AGAPOSTEMON ANGELICUS COCKERELL AND OTHER WILD BEES AS POTENTIAL POLLINATORS OF MALE-STERILE COTTON ON THE TEXAS HIGH PLAINS

By

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Bachelor of Science

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Laramie, Wyoming

1980

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 1982

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ACKNOWLEDGMENTS

This study was conducted under memorandum of agreement number 80-466 between the Texas Agricultural Experiment Station and the Department of Entomology, Oklahoma State University and was funded by the Texas Agricultural Experiment Station; Cotton Inc.; Plains Cotton Growers, Inc.; Cargill Seed Division; Cottonseed Services; Funk Seeds International; Cotton Hybrids, Inc.; DeKalb Ag. Research; Ring Around Seed Co.; Ranger Seed Co.; and Pioneer Hi-Bred International, Inc.

The aid and assistance of a great many people made this study possible. The advice of my advisor, Dr. Joseph Moffett, and other committee members, Drs. William Drew, Jerry Young, and Laval Verhalen was sincerely appreciated.

Abdool Annief, Brad Cobb, Suzanne Schneider, and James Thiebaud helped collect much of the field data.

I wish to thank Dr. Don Rummel of the Texas Agricultural Experiment Station for his encouragement throughout my study. Stan Carroll of the Texas Agricultural Experiment Station was a great help in gathering much of the supplies and equipment.

Ms. Sammie J. Merritt of the Entomological Museum at Texas A & M University served as the wild bee taxonomist and offered much advice throughout the study. Don Arnold of the Oklahoma State University also contributed suggestions on identification of the 1981 metallic halictids.

Dr. Ron Tyrl of the Oklahoma State University identified the plant specimens.

I wish to sincerely thank the Berger Family and my dear friend Kris Goetze for their continued support throughout this study.

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CHAPTER I

INTRODUCTION

Recent advances in genetic technology have made the commercial production of hybrid cotton (*Gossypium hirsutum* L.) possible. At present, several seed companies in the United States have breeding programs in progress and hope to release hybrids in the near future. One of the major unsolved problems in this effort concerns the adequate and economical pollination of the male-sterile plants.

This study was part of a continuing project to determine the most efficient and economical method of producing hybrid cottonseed on the Texas High Plains. Wild bees are considered abundant on the High Plains and could possibly serve the pollination needs of this area. In particular, a wild green sweat bee *Agapostemon angelicus* Cockerell had previously been reported to be very active in cotton and to carry large amounts of pollen.

This investigation was conducted to determine the potential of wild bees as pollinators of male-sterile cotton with a special emphasis on *A. angelicus*. The primary areas of interest were to examine:

1. The distribution and abundance of *A. angelicus*,
2. Seasonal wild bee population trends,

3. Host plants on which wild bees forage prior to and during the cotton blooming period,
4. Wild bee activity in both commercial and hybrid cotton lines, and
5. The effect of alternate host plants on wild bee populations and visitation in cotton.

CHAPTER II

REVIEW OF LITERATURE

Hybrid Cotton

Interest in the development of of hybrid cotton arose after Mell (1894) first showed that interspecific crosses between long-staple cotton (*Gossypium barbadense* L.) and short-staple cotton (*G. hirsutum* L.) exceeded their parents in certain characteristics. Fryxell et al. (1958), Hutchinson et al. (1938), Marani (1967), Stroman (1961), Ware (1931), and others also reported superior offspring from such crosses. Hybrid vigor in cotton offers the potential for incorporating increased pest resistance, yield, and lint qualities into existing cultivars.

The use of male-sterile lines offers the best possibility for the development of hybrid cotton (Loden and Richmond 1951). Sterility in cotton may be genetic (Allison and Fisher 1964, Justus and Leenweber 1960, Justus et al. 1963, Srinivasan et al. 1972, and Weaver 1968), chemical (Eaton 1957), or cytoplasmic (Meyer and Meyer 1961, Meyer 1973). All present commercial work on hybrid cotton uses the male-sterile cytoplasms developed by Meyer. Current breeding problems involve finding those parental combinations which show superior combining ability and finding a reliable fertility restorer.

Pollination of Hybrid Cotton

Meyer (1969) wrote that one of the main obstacles to the commercial production of hybrid cottonseed is an adequate and economical method of pollinating the male-sterile plants. Due to the heavy and sticky nature of the cotton pollen, wind is an inadequate pollen vector (Balls 1915). Hand pollination of flowers made sterile by hand emasculation has been practiced on a large scale in India (Srinivasan et al. 1972). This method, however, is not economical to use in the United States due to the high cost of labor. Insects, usually the Apoidea (bees), are the most efficient pollen transfer agents for cotton.

Honey bees (*Apis mellifera* L.) have been shown to be an effective pollinator of cotton (McGregor 1959). Moffett et al. (1978) reported that the cost of providing honey bee hives around fields needing pollination is justified when a superior hybrid is produced.

Wild bees also visit cotton flowers, but their populations fluctuate according to the time of year, season, and location (Butler et al. 1960, McGregor et al. 1955, Moffett et al. 1976, and Ware 1927). For these reasons, wild bees have tended to be an unpopular choice when planning the pollination of large acreages of A-line cotton.

The bumblebee (*Bombus* spp.) is generally considered to be the most important pollinator of cotton in the Eastern United States (Allard 1910, Loden and Richmond 1951, Stephens and Finkner 1953, and Thies 1953). This bee tends to be quite abundant east of the Brazos River, but is rare in the west (Butler et al. 1960).

Other bees observed to be active in cotton include *Melissodes* spp. (Butler et al. 1960) and *Anthophora* spp. (Afzal and Khan 1950).

A preliminary survey of pollinators visiting cotton on the Texas High Plains was made in 1979 (Moffett et al. 1980). Of the 35 wild bee species collected, *Agapostemon angelicus* was considered the most important pollinator (Table I). G. E. Bohart (1979) of the USDA Wild Bee Biology and Systematics Lab, Logan, Utah, states,

> It is clear that *A. angelicus* was by far the most important pollinator in terms of numbers found in cotton flowers, per cent carrying pollen, and amounts of pollen per individual (Personal Communication).

Agapostemon angelicus

Bees of the genus *Agapostemon* may easily be recognized by their bright green metallic color. Females and males are distinguished by their size and coloration. Twelve species are found in the United States (Roberts 1972).

Factors which influence the distribution of *Agapostemon* spp. are not well understood. *A. angelicus* is widespread, occurring from below sea level in Death Valley, California

TABLE I

THE 10 MOST NUMEROUS SPECIES OF BEES FOUND IN COTTON FLOWERS ON THE TEXAS HIGH PLAINS, 1979[a]

	Species	Number Collected	% of Total Bees Collected
1.	*Agapostemon angelicus* Cockerell	65	24.6
2.	*Apis mellifera* L.	39	14.8
3.	*Halictus ligatus* Say	16	6.1
4.	*Melissodes thelypodii* Cockerell	15	5.7
5.	*Bombus fraternus* (F. Smith)	13	4.9
6.	*Svastra atripes* (Cress.)	13	14.9
7.	*Evylaeus* (*Dialictus*) spp.	13	4.9
8.	*Triepeolus helianthi* Root[b]	11	4.2
9.	*Bombus americanorum* (F.)	8	3.0
10.	*Nomada texana* Cress.[b]	8	3.0
	Others	63	23.9

[a]From Moffett et al. 1980.

[b]*Triepeolus* spp. and *Nomada* spp. are parasitic on other bees during their larval stage.

to 12,000 feet on Mt. Evans in Colorado (Roberts 1972).

Roberts (1969 and 1973) has summarized the biology of *Agapostemon* spp. as follows: most species (including *A. angelicus*) are bivoltine with fertilized females serving as the overwintering generation. Emergence is usually in April or as soon as pollen and nectar sources become available in the spring. It is not known whether the few males found in the spring overwinter as larvae, pupae, or adults. The overwintering (parent) generation of females nests in April and May and probably dies in mid-May.

The summer generation emerges in June and consists almost entirely of females. This generation begins nesting activities soon after emergence and usually produces male offspring. Throughout the season the number of females remains fairly constant while males become increasingly abundant.

Females which emerge in August are fertilized and are the overwintering generation. These females may be distinguished by their unworn wings and mandibles and slender ovaries.

Agapostemon angelicus is a solitary species making its nests in the soil. The nest architecture of this species consists of a main burrow with several lateral branches extending outward. Particular nesting habits of *A. angelicus* (depth, lateral length, etc.) are not known.

The life cycle of *Agapostemon* spp. from oviposition to emergence is 32$\pm$ 4 days. Females oviposit on a pollen ball at the end of a lateral branch in the nest. After 2-days the egg hatches; the next 4-5 days, the larva feeds upon and completely consumes the provision. The post defecated larva lies on its back for 5-6 days as a prepupa. After 16 days as a pupa, the bee molts for the last time. The adult remains in the cell for two days during which time the cuticle becomes sclerotized.

CHAPTER III

MATERIALS AND METHODS

The Texas High Plains is a part of the Great Plains region comprising about 20,000,000 acres (Figure 1). The high level plateau is separated from the Rolling Plains by the Cap Rock Escarpment. Elevation ranges from 3,000 to 4,500 feet and gently slopes towards the southeast (Gould 1969).

The southern portion of the Texas High Plains is devoted to intensive row crop agriculture with relatively little acreage in native or improved rangeland. This region is the largest cotton growing region in the United States with approximately 4.7 million acres planted in 1981.

