6. DIFFERENTIAL ATTRACTIVENESS OF SOUTH AFRICAN SUNFLOWER CULTIVARS TO BEES

6.1. INTRODUCTION

Foraging honeybees discriminate between crops and even cultivars of the same crop when a choice is offered (Free, 1970). These preferences among foragers are determined by quantity and / or quality of nectar (Burmistrov, 1965; Vansell, 1934). Pollination and the eventual crop yield, is indirectly affected as foraging is influenced by availability and quality of nectar.

Factors which influence nectar production are discussed in full by Beutler (1953). These include air humidity, soil moisture, rain and temperature. General plant characteristics which influence nectar secretion include size of nectary, position of flower on plant, diameter of shoot, cultivar and age of flower. Because of these numerous environmental and plant variables, the quantity of nectar secreted cannot be used as an index of the performance of the nectary. The true secretory activity of a nectary can only be estimated from the sugar content of nectar that is secreted by a flower in 24 hours (Beutler, 1953).

Cirnu et al. (1974) and Shein et al. (1980) indicated that the accessibility of nectar and other morphological cultivar

characteristics further influence preferences of honeybees. Corollar tube length is the most important discriminating factor in the case of sunflower as it limits accessibility.

Pigmentation is another important morphological characteristic. The flower heads of cultivars with dark pigmentation of stigmas are very similar in appearance to the heads of cultivars with light coloured stigmas in post-bloom stage. Dark pigmentation might resemble the signal that flowering has finished and nectar is no longer available (Shein et al., 1980). Beutler (1953) reached the conclusion that post-pistillate florets secrete less nectar. This was confirmed by Furgala et al. (1976).

With regard to accessibility of nectar, the tongue lengths was measured of sunflower-foraging bees belonging to three different families. These were the African honeybee, Apis mellifera scutellata (Apidae), a long tongue solitary bee, Anthophora sp. (Anthophoridae) and a short tongue solitary bee, Lasioglossum sp. (Halictidae). In taxonomically related studies of bee tongue lengths, the overall length is measured from the distal point of the submentum to the flabellum on the posterior end of the glossa (Ruttner, 1978 and Winston, 1979).

To determine the effective depth to which the different genera can extend their proboscis in the tubular sunflower

floret, both behavioural and morphological phenomena were investigated. The honeybee can insert its proboscis (the labiomaxillary complex) into the narrow disk floret. Penetration was restricted by the broad labrum that covers the mouth opening. The length of the prementum and glossa was taken directly as the effective tongue length, as the prementum can be inserted to some extend into the corollar tube. In the Halictid bee, the total length of the prementum and glossa was also used as the effective tongue length. In the Anthophorid only the length of the glossa was taken into account.

6.2. MATERIAL AND METHODS

Nectar production

After consultation with the Grain Crops Research Institute, seventeen common as well as promising new cultivars of commercial sunflower were selected and grown in a glasshouse for comparative studies on nectar secretion. Five replicates of each cultivar were used.

Single sunflower plants were grown in 0,5 m^3 pots with a surface area of 0,32 m^2. A sandy-loam soil, mixed with 10% humus was used as growth medium. Fertiliser (N3-P2-K3) was applied to pots (0,25g/pot, which is equivalent to 800kg/ha). The plants were watered every day. A micronutrient solution containing i.a. boron was applied

once, when the seedlings were one week old. The sunflowers were planted on 1986-11-08 and started flowering on 1987-01-07. The plants achieved heights of 1,80 -2,10 meters, with head diameters between 120 - 190 mm. This compared well with plants in commercial fields. The design of the experiment was a randomized block. Plants were spaced the same distance apart as for stands in a commercial sunflower field with 30 000 plants per hectare (fig. 24).

