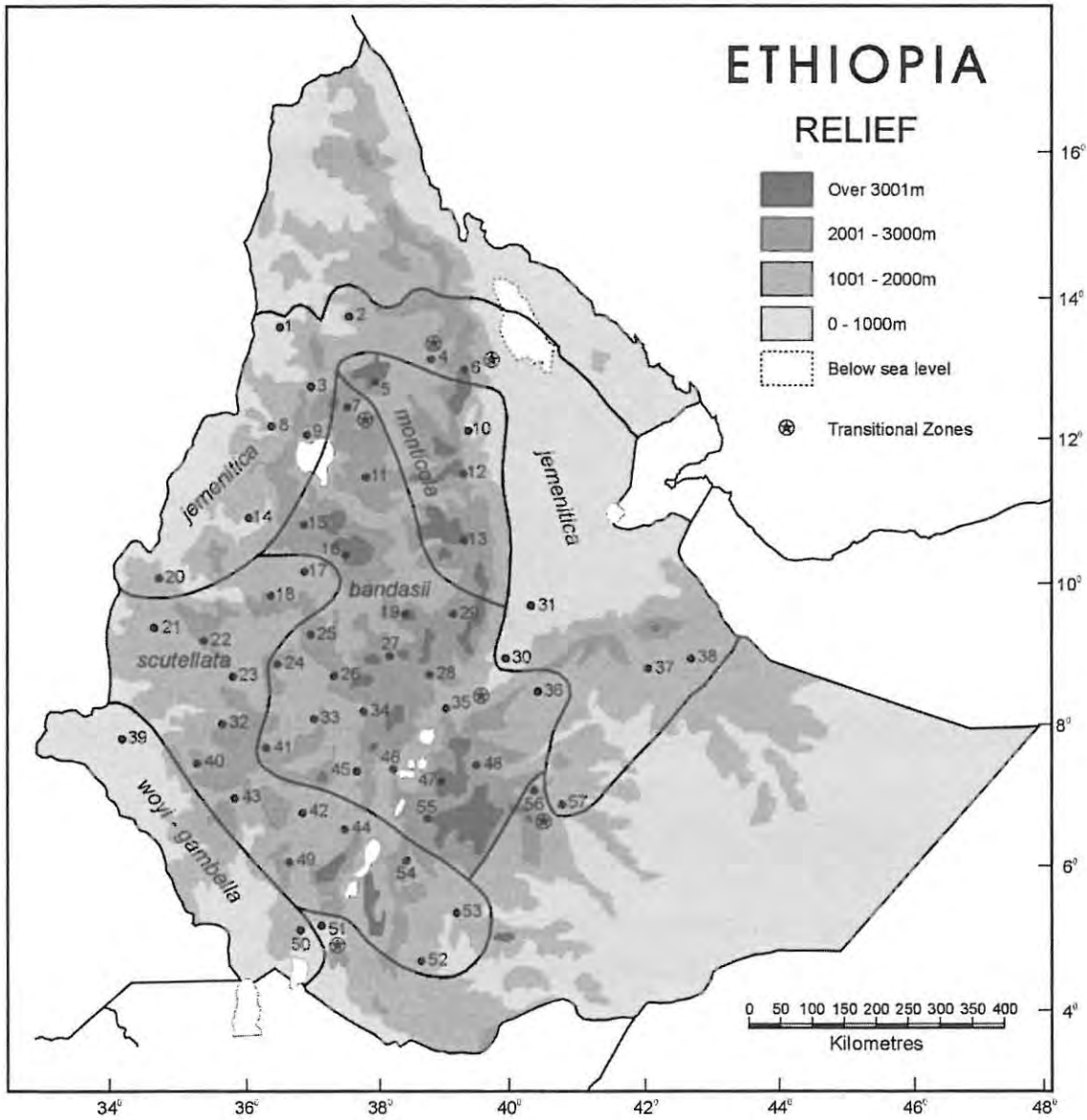
Fig. 47. Annual rainfall distribution in Ethiopia.



Source: Mesfin (1970).