In 1980 and 1981, surveys were conducted to determine the distribution and abundance of wild pollinators, primarily the Apoidea, on the Texas High Plains. These data serve to supplement and extend previous surveys in this area.

Insects were collected from flowering plants along roadsides and edges of fields, and in rangeland. Collections were made daily except during cool or rainy weather. These insects were caught with aerial sweep nets and killed with cyanide in glass collection jars. The

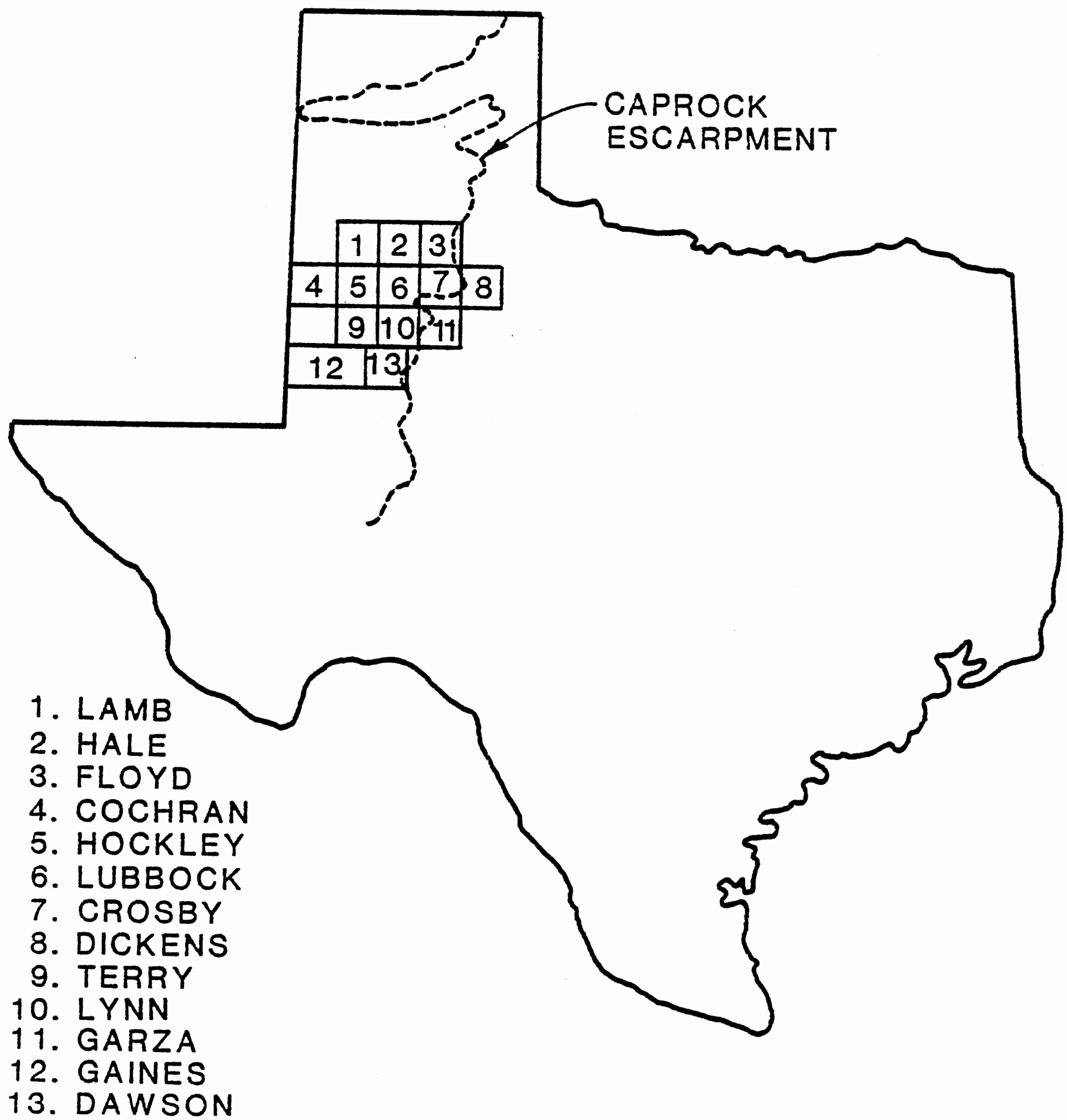

Figure 1. Thirteen County Region on the Texas High Plains in Which Wild Bees Were Surveyed, 1980-81

specimens were mounted and labelled. The metallic Halictids collected in 1981 were identified by the author. All other wild bees were or are being identified by Sammy Merritt, Entomological Museum curator at Texas A & M University.

The wild plants on which bees were noted foraging for pollen or nectar were collected. Specimens were identified by Dr. Ron Tyrl of Oklahoma State University.

1980 Study - Wild Bee Survey

From June 3 through July 27 a survey of wild pollinators was made in the following 13 Texas counties: Cochran, Crosby, Dawson, Dickens, Floyd, Gaines, Garza, Hale, Lamb, Lynn, Lubbock, Hockley, and Terry (Figure 1).

Bees were collected in flight or as they collected pollen, nectar, or both from native plant species.

1981 Study - Wild Bee Survey

From May 18 through August 18, three major regions on the Texas High Plains were surveyed for wild pollinators. These were: 1) a primarily irrigated region (Hale and Lubbock Counties), 2) a primarily dryland region (Cochran, Hockley, and Lynn Counties), and 3) a region bordered by the Cap Rock (Crosby, Dawson, and Garza Counties).

Wild bees were regularly collected from sunflowers (*Helianthus* spp.) and alfalfa (*Medicago sativa* L.). These plants are readily available in early summer and support substantial bee populations prior to and during the cotton blooming period. Therefore it was possible to monitor trends and tendencies in wild bee populations throughout the season. Each region was sampled at least 1-day per week at half-hour intervals between 0930 and 1530 hours.

Wild Bee Visitation in Commercial Cotton

Sixteen fields of commercial cotton were chosen to represent 4 types of locations: 1) dryland, 2) dryland near an alternate host, 3) irrigated, and 4) irrigated near an alternate host. These fields were in Dawson, Garza, Hale, Hockley, Lubbock, and Lynn Counties and represented the major soil types and moisture conditions found on the Texas High Plains. Cultivar designation was undetermined as was the history of pesticide usage in these fields.

From July 20 until August 20, four fields of each location type were observed. Bee visitation was monitored by an observer walking slowly down the row and counting the number of bee visitations per 100 flowers as described by McGregor (1958). Counts were taken as early as 0915 until 1800 hours when visitation by wild bees had ceased due to closure of the cotton blooms. As the season progressed, the cotton blooms responded to shorter day length by opening later in the morning, requiring counts to be taken later in the day.

Wild Bee Visitation in A- and B-line Cotton

Between July 25 and August 22, a 2Ø-acre field of A- and B-line cotton (2:4 row ratio) near Lamesa (Dawson County) was monitored for visitation. This field was bordered on 3 sides by native pasture and was known to have good visitation by native pollinators. In addition, 94 colonies (4.7 colonies/A) of honey bees were placed on the western edge of the field. Visitation by wild bees and honey bees was observed once a week for 5 weeks. Counts were taken using the McGregor method at 1ØØØ, 12ØØ, 14ØØ, and 16ØØ hours.

CHAPTER IV

RESULTS

Wild Bee Activity in Wild Plants and Alfalfa

A total of 11,984 bees were collected during this two year survey. In both years _A. angelicus_ was abundant, comprising over 16% of all wild bees collected in 1980 and over 22% in 1981 (Table II). In addition, a large number of other species were collected on the Texas High Plains (Table III, Appendix). The 1981 collection has yet to be completely identified.

Several plant species were attractive pollen and nectar sources for wild bees (Table IV). Native sunflowers (_Helianthus_ spp.), alfalfa (_Medicago sativa_ L.), and field bindweed (_Convolvulus arvensis_ L.) were the most consistently abundant and attractive plant species to wild bees, although these species did not come into bloom until early June.

The earliest collection of _A. angelicus_ was on May 18 of 1981. Both males and females were active in yellow sweetclover {_Melilotus officinalis_ (L.) Lam.}, which was the earliest, most abundant, and most attractive floral source

TABLE II

PERCENTAGE *AGAPOSTEMON* SPP. OF TOTAL WILD BEES COLLECTED ON THE TEXAS HIGH PLAINS, 1980-81

Week	Total wild bees collected 1980	Total wild bees collected 1981		Percent *Agapostemon* spp. / Total wild bees collected 1980	Percent *Agapostemon* spp. / Total wild bees collected 1981
1	--	46		--	21.7
2	--	455		--	32.5
3	37	666		2.7	36.3
4	533	1476		11.3	27.9
5	668	776		17.9	36.1
6	751	901		20.5	52.2
7	612	959		10.3	14.4
8	939	998		19.4	1.2
9	301	823		7.7	2.1
10	169	325		32.7	1.5
11	67	165		1.5	17.6
12	--	274		--	3.6
13	--	43		--	4.7
Total	4077	7907	Mean	13.8[a] 16.2[b]	19.4[a] 22.6[b]

[a] Weekly mean.
[b] Yearly mean.