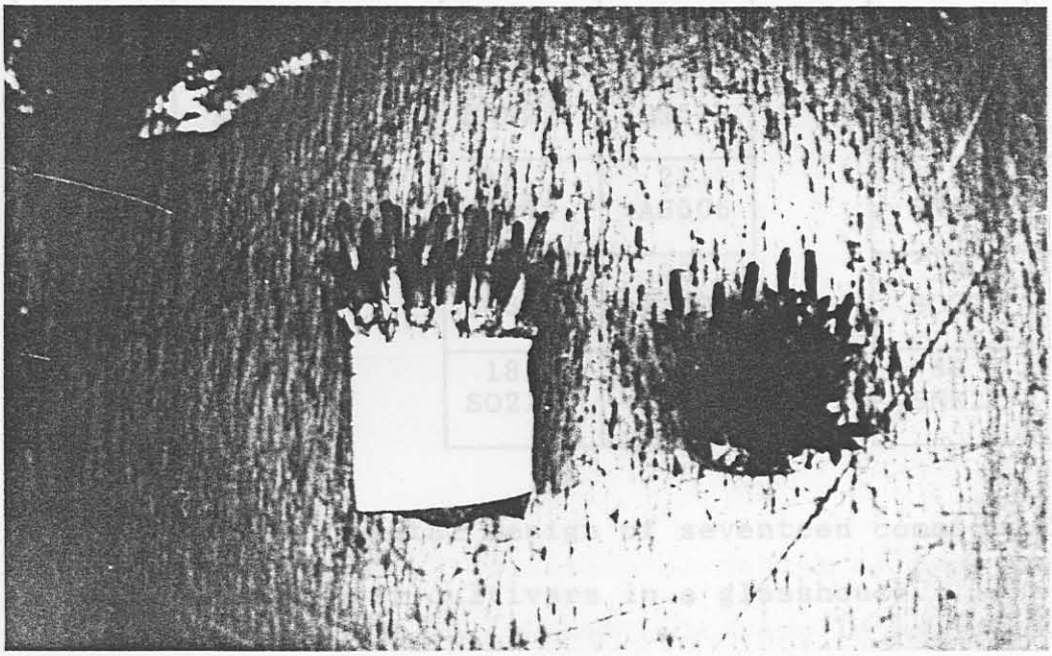

Fig. 23. Disk floret plug as prepared for centrifuging.

The centrifuge technique developed by Furgala et al. (1976) to extract nectar from the floral plug was used with minor modifications (fig. 23). Only floral plugs of the pistillate stage were used in the study, as Furgala et al. (1976) reported that such florets contained more nectar solids than did staminate or post-pistillate florets.

The glasshouse was isolated from all pollinating insects by wire gauze in front of all the ventilation openings.

01 SO306	12 PNR7441
02 SNK22	11 SNK22
03 PNR7204	10 S0171
04 AS515	09 SO306
05 SNK22	08 PNR7441
06 PNR7204	07 PNR7441

13 AS540	24 AS532
14 SUNKING	23 PNR7225
15 SNK22	22 AS532
16 AS540	21 AS505
17 SO323	20 AS505
18 SO210	19 SO210

25 AS515	36 SO210
26 SO323	35 AS540
27 S0210	34 SO210
28 SNK26	33 AS532
29 SO222	32 SO306
30 SNK22	31 SO171

Fig. 24. Experimental design of seventeen commercial sunflower cultivars in a glasshouse.

37 AS540	60 AS532
38 SO323	59 AS505
39 SNK26	58 SUNKING
40 SO222	57 AS515
41 SNK26	56 CAR1006
42 SNK25	55 AS532
43 CAR1006	54 SNK25
44 SO171	53 PNR7225
45 SO306	52 SO222
46 CAR1006	51 AS540
47 CAR1006	50 CAR1006
48 SNK25	49 SUNKING

	85 SNK26
61 PNR7204	84 AS505
62 SNK25	83 SUNKING
63 SO222	82 SNK26
64 SO222	81 SNK25
65 PNR7204	80 PNR7225
66 PNR7204	79 AS515
67 PNR7441	78 SUNKING
68 PNR7225	77 S0306
69 SO171	76 AS515
70 PNR7441	75 SO171
71 AS505	74 PNR7225
72 SO323	73 SO323

Fig. 24. (Continued) Experimental design of seventeen commercial sunflower cultivars in a glasshouse.

The temperature and air humidity in the glasshouse was recorded with a thermo-hygrograph. During the growth period the minimum temperature measured in the glasshouse was 18°C (between 05h00 and 06h00). The highest maximum temperature of 38°C was reached between 12h00 and 14h00. Relative humidity varied between 25% and 75%, during the growth period. During bloom the humidity varied between 35% and 65%, and the temperature between 21°C and 36°C.