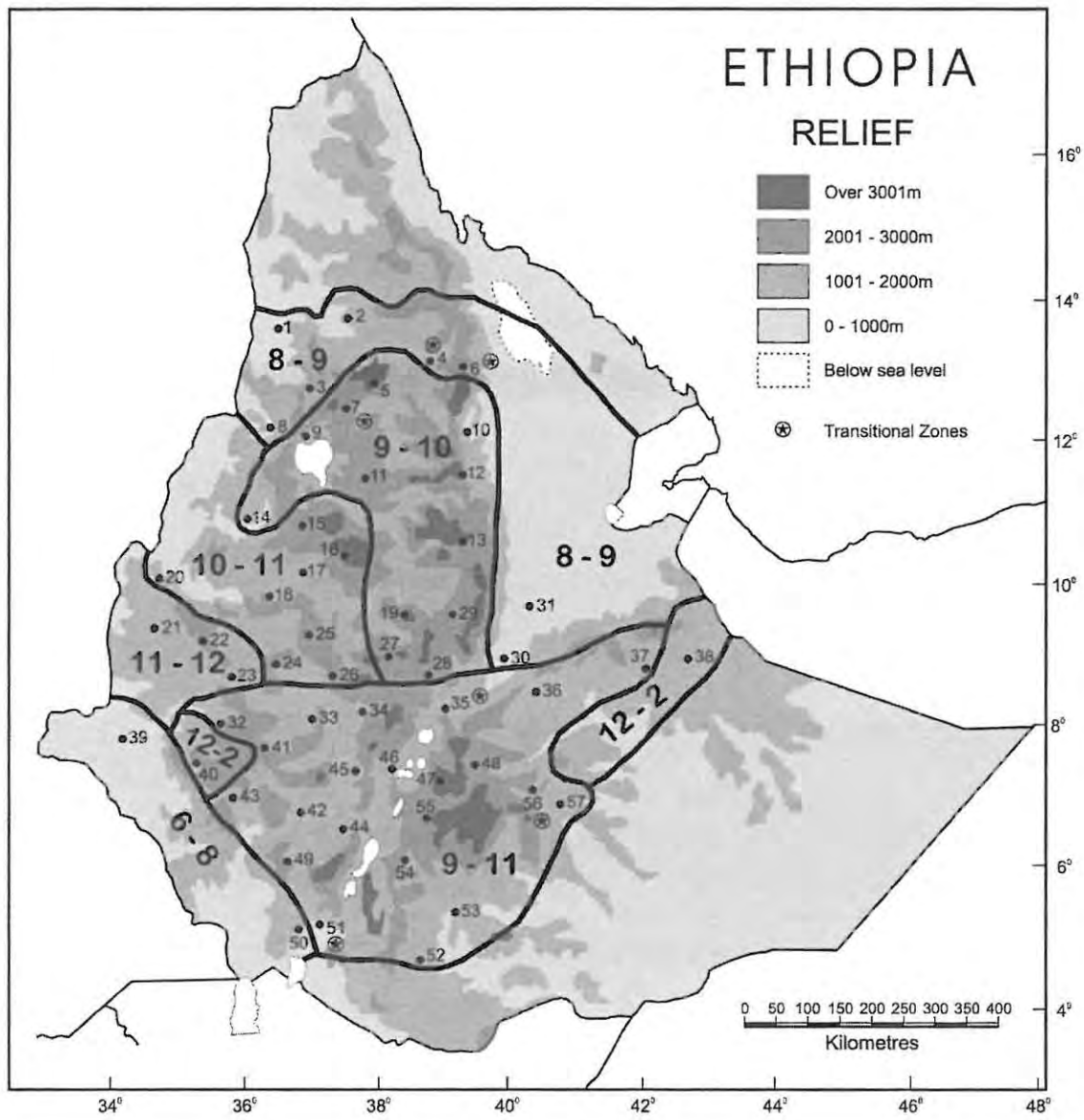
Fig. 48. Physiography, localities and geographical distribution of the 5 honeybee clusters in Ethiopian region.

Figure 1.