TABLE IV

PLANTS FROM WHICH WILD BEES WERE COLLECTED, ON THE TEXAS HIGH PLAINS, 1980-81

Scientific Name	Common Name[a]
Family Amaranthaceae	
1. *Amaranthus* sp.	pigweed
Family Compositae	
2. *Aphanostephus ramosissimus* DC.	lazy daisy
3. *Centaurea americana* Nutt.	starthistle
4. *Coreopsis tinctoria* Nutt.	plains coreopsis
5. *Engemannia pinnatifida* T. & G.	Engelmann daisy
6. *Erigeron* sp.	fleabane
7. *Gaillardia pulchella* Foug.	rosewing gaillardia
8. *Helianthus annus* L.	common sunflower
9. *H. ciliaris* DC.	blueweed sunflower
10. *H. petiolaris* Nutt.	prairie sunflower
11. *Helenium* spp.	sneezeweed
12. *Hymenopappus flavescens* Gray	yellow woolly white
13. *Hymenoxys scaposa* (DC.) Parker	bitter rubberweed
14. *Lygodesmia aphylla* DC.	skeletonweed
15. *Psilostrophe villosa* Rydb.	hairy paperflower
16. *Ratibida columnifera* (Nutt.) Woot.& Standl.	prairie coneflower
17. *R. tagetes* (James) Barnhart	shortray prairie coneflower
18. *Taraxacum officinale* Weber	dandelion
19. *Thelesperma ambiguum* Gray	Colorado greenthread
20. *T. megapotamicum* (Spreng.) Kuntz	greenthread
21. *Verbesina encelioides* Gray	crownbeard
22. *Xanthisma texana* DC.	sleepy daisy
23. *Zinnia grandiflora* Nutt.	plains zinnia
Family Convolvulaceae	
24. *Convolvulus arvensis* L.	field bindweed

TABLE IV (Continued)

Scientific Name	Common Name
Family Cucurbitaceae	
25. *Cucurbita foetidissima* H.B.K.	buffalo gourd
Family Gramineae	
26. *Sorghum halepense* (L.) Pers.	johnsongrass
Family Labiatae	
27. *Monarda* spp.	bee balm
Family Leguminoseae	
28. *Medicago sativa* L.	alfalfa
29. *Melilotus alba* (L.) Desr.	white sweetclover
30. *M. officinalis* (L.) Lam.	yellow sweetclover
Family Malvaceae	
31. *Gossypium hirsutum* L.	upland cotton
Family Papaveraceae	
32. *Argemone polyanthemos* (Fodde) G. B. Ownbey	pricklepoppy
Family Solanaceae	
33. *Solanum elaegnifolium* Cav.	silverleaf nightshade
Family Zygophyllaceae	
34. *Tribulus terrestris* L.	puncturevine

[a]Most common names are after Gould (1969), McGregor (1976), and Weed Society of America (1966).

for wild bees on the Texas High Plains.

Seasonal Abundance of *A. angelicus*

Agapostemon angelicus was by far the most abundant *Agapostemon* species in both years of this study, comprising over 98% of the individuals collected (Tables V and VI). Five other *Agapostemon* species were collected: *A. cockerelli* Crawford, *A. coloradinus* (Vachal), *A. melliventris* Cresson, *A. texanus* (Lepeletier), and *A. splendens* (Lepeletier).

Populations of *A. angelicus* foraging in wild plants and alfalfa peaked between June 16 and 29 in both 1980 and 1981 (Figures 2 and 3). Populations observed in sunflowers and alfalfa in 1981 dropped markedly after June 27.

Females of *A. angelicus* were relatively abundant in the early season (Figures 4 and 5). A decrease in numbers occurred towards early June as overwintered females had completed nesting activities and eventually died. Emergence of summer generation females was evidenced by a mid-season peak in numbers collected. The seasonal abundance of females found in sunflowers was consistent with the findings of Roberts (1973). The fall-spring females emerged in early to mid-August and served as the overwintering generation. Due to the time limitations of this study, observations could not be made on females of *A. angelicus* beginning fall nesting activities. The last females enter their hibernacula to overwinter in mid-September as pollen and

TABLE V

AGAPOSTEMON SPP. COLLECTED ON WILD FLOWERS, ON THE TEXAS HIGH PLAINS, 1980

Species	Female	Male	Total	% of Total *Agapostemon* spp. collected
A. angelicus Cockerell	171	638	809	98.3
A. cockerelli Crawford	1	0	1	0.1
A. coloradinus (Vachal)	1	0	1	0.1
A. melliventris Cresson	2	1	3	0.4
A. splendens (Lepeletier)	4	5	9	1.1
Total	179	644	823	100.0

TABLE VI

AGAPOSTEMON SPP. COLLECTED ON NATIVE SUNFLOWERS AND CULTIVATED ALFALFA, ON THE TEXAS HIGH PLAINS, 1981

Species	Female	Male	Total	% of Total *Agapostemon* spp. Collected
A. angelicus Cockerell	132	1524	1656	98.6
A. cockerelli Crawford	1	0	1	0.1
A. melliventris Cresson	7	9	16	1.0
A. splendens (Lepeletier)	2	0	2	0.1
A. texanus (Lepeletier)	0	4	4	0.2
Total	142	1537	1679	100.0

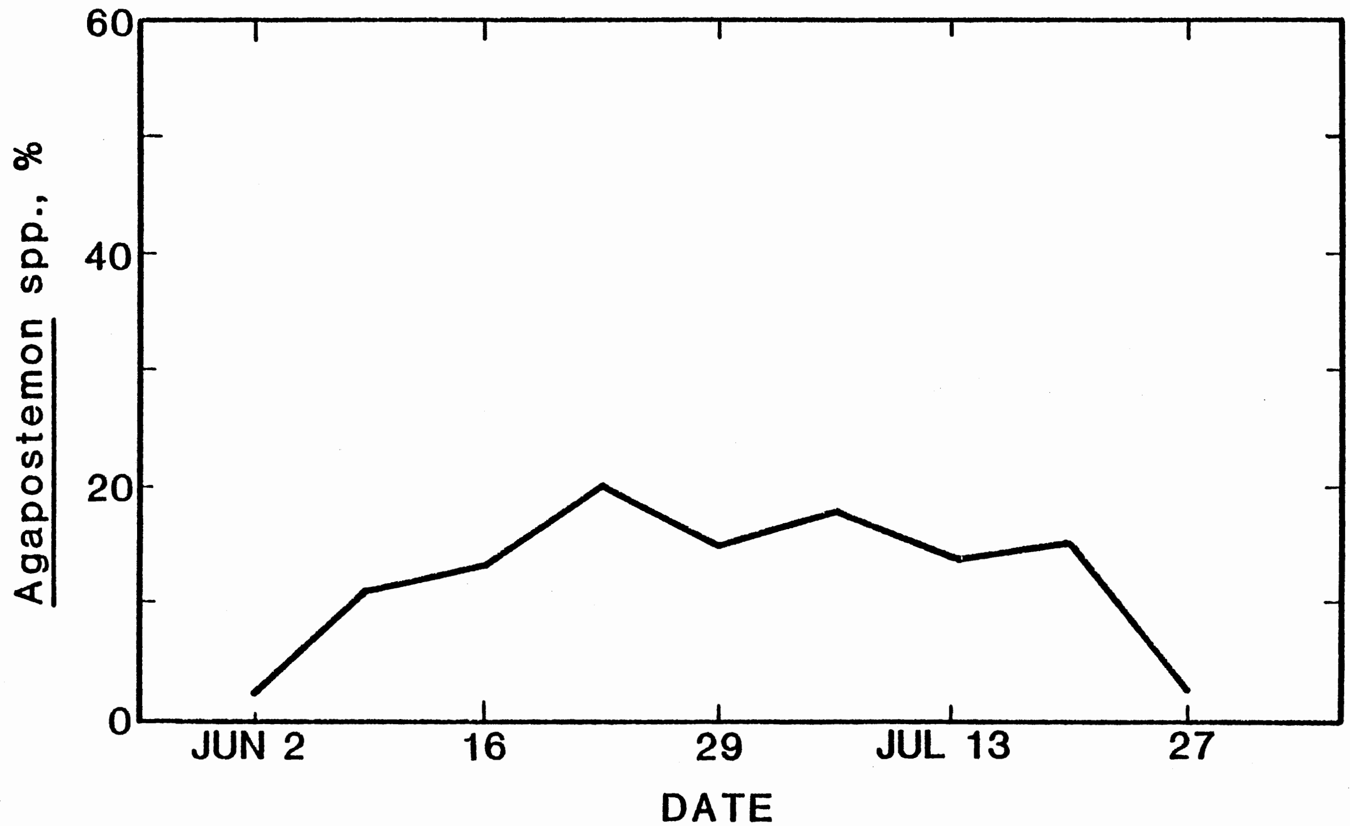

Figure 2. Seasonal Percentage of _Agapostemon_ spp. of Total Wild Bees Collected in Wild Flowers on the Texas High Plains (Two Week Running Mean), 1980