One to four whorls of florets opened every night between 02h00 and 04h00. The anther tube had grown out fully by 05h00 but the first pollen was released only between 05h00 and 06h00. The growing style pushed the pollen out of the anther tube. Styles were fully extended by 17h00. The stigmatic lobes open between 17h00 and 24h00, at which time most of the pollen, released early in the morning, was no longer available. It would have been removed by pollen foragers or simply fallen from the floret due to gravitation. It is not uncommon to see pollen grains on the top leaves of the plant.

The pollen was removed twice a day with a light weight, battery operated vacuum cleaner. It was found that the removal of the pollen was essential prior to centrifuging to obtain accurate readings of nectar volume.

In preliminary investigations floral plugs from newly opened florets (staminate stage) were sampled at 07h30 and centrifuged. No nectar was centrifuged from these floral plugs. Plugs cut at 08h30 contained nectar. It was therefore assumed that florets of the pistillate stage, cut at 07h30, would represent nectar secretion over a period of 24 hours.

Floral plugs containing 30 - 40 pistillate florets were cut from the sunflower heads at 07h30, with a cork borer. These plugs were divided into three groups according to their position on the head, namely from the periphery, the intermediary section and the center of the head. The original randomized block with five replicates was subdivided with two to three plugs of each group from the same head over the eight day flowering period of the head. Ten to fifteen variants were thus obtained for each replicate. These plugs were transported in a polystyrene container to the laboratory. All non-pistillate stage florets were removed from the plugs which were then placed in calibrated sedimentation tubes and centrifuged at 1800 to 2000 r.p.m. for 10 minutes.

The volumes of nectar were recorded and the percentage solids were determined with an Atago 500 hand refractometer. The data were converted to volume nectar and mg. solids per 100 florets.

Attractiveness of flower heads and accessibility of nectar

In studies on the variation of morphological characteristics between cultivars which bees can discriminate, the colour of the disk floret corolla tube was estimated on a 1 - 5 point scale (Shein et al., 1980), 1 being the lightest and 5 the darkest. The stigmatic surface was similarly evaluated for colour on a 1 - 5 point scale. Furthermore the disk florets were measured with calipers from the distal section of the corolla tube to the most basal section of the corolla tube opening (fig. 25). The florets used for centrifuging were afterwards used for these measurements.

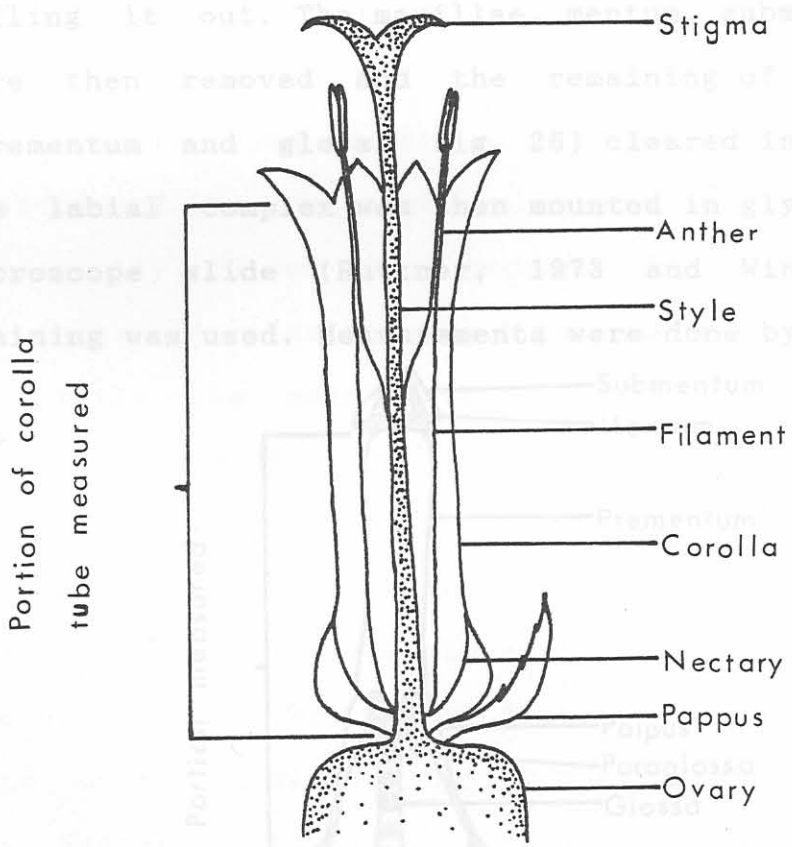

Fig. 25. Sunflower disk floret, to show portions measured.