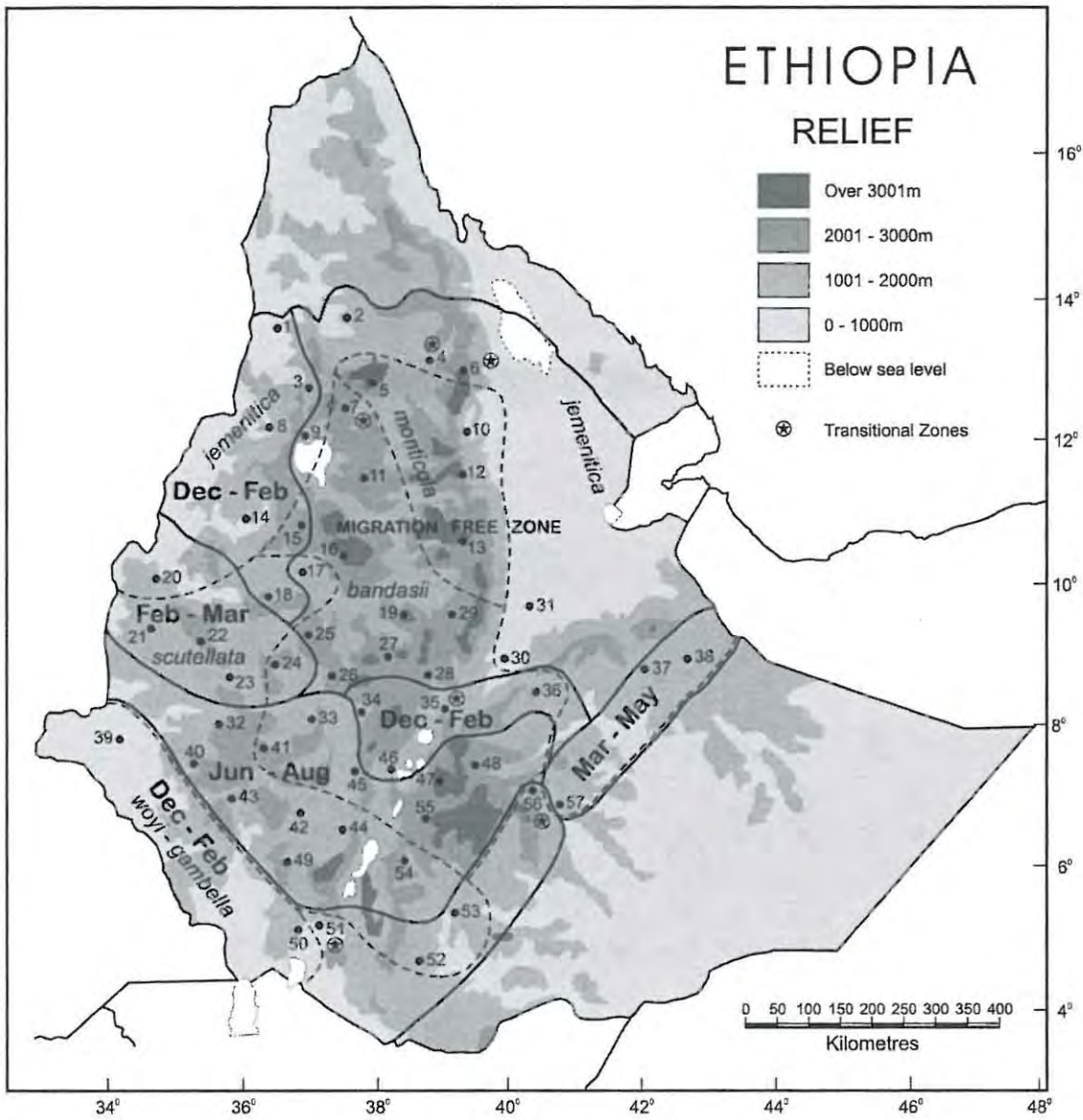
Source: Amssalu *et al.* (2002).

Fig. 49. Reproductive swarming phenology of honeybees in Ethiopian region.



Source: Nuru *et al.* (2002).

Fig. 50. Migration phenology of honeybees in Ethiopian region.



Source: Nuru *et al.* (2002).