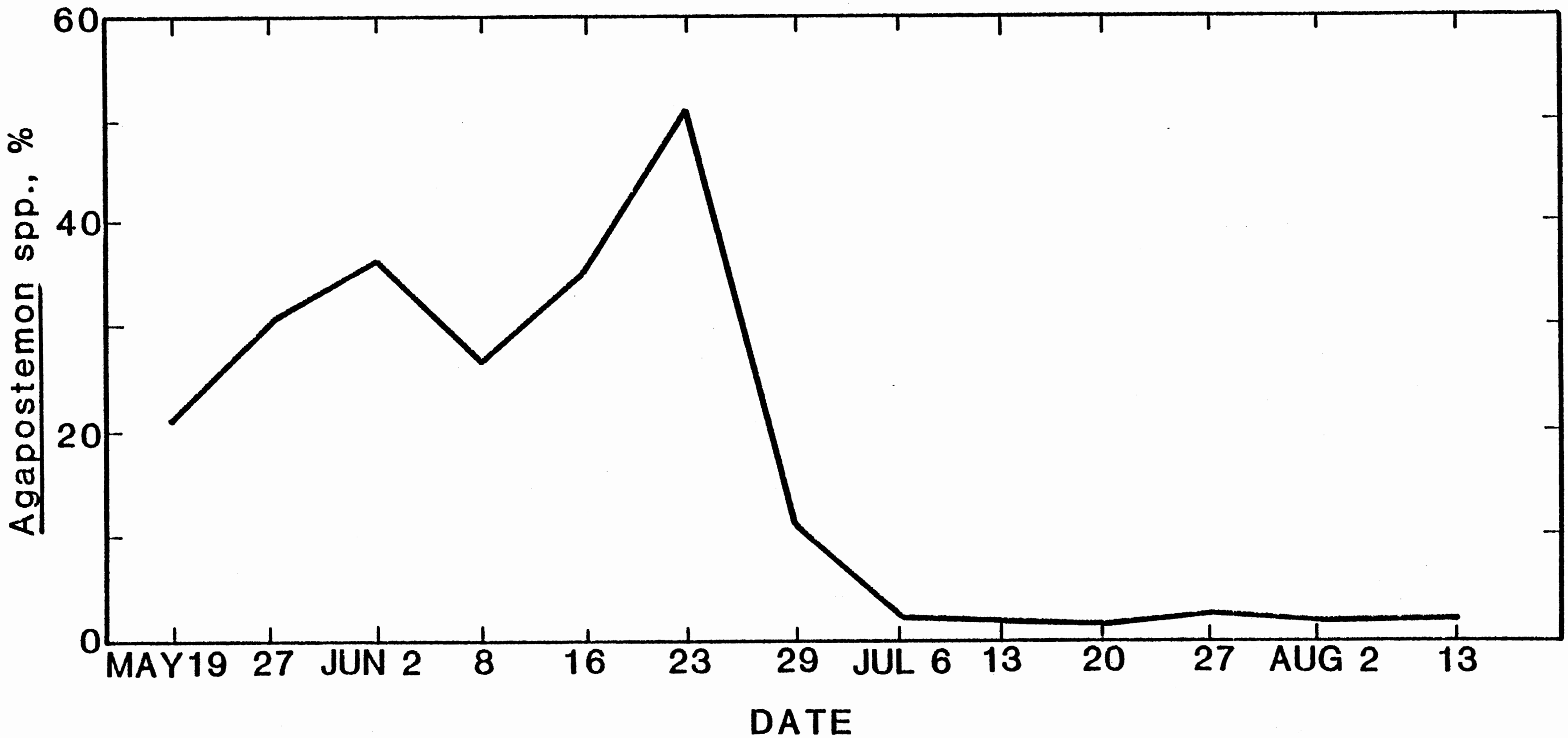

Figure 3. Seasonal Percentage of _Agapostemon_ spp. of All Wild Bees Collected in Native Sunflowers and Cultivated Alfalfa on the Texas High Plains (Two Week Running Mean), 1981

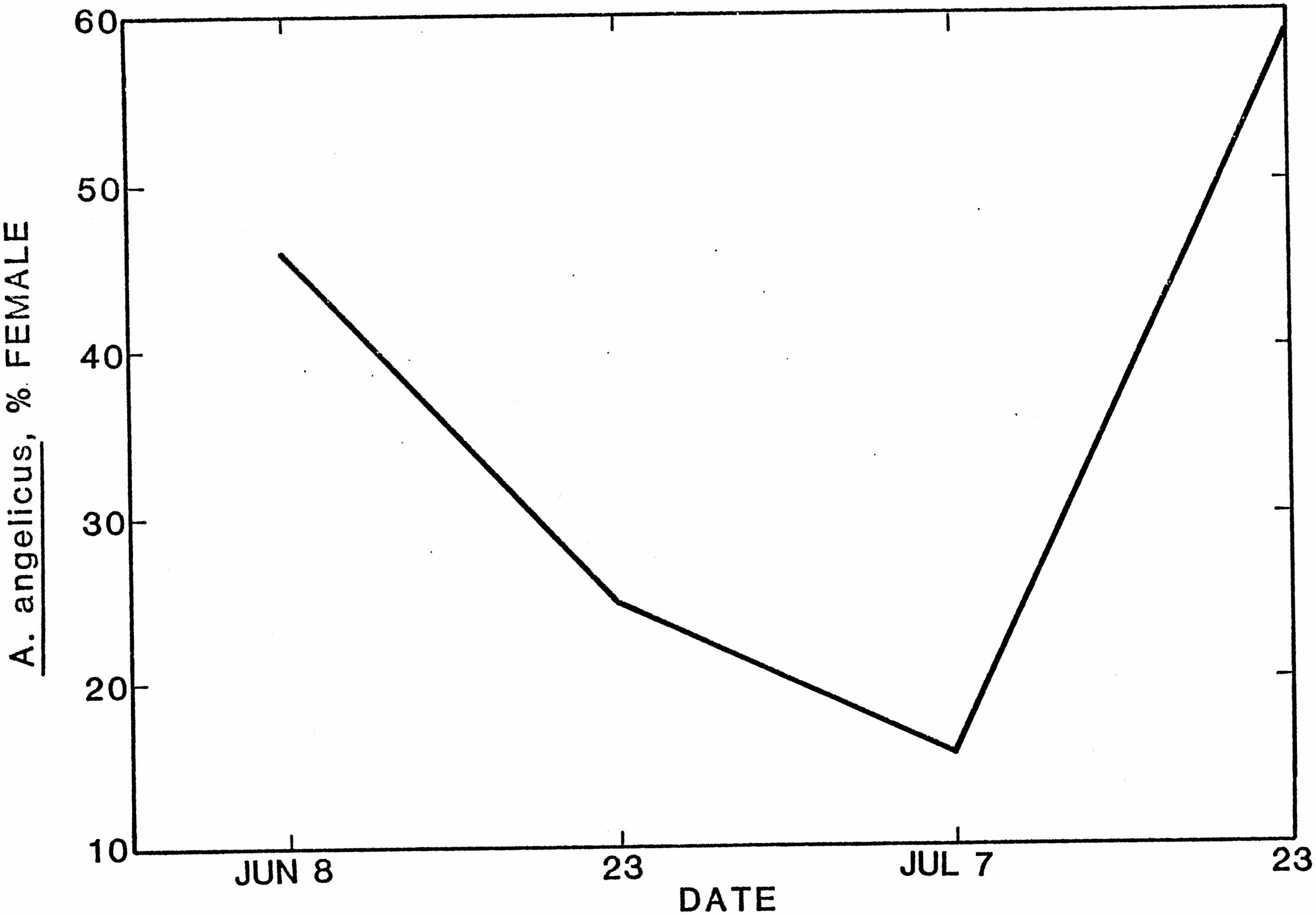

Figure 4. Seasonal Percentage of Female *A. angelicus* Collectea in Wild Flowers on the Texas High Plains (Two Week Running Mean), 1980