Bee tongue lengths

Foraging honeybees and the two species of solitary bees were sampled at random while visiting commercial sunflower heads for measurements of tongue lengths. For honeybees this method of sampling is important, as honeybees from one colony might not reflect the true variation in tongue length.

The labiomaxillary complex of the bees being investigated was removed under a dissecting microscope by inserting a tweezer at the lorum, pushing the proboscis forward and pulling it out. The maxillae, mentum, submentum and muscles were then removed and the remaining of the labio complex (prementum and glossa Fig. 26) cleared in boiling 10% KOH. The labial complex was then mounted in glycerine jelly on a microscope slide (Ruttner, 1973 and Winston, 1979). No staining was used. Measurements were done by calipers.

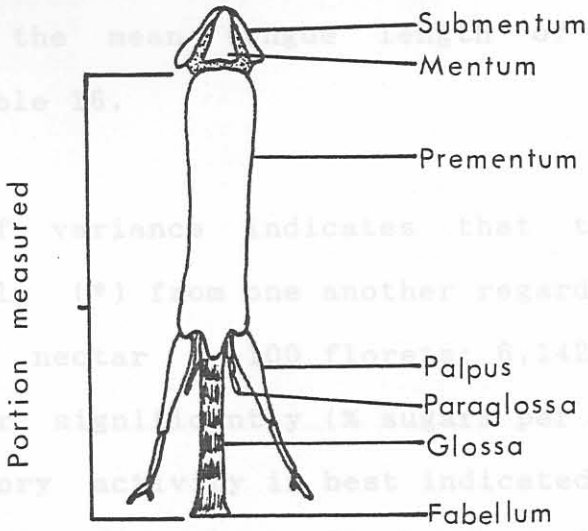

Fig. 26. Schematic drawing of the labial complex of bees, indicating the parts measured.

Statistics

Analysis of variance with random replication was carried out for the following variables: volume of nectar per 100 florets, mg solids per 100 florets and corolla tube length.

Degrees of freedom were: cultivars - 16; positions on head - 2; cultivars x positions - 32; replicates - 4. F-test and Bonferroni's t-test were used during analysis. Standard deviation (S.D.) and standard error of the mean (S.E.) was also calculated.

6.3. RESULTS

The quantity and quality of nectar obtained from pistillate florets of the seventeen evaluated cultivars is presented in tables 11, 12 and 13. Pigmentation of disk florets is given in table 14. The corolla tube length is presented in table 15, while the mean tongue length of three bee genera is shown in table 16.

Analysis of variance indicates that the cultivars differ significantly (*) from one another regarding the quantity of nectar (ul nectar / 100 florets: 6,142 *). Nectar quality also differ significantly (% sugars per 100 florets : 4.596 *). Secretory activity is best indicated by the mass of the solids secreted over a 24 hour period (table 13). A significant difference in secretory activity between

TABLE 11. MEAN VALUES IN ASCENDING ORDER FOR VOLUME OF NECTAR (ul / 100 FLORETS).

Cultivar	Mean	S.D.	S.E.	max.	min.	n
SO 171	188,03	73,00	24,30	321,5	76,9	19
PNR7204	231,94	72,29	20,86	355,3	105,2	29
SNK 25	241,00	78,85	20,36	404,0	129,2	38
SUNKING	247,44	48,70	12,57	358,5	163,3	39
SO 210	250,89	51,98	13,40	337,5	149,3	38
AS 540	255,16	63,47	15,86	383,4	144,7	40
CAR1006	257,58	81,78	23,60	381,8	152,2	29
SO 306	273,52	67,94	17,54	423,5	158,2	40
SO 222	279,82	65,01	16,78	355,6	166,4	36
AS 532	282,63	52,65	15,19	394,3	200,0	32
PNR7225	292,62	75,16	19,40	382,4	198,4	38
PNR7441	294,16	78,36	20,23	435,2	196,2	40
SO 323	310,14	84,17	21,73	519,3	193,2	36
SNK 22	310,74	60,91	40,60	412,6	198,1	40
AS 505	321,22	70,80	18,28	434,2	143,1	40
AS 515	357,78	99,32	33,10	455,9	151,5	21
SNK 26	359,45	86,92	22,44	546,9	221,6	39

TABLE 12. MEAN VALUES IN ASCENDING ORDER FOR CONCENTRATION OI NECTAR SOLIDS (% / 100 FLORETS).