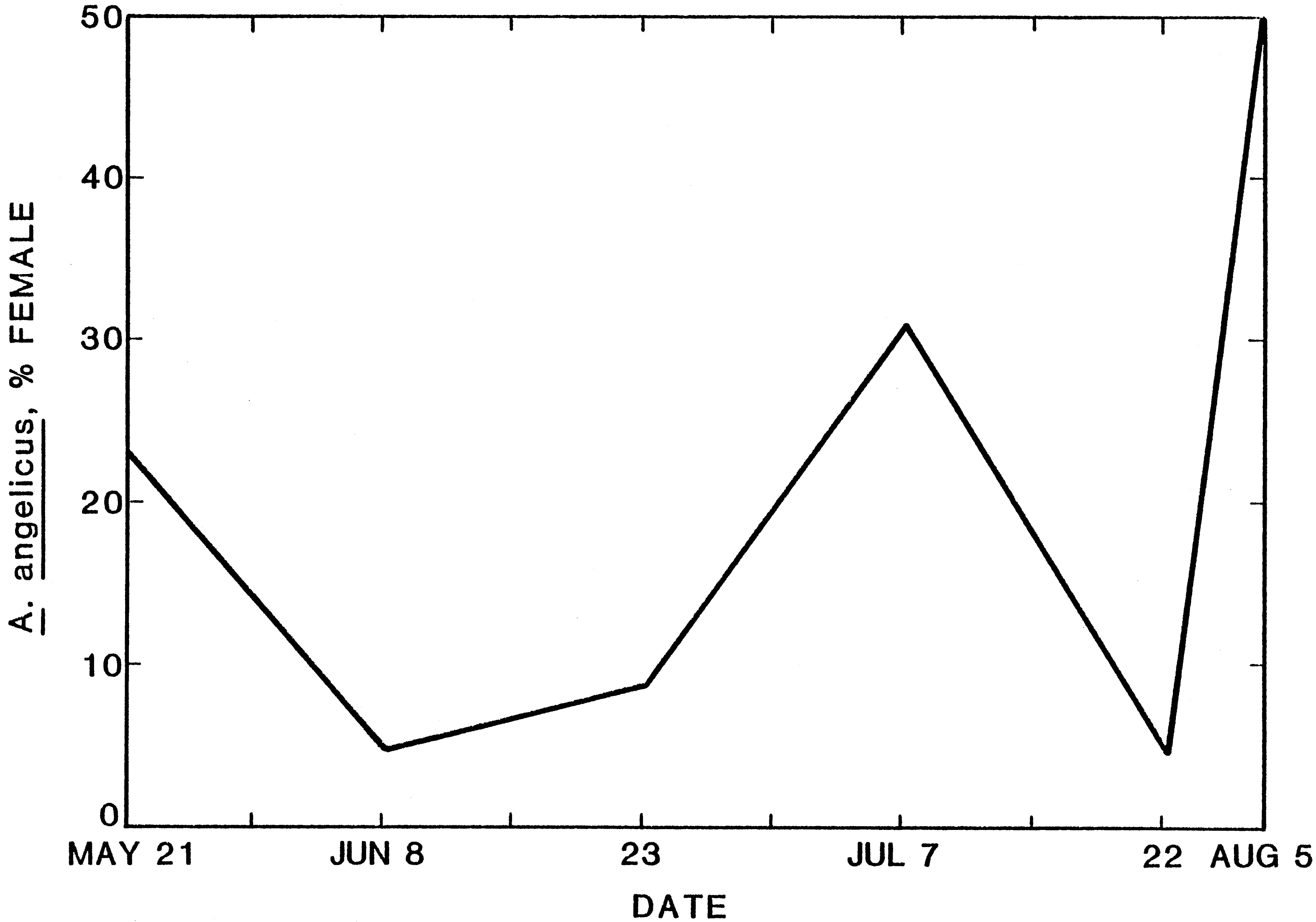

Figure 5. Seasonal Percentage of Female *A. angelicus* Collected in Native Sunflowers and Cultivated Alfalfa on the Texas High Plains (Two Week Running Mean), 1981

nectar sources become scarce.

Wild Bee Population Trends

In 1981, the population trends of wild bees were observed from May 18 to August 18 on both alfalfa and sunflowers. Alfalfa was fairly attractive in early season, but wild bee visitation dropped steadily towards midsummer (Figure 6). Wild bee visits to native sunflower, however, peaked at June 1 and remained high until July 1; then dropped markedly (Figure 7). Overall wild bee visitation to native sunflowers was consistently higher than to alfalfa.

The mean number of bees collected in either dryland (54.3 per 30-minute sample) near the Cap Rock Escarpment (29.39) was greater than from the irrigated region (20.6). These differences, however, were not significant as the variability was large and the number of replications relatively small.

Visitation to Commercial Cotton by *A. angelicus*

Agapostemon angelicus made over 34% of the total number of wild bee visits to commercial cotton flowers (Table VII). Visitation was quite variable according to field location and time of season. Similar variability was reported by Moffett et al. (1976b) in Arizona cotton fields.

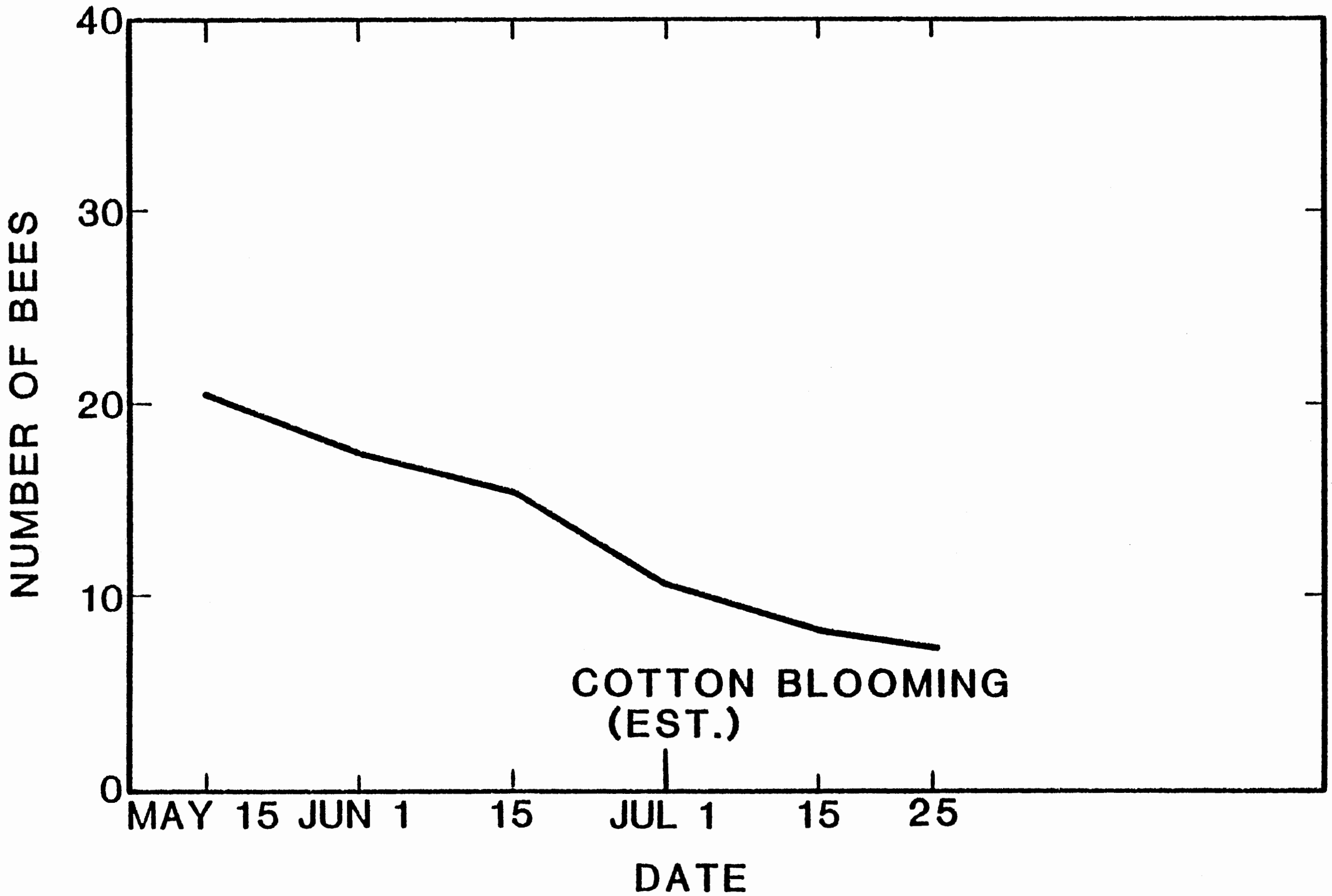

Figure 6. Mean Number of Wild Bees Collected per 30 Minute Sampling Period in Cultivated Alfalfa on the Texas High Plains (Two Week Running Mean), 1981