Cultivar	Mean	S.D.	S.E.	max.	min.	n
AS 515	40,64	4,97	1,65	50,95	36,80	21
SNK 22	44,69	2,95	0,76	47,77	37,60	40
S0 306	45,84	4,70	1,21	52,13	38,77	40
AS 505	46,18	4,43	1,14	51,97	34,75	40
SNK 26	46,23	3,92	1,01	52,87	38,90	39
AS 532	46,35	5,67	1,63	51,50	34,70	32
PNR7441	46,96	4,60	1,18	52,03	35,77	40
PNR7225	47,98	7,89	2,03	58,67	32,40	38
SUNKING	48,28	3,84	0,99	54,03	39,90	39
CAR1006	48,39	3,00	0,86	52,65	42,85	29
PNR7204	48,78	2,91	0,84	53,45	42,30	29
SO 171	48,92	7,49	2,49	57,00	38,50	19
SO 323	49,43	4,35	1,12	55,60	42,67	36
SO 222	49,95	4,34	1,12	56,95	43,57	36
SNK 25	50,18	4,41	1,14	55,00	40,03	38
SO 210	50,41	4,30	1,11	57,25	41,73	38
AS 540	51,54	5,33	1,37	57,77	42,10	40

TABLE 13. MEAN VALUES IN ASCENDING ORDER FOR NECTAR SOLIDS (mg / 100 FLORETS).

Cultivar	Mean	S.D.	S.E.	max.	min.	n
SO 171	91,18	35,63	11,87	162,0	40,1	19
PNR7204	111,89	29,86	8,62	150,7	78,1	29
SUNKING	117,92	21,72	5,60	163,1	81,7	39
SNK 25	119,62	36,68	9,47	190,6	59,3	38
CAR1006	122,40	33,56	9,68	166,9	79,0	29
SO 210	125,56	25,19	6,50	170,9	92,0	38
AS 540	129,41	30,39	7,84	184,1	81,1	40
PNR7441	133,68	36,55	9,43	201,0	92,0	40
AS 532	134,38	31,38	9,05	200,2	90,6	32
PNR7225	135,43	21,32	5,50	165,5	103,9	38
SNK 22	138,20	24,06	6,21	185,3	92,4	40
SO 306	138,45	51,67	13,34	303,3	90,3	40
SO 222	138,70	27,49	7,21	191,7	85,0	36
AS 515	141,63	29,73	9,91	165,0	77,7	21
AS 505	146,60	29,36	7,58	186,4	74,0	40
SO 323	151,77	44,16	11,40	286,8	106,5	36
SNK 26	165,60	41,87	10,81	252,7	95,0	39

TABLE 14. MEAN PIGMENTATION VALUES FOR COROLLAR TUBE AND STIGMA O SEVENTEEN SUNFLOWER CULTIVARS.

Cultivar	Corollar tube pigmentation	Stigma pigmentation	Range of stigma pigmentation
SO 171	1	1,00	1 - 1
SO 222	1	1,00	1 - 1
SUNKING	1	1,00	1 - 1
AS 540	1	1,00	1 - 1
AS 532	1	1,05	1 - 2
PNR7225	1	1,05	1 - 2
SO 323	1	1,08	1 - 2
SO 210	1	1,20	1 - 2
CAR1006	1	1,20	1 - 2
SO 306	1	1,50	1 - 3
AS 505	1	1,70	1 - 3
SNK 25	1	1,80	1 - 3
PNR7441	1	2,00	1 - 3
PNR7204	1	2,10	1 - 3
AS 515	1	2,20	1 - 4
SNK 22	1	2,80	1 - 4
SNK 26	1	4,80	4 - 5

cultivars can be expected, as it is a function of volume of nectar and concentration of sugars present in the nectar.

Corollar tube colouration, as evaluated at the distal portion of the corolla (fig. 21), for the seventeen cultivars were all rated as 1 (table 14). With the exception of PNR7441, PNR7204, AS 515, SNK 22 and SNK 26, all the cultivars were evaluated as less than 2 regarding pigmentation of the stigma (table 14).

A significant difference between corollar tube lengths of the seventeen cultivars was indicated by analysis of variance (16,430 *) (table 15). The shortest corollar tube lenght measured, was SNK 25 (4,93mm), while the longest was SUNKING, measuring 5,80mm. The mean tongue length for honeybees was 5,24mm, against 8,74mm for the anthophorid and only 1,62mm for the halictid.

6.4. DISCUSSION

Quality and quantity of nectar is influenced by a number of factors, as indicated by Beutler (1953). Working in a glasshouse causes some problems but these were outweighed by the need for plants grown under similar conditions for comparable results. The major problem with field experiments is to keep anthophilous insects from utilizing the nectar. It is possible to avoid this but enclosing heads or plants

TABLE 15. MEAN VALUES IN ASCENDING ORDER FOR COROLLAR TUBE LENGTH (mm).

Cultivar	Mean	S.D.	S.E.	max.	min.	n
SNK 25	4,934	0,34	0,08	5,64	4,39	38
SO 171	5,247	0,24	0,08	5,64	4,89	19
CAR1006	5,375	0,13	0,04	5,55	5,04	29
SO 210	5,378	0,29	0,07	5,95	4,95	38
PNR7225	5,399	0,18	0,04	5,71	5,11	38
SO 222	5,432	0,21	0,05	5,78	5,06	36
AS 540	5,422	0,22	0,05	5,75	4,99	40
PNR7204	5,436	0,17	0,05	5,83	5,17	29
SNK 26	5,480	0,29	0,07	5,97	5,00	39
AS 505	5,481	0,19	0,05	5,82	5,05	40
SO 323	5,498	0,30	0,07	5,94	5,09	36
AS 515	5,513	0,20	0,06	5,85	5,23	21
SO 306	5,546	0,25	0,06	5,99	5,16	40
AS 532	5,580	0,28	0,08	6,04	5,09	32
PNR7441	5,615	0,19	0,05	5,93	5,22	40
SNK 22	5,694	0,21	0,05	6,07	5,28	40
SUNKING	5,805	0,25	0,06	6,11	5,27	39

TABLE 16. MEAN TONGUE LENGTH OF THREE BEE GENERA VISITING SUNFLOWER

Taxon	Mean	S.D.	S.E.	max.	min.	n
Honeybee	5,24	0,082	0,015	5,39	5,08	30
Anthophorid	8,74	0,210	0,090	8,95	8,45	5
Halictid	1,62	0,067	0,030	1,70	1,55	5

with exclusion bags introduces a whole series of physical and physiological artifacts.

The significant differences found between nectar yielding capacities of cultivars under glasshouse conditions, suggest that similar differences could be expected under field conditions. Nectar yield in field conditions could further differ in various regions, as soil type and climatic conditions play a major role (Beutler, 1953).

Visual attractiveness of the head seems to be of little importance in modern hybrid cultivars. Pigmentation of the distal portion of the corollar tube and stigma was in an acceptable range with SNK 26 as the only exception.

When the average tongue length of honeybees (5,24mm) is compared to the mean range of corollar tube length (4,93 - 5.80mm), it can be seen that this parameter can be one of the most important discriminating factors. Shein et al. (1980) found accessibility of nectar of sunflower to be directly linked to abundance of foragers in a field. Under conditions where large heads develop, this factor can be of even greater importance. A low number of honeybees visit plants with long corollas, while the abundance on short corolla cultivars are higher (Shein et al., 1980). Long tongue anthophorid bees can reach nectar in all the cultivars and would presumably be able to do so under almost

all growing conditions. Short tongue halictids cannot reach nectar in the tubular sunflower disk floret and forage only for pollen on the heads.

Morphological characteristics must be of great importance to sunflower geneticists when breeding cultivars with the most desirable characteristics for forager attractiveness.

Future research on attractiveness should include studies on pheromones released at nectar or pollen sources. Chemical volatiles produced by the plant could also be important pollinator attractants according to Etievant et al. (1984).