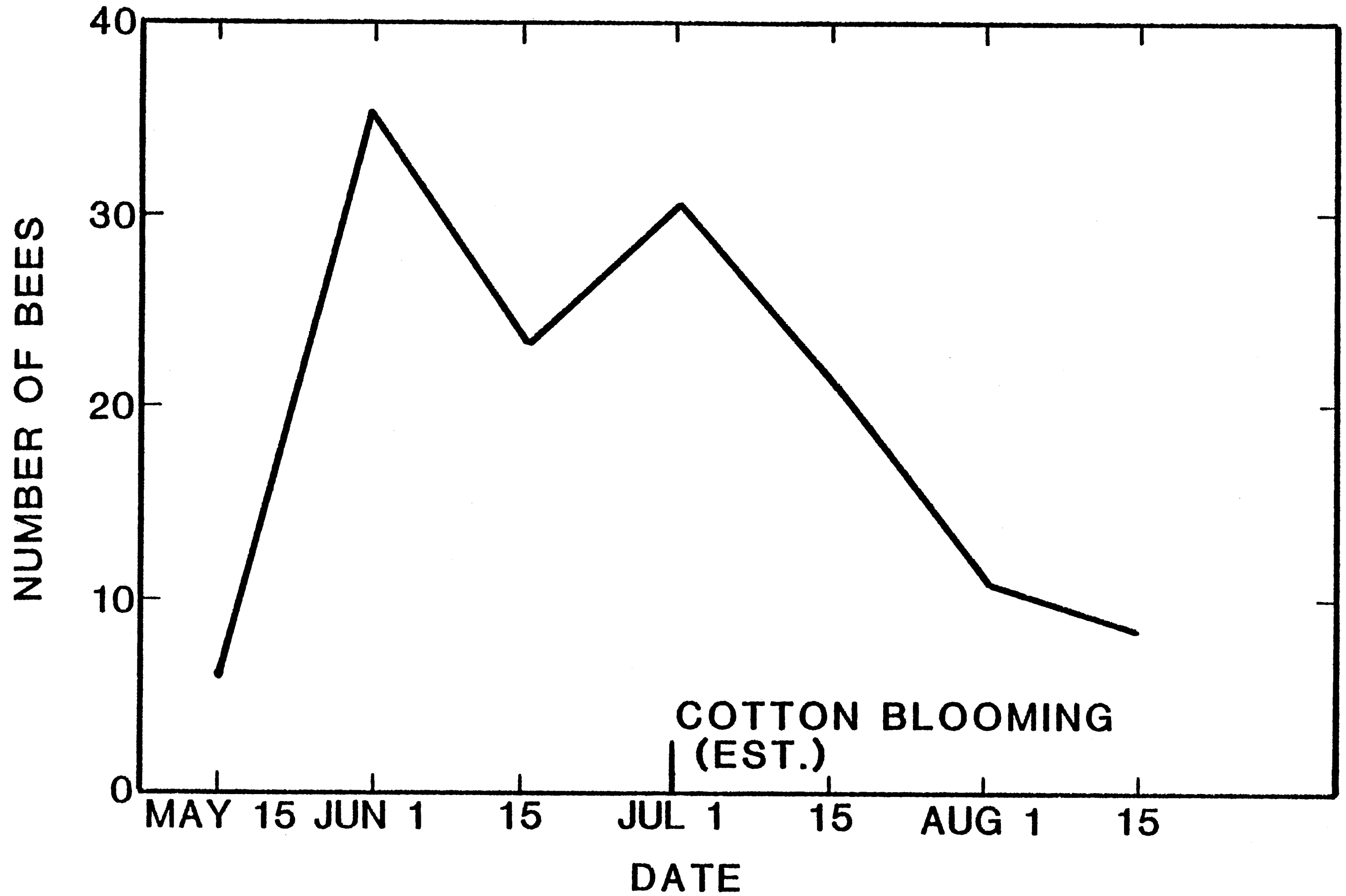

Figure 7. Mean Number of Wild Bees Collected per 30 Minute Sampling Period in Native Sunflower on the Texas High Plains (Two Week Running Mean), 1981

TABLE VII

PERCENTAGE OF TOTAL WILD BEE VISITS MADE BY *A. ANGELICUS* TO 16 FIELDS OF COMMERCIAL COTTON ON THE TEXAS HIGH PLAINS, 1981

Field	*Agapostemon angelicus*	Total wild bee visits		% *Agapostemon angelicus* of total wild bee visits
1	7	31		22.6
2	6	18		33.3
3	0	20		0.0
4	51	74		68.9
5	2	8		25.0
6	1	16		6.3
7	0	0		--
8	1	16		6.3
9	4	6		66.7
10	0	6		0.0
11	2	4		50.0
12	3	11		27.3
13	4	29		13.8
14	3	10		30.0
15	2	3		66.7
16	4	8		50.0
Total	90	260	Mean	29.2[a] 34.6[b]

[a]Weekly mean.
[b]Overall mean.

Daily Visitation Patterns of Wild Bees in Commercial Cotton

Agapostemon angelicus and other wild bees were very active in cotton fields as soon as blooms were open in the morning. Peak visitation was between 0930 and 1030 C.D.T. (Figure 8). Visitation by all wild bees gradually declined until around 1830 when most cotton flowers were closed.

Wild Bee Visitation to Commercial Cotton Fields Under Dryland and Irrigated Conditions

Significant differences in wild bee visitation to dryland and irrigated fields of commercial cotton were not observed (Table VIII). Excessive rains in August may have influenced these results.

Wild Bee Visitation to Commercial Cotton Fields With and Without Alternate Hosts

Wild bee visitation to cotton fields near alternate floral sources was significantly greater ($p < 0.05$) than visitation to cotton fields without alternate floral sources (Table IX). Native sunflowers appeared to be the best alternate host for most wild bee species, including *A. angelicus*, due to their abundance and apparent attractiveness.

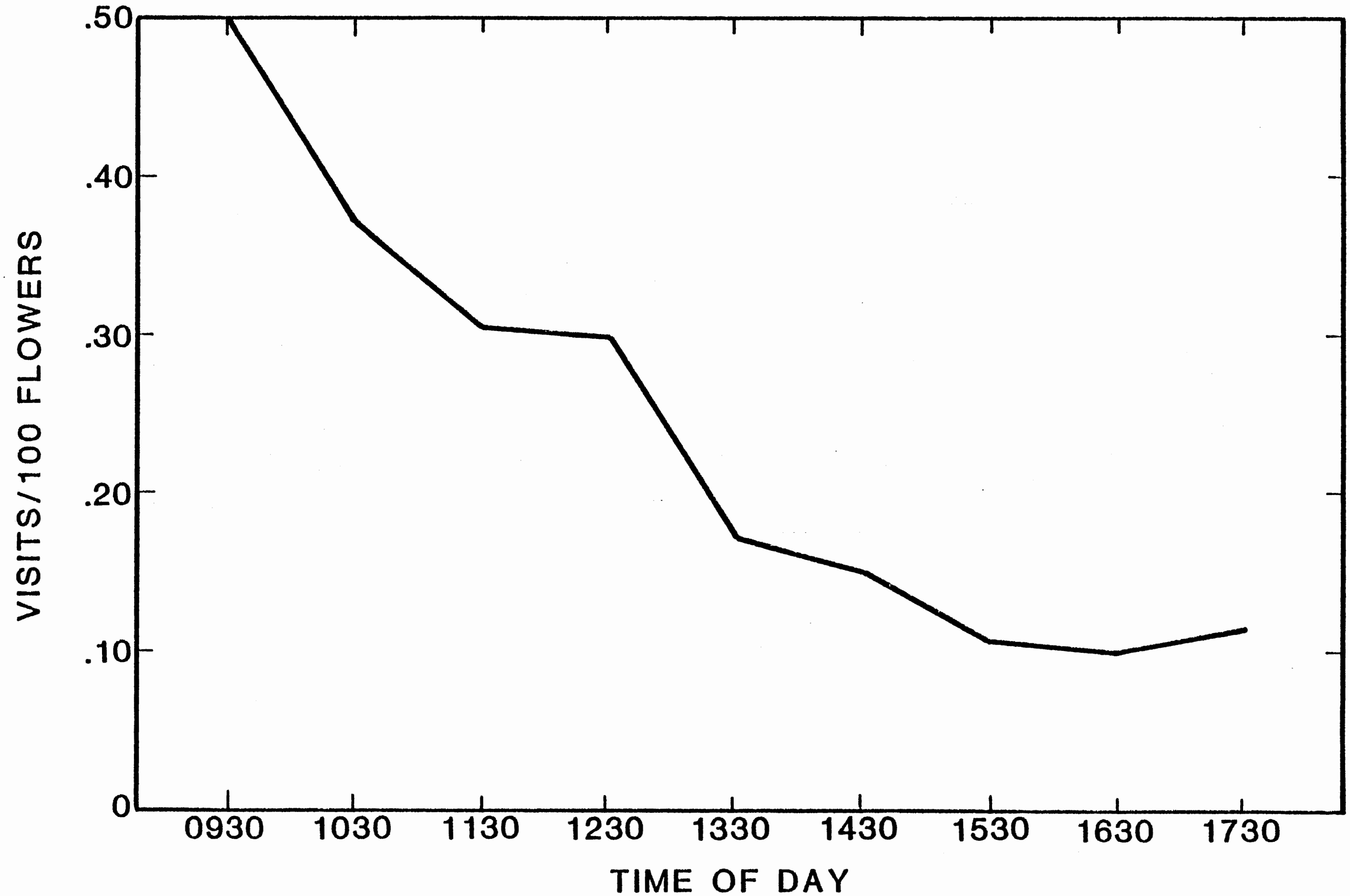

Figure 8. Mean Daily Visitation Pattern of Wild Bees in Commercial Cotton on the Texas High Plains, 1981

TABLE VIII

COMPARISON OF WILD BEE VISITATION IN COMMERCIAL COTTON UNDER DRYLAND AND IRRIGATED CONDITIONS ON TEXAS HIGH PLAINS, 1981

Dryland		Irrigated	
Field	Visitation	Field	Visitation
1	0.39	1	0.49
2	0.29	2	0.10
3	1.15	3	0.05
4	0.09	4	0.13
5	0.16	5	0.11
6	0.10	6	0.04
7	0.00	7	0.04
8	0.13	8	0.14
Mean	0.29*		0.14

*Not significantly different at the 0.05 level of probability.

TABLE IX

COMPARISON OF WILD BEE VISITATION IN COMMERCIAL COTTON FIELDS WITH AND WITHOUT ALTERNATE HOSTS ON THE TEXAS HIGH PLAINS, 1981

Field	No. wild bees	No. blooms	% visitation throughout the day
Fields with alternate host			
1	31	7884	0.39
2	18	6218	0.29
3	20	20838	0.10
4	74	6458	1.15
5	29	5983	0.48
6	10	10281	0.10
7	3	5546	0.05
8	8	6208	0.13
Total	193	69416	Mean* 0.34[a]
			0.28[b]
Fields without alternate host			
1	8	9177	0.09
2	16	12207	0.13
3	0	7921	0.00
4	16	10075	0.16
5	6	5441	0.11
6	6	14344	0.04
7	4	15671	0.04
8	11	7885	0.14
Total	67	82721	Mean* 0.09[a]
			0.08[b]

*Significantly different at the 0.05 level of probability.

[a] Field mean.

[b] Overall mean.

Wild Bee, Honey Bee, and Wasp Activity in A- and B-line Cotton

Visitation by bees to both male-sterile and male-fertile flowers at the Lamesa field was abundant. The majority of visits were made by honey bees (Figures 9 and 10). Visitation averaged 2.10% in A-line cotton and 1.56% in B-line cotton. The breakdown of visitation to the A-line was honey bees, 76.5%; wild bees, 12.7%; and wasps, 0.8%. In the B-line it was honey bees, 62.4%; wild bees, 36.8%; and wasps, 0.8%.

Agapostemon angelicus females made 36% of the wild bee visits to cotton flowers in the Lamesa field. The B-line was preferred by a 7 to 1 ratio over the A-line by *A. angelicus* females.

Peak activity of wild bees foraging in A- and B-line cotton was observed prior to 1200 hours. Wild bees preferred the pollen bearing B-line and made 68.7% of their total visits to it.

Honey bees preferred to forage on the A-line. Peak activity of foragers was between 1200 and 1400 hours on the A-line and between 1400 and 1600 hours on the B-line. Over 64% of the total honey bee visits were made to A-line flowers.

Wasps made only 0.8% of the total visits to both lines and were not observed to carry sizeable quantities of pollen.

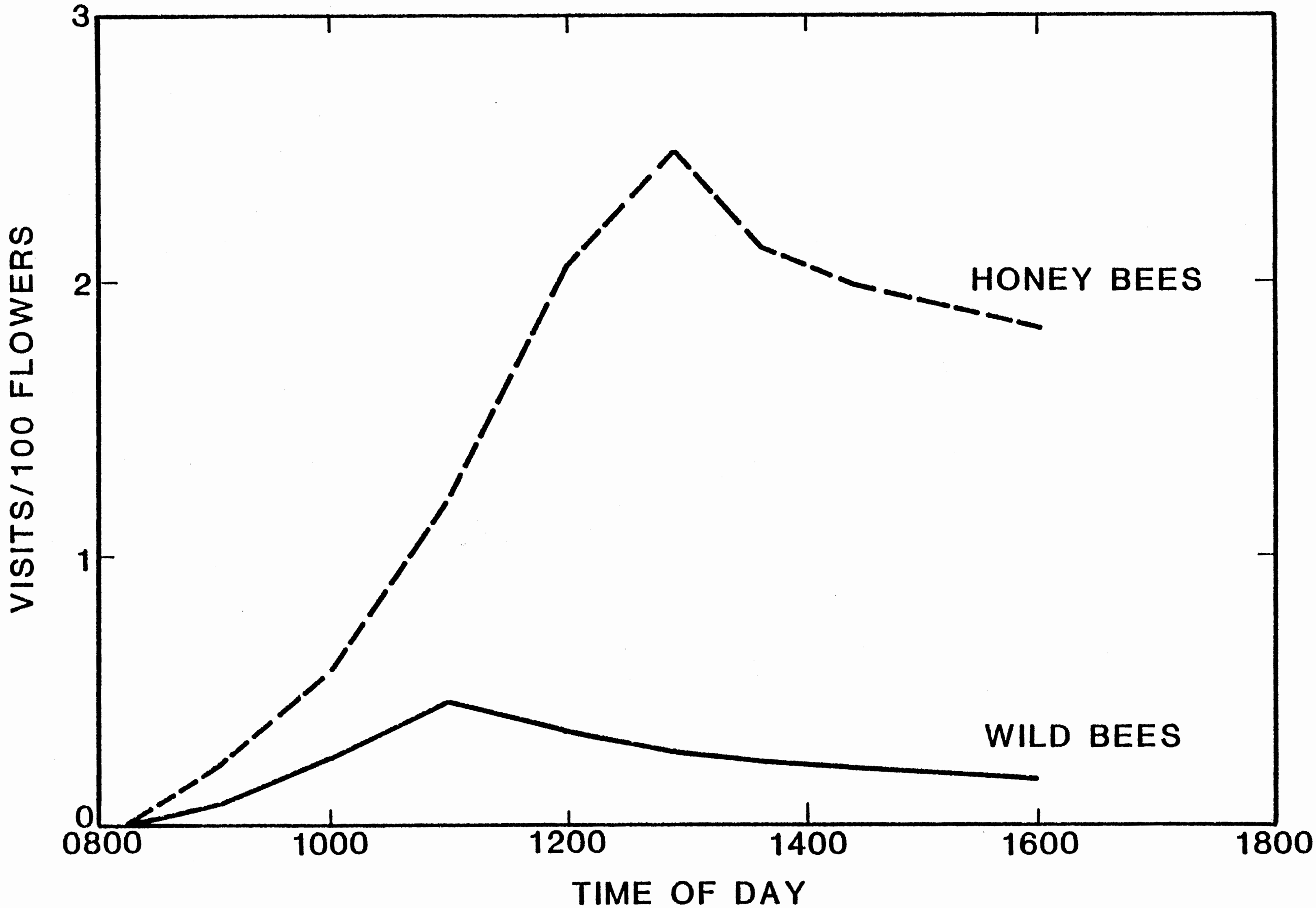

Figure 9. Mean Daily Visitation Patterns of Honey Bees and Wild Bees to Male-Sterile (A-line) Flowers (Dawson County, Texas; July 25 - August 22, 1981)

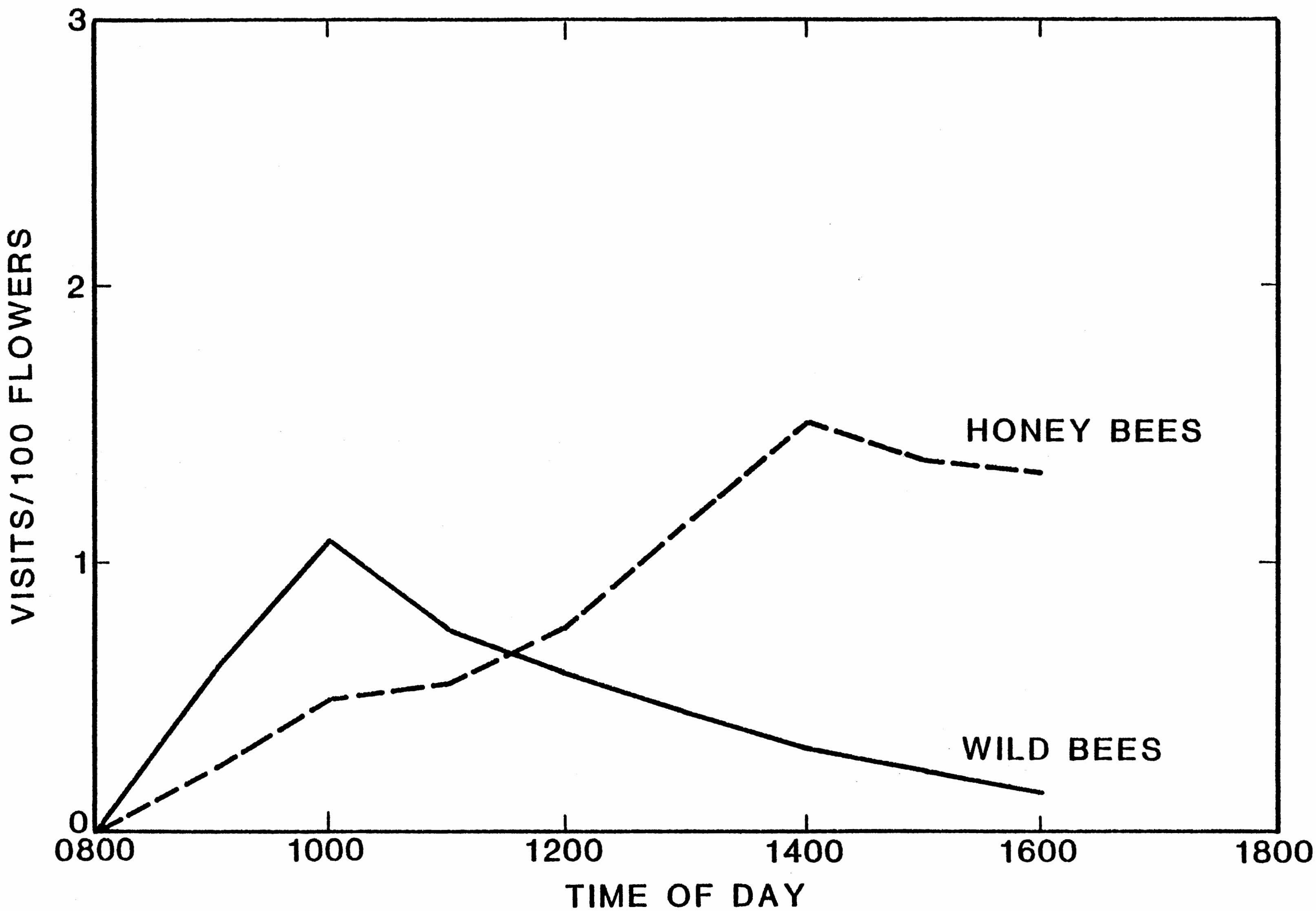

Figure 10. Mean Daily Visitation Patterns of Honey Bees and Wild Bees to Male-Fertile (B-line) Flowers (Dawson County, Texas; July 25 - August 22, 1981)

CHAPTER V

DISCUSSION

The aerial sweep net method of collection permitted uniform sampling of wild bee populations over a large geographical region. This method was useful in that the sampling intervals were short enough so the proportional abundance of *A. angelicus* was possible to monitor over short periods of time. Since only the bees actually "sighted" were collected, it should be considered that some species were not collected as often as the larger, more active, and more conspicuous species. This sampling technique was applied consistently however; and this survey does serve as an index of the relative abundance of *A. angelicus* on the Texas High Plains.

The Distribution and Abundance of *A. angelicus*

The distribution and abundance of animal species should be regarded as different aspects of the same problem (Andrewartha and Birch 1954). Inside the distribution area there may be favorable zones where a high level of abundance is maintained. Richards (1941) also states that a population will occupy a fairly well-defined area, although this distribution is hardly ever continuous. The surveys conducted in 1980 and 1981 show that *A. angelicus* is within the reported range of usual distribution for this species (Roberts 1972). *A. angelicus* was collected in all 13 counties surveyed. Favorable zones for this and other wild bee species are those supporting large numbers of wild plants in early spring and summer. Dryland areas and areas near the Cap Rock Escarpment appeared to provide more suitable habitat for wild bees than did the intensively cultivated irrigated region.

The tendency of wild bee populations in native sunflowers and alfalfa to decline in late June (Figures 6 and 7) suggests a migration from these plants (especially sunflower) may occur as cotton comes into bloom. Populations monitored after July 1 never regained the high numbers observed earlier in the season. The abundance of *A. angelicus* (Table VII) and all wild bees in cotton fields, particularly those near alternate hosts (Table IX) supports this hypothesis. Thus, the combined culture and preservation of alternate hosts such as native sunflower near A- and B-line cotton fields could promote wild bee populations. In a similar situation, Stephen (1955) has reported that the production of alfalfa seed in Manitoba was most successful in the lands adjacent to uncultivated areas. The elimination of native bee fauna was the primary cause of the decline in the number of available pollinators.

Females of *A. angelicus* are capable of transferring large amounts of pollen while males are not. Seasonal sex ratios observed in sunflower and alfalfa (Figure 3) indicate that females are abundant as cotton comes into bloom. The actual number of females observed visiting cotton flowers (Table VII) also confirms that their seasonality is in synchrony with the cotton blooming period.

A. angelicus as a Pollinator of A-line Cotton

The mean daily visitation of *A. angelicus* and other wild bees to both commercial (Table VII) and A- and B-line cotton fields (Figures 9 and 10) show they are primarily morning foragers. According to McGregor (1976), the pollen applied earliest to the stigma is more effective in maximizing seed set than pollen applied later. On that basis, wild bees (as compared to honeybees) could potentially be more efficient pollinators if populations are adequate, stable, and visitation patterns consistent.

A major consideration of *A. angelicus* as a potential pollinator of hybrid cotton is its selective activity on A- and B-lines. This species, like many wild bees, preferred to make its visits to the pollen bearing B-line. Only 12.5% of the total *A. angelicus* visits were to A-line flowers. This foraging behavior was consistent over the 5-week study at Lamesa. Although *A. angelicus* is reported to carry large amounts of pollen (Bohart 1980), these findings may possibly be misleading. Since 87.5% of the total visits by this species were to the B-line, it would follow that these bees would be dusted with pollen purely due to the nature of the flowers they preferred to visit. Further studies need to be made on the pollen loads of A. angelicus foraging on A-line rows. Breeding programs could possibly incorporate attractive traits into the A-line and encourage visitation by all wild bees, especially by A. angelicus.

The problems associated with using a wild pollinator to produce hybrid cottonseed appear twofold: 1) Some bees such as A. angelicus are abundant in cotton fields, but the frequency at which they visit both lines is not uniform and adequate pollination of the A-line probably does not result. 2) Other bees such as Bombus spp. were observed to freely collect pollen and nectar from both lines, yet their scarcity on the Texas High Plains makes them unsuitable as pollinators at this time.

CHAPTER VI

SUMMARY AND CONCLUSIONS

This 2-year study was undertaken to determine the distribution and abundance of *A. angelicus* on the Texas High Plains. Seasonal cycles and foraging patterns relative to the species potential as a pollinator of hybrid cotton lines were examined. Observations on other wild bees and honeybees were made whenever possible. Some of these findings are listed below:

1. Areas on the High Plains of Texas which appear to support an abundance of *A. angelicus* and other wild bees are those which provide attractive and abundant floral sources early in the spring and summer. Dryland regions and those near the Cap Rock Escarpment appear to support the most suitable habitat for wild bee species.
2. Total wild bee population trends in sunflower and alfalfa peaked in mid-to-late June and declined markedly around July 1. It was hypothesized that the wild bees migrate to cotton at this time when the cotton starts to bloom.
3. *Agapostemon* spp. comprised over 20% of the 11,984

wild bees collected in 1980 and 1981 and over 34% of the total wild bee visits observed in commercial cotton.

4. More than 98% of the six species of *Agapostemon* collected were *A. angelicus*. The other five species included *A. cockerelli*, *A. coloradinus*, *A. melliventris*, *A. splendens*, and *A. texanus*.
5. *Agapostemon* spp. were most abundant in wild flowers and alfalfa in mid-to-late June.
6. Almost 90% of the total *A. angelicus* collected in wild flowers and alfalfa were males.
7. *A. angelicus* was most active in commercial and A- and B-line cotton prior to 1200 hours. This bee preferred to forage on the pollen-bearing B-line to the A-line by a 7 to 1 ratio.
8. Honey bees made most of their visits between 1200 and 1600 hours. Over 60% of their visits were to the A-line.
9. Cotton fields next to alternate hosts had significantly greater populations and visitation by *A. angelicus* and other wild bees than those fields without alternate hosts.

Although *A. angelicus* is a primary wild bee species in cotton, its preference for the pollen bearing B-line makes its value as a potential pollinator of hybrid cotton lines questionable. Increasing the attractiveness of the A-line could possibly remedy this situation.

Alternate hosts planted next to or near cotton fields requiring pollination would promote wild bee populations. Suggested floral sources are yellow sweetclover, sunflowers, alfalfa, or any other flowering plant which is early, attractive, and abundant.

At this time, few areas on the Texas High Plains appear to support sufficient wild bee populations to adequately and efficiently pollinate large acreages of A-line cotton. However, the potential advantage of using wild bees to pollinate small fields of male-sterile cotton justifies continued research efforts in this area.

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APPENDIXES

TABLE III

LIST OF APOIDEA COLLECTED ON THE TEXAS HIGH PLAINS, 1980

Name	No. Collected
Family Andrenidae	
1. *Andrena* spp.	35
2. *Perdita* spp.	365
3. *Psaenythia* spp.	5
Family Anthophoridae	
4. *Anthophora californica texana* Cresson	6
5. *Anthophora curta* Provancher	13
6. *Anthophora* spp.	1
7. *Centris caesalpiniae* Cockerell	46
8. *Centris* spp.	5
9. *Diadasia diminuta* (Cresson)	7
10. *Diadasia enavata* (Cresson)	477
11. *Diadasia olivacea* (Cresson)	5
12. *Diadasia rinconis* Cockerell	28
13. *Ericiosis* sp.	1
14. *Exomalopsis compactula* (Cockerell)	11
15. *Exomalopsis solani* Cockerell	70
16. *Martinapis luteicornis* (Cockerell)	22
17. *Melissodes communis* (Cresson)	25
18. *Melissodes coreopsis* Robertson	33
19. *Melissodes thelypodii* Cockerell	42
20. *Melissodes tristis* Cockerell	107
21. *Melissodes* spp.	838
22. *Nomada texana* Cresson	193
23. *Nomada* spp.	1
24. *Svastra aegis* (La Berge)	3
25. *Svastra atripes* (Cresson)	63
26. *Svastra comanche* (Cresson)	9
27. *Svastra obliqua* (Say)	123
28. *Svastra petulca* (Cresson)	92
29. *Svastra* spp.	2
30. *Triepeolus helianthi* (Robertson)	67
31. *Triepeolus nevadensis* (Cresson)	5

TABLE III (Continued)

Name	No. Collected
Family Anthophoridae cont.	
32. *Triepeolus* spp.	52
33. *Xenoglossa strenua* (Cresson)	3
34. *Xenoglossa eriocarpi* (Cockerell)	13
Family Apidae	
35. *Apis mellifera* Linnaeus	25
36. *Bombus* spp.	14
Family Colletidae	
37. *Colletes* spp.	15
Family Halictidae	
38. *Agapostemon angelicus* Cockerell	809
39. *Agapostemon cockerell* Crawford	1
40. *Agapostemon coloradinus* Crawford	1
41. *Agapostemon melliventris* Cresson	3
42. *Agapostemon splendens* (Lepeletier)	9
43. *Agapostemon* spp.	2
44. *Augochlorella striata* (Provancher)	8
45. *Augochloropsis metallica* (Fabricus)	10
46. *Augochloropsis sumptuosa* (Smith)	41
47. *Dialictus* spp.	59
48. *Evylaeus* spp.	16
49. *Halictus ligatus* Say	134
50. *Halictus parallelus* Say	5
51. *Halictus* spp.	107
52. *Hemihalictus lustrans* (Cockerell)	1
53. *Nomia bakerii* Cockerell	19
54. *Nomia foxii* Dalla Forre	94
55. *Nomia heteropoda* Say	89
Family Megachilidae	
56. *Anthidiellum* spp.	4
57. *Anthidium* spp.	4
58. *Ashmeadiella* spp.	12
59. *Coelioxys* spp.	12
60. *Heteranthidium*	1
61. *Lithurge bruesi* (Mitchell)	1
62. *Megachile integra* Cresson	46

TABLE III (Continued)

Name	No. Collected
Family Megachilidae cont.	
63. *Megachile parallela* Smith	96
64. *Megachile policaris* Say	31
65. *Megachile* spp.	102
66. *Osmia subfasciata* Cresson	1
Family Mellitidae	
67. *Hesperapis* spp.	4

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