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By

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ABSTRACT

COMPONENTS OF STRAWBERRY POLLINATION IN MICHIGAN

By

Lawrence John Connor

A system of evaluating the effectiveness of strawberry pollination in commercial fields is presented based upon flower and insect related pollination mechanisms. Strawberry flowers were pollinated through self-, wind-motion, and insect pollination mechanisms, although the relative amount each contributed to the pollination of a specific cultivar was related to floral morphological aspects--particularly stamen and receptacle height of that cultivar. Based upon observations on 11 cultivars, self-pollination resulted in 53% achene set, the addition of wind-motion resulted in an average of 67% achene set, and the addition of insect pollinators resulted in 91% achene set. Insect pollination contributed greatest to the pollination of intermediate and short-stamened flowers with tall receptacles, while self-pollination and wind-motion pollination made the greatest contribution to flowers with stamens taller than the receptacle. Stamen height was correlated at the 1% probability level with percent achene set in cloth covered cages ($r = 0.657$, $n = 44$) and in screen covered cages ($r = 0.599$, $n = 44$) although considerable variation was present in these data. Further correlation of stamen height of the primary,

secondary, tertiary and quaternary flowers with the corresponding percent achene set demonstrated significance at the 5% probability level only in the primary and secondary berries in the self pollinated plots, and only the primary berries in the wind-motion pollinated plots. This variation was due to other morphological aspects of the flowers, particularly differences in the ratio of the height of the stamens to the height of the receptacle. Within a cultivar, as stamen height increased from primary to quaternary flowers, the height of the receptacle on the corresponding flowers decreased, causing the variations in the data.

Insect pollinators approximately the size of honey bees (Apis mellifera L.) touched both the stamens and stigmas of hermaphroditic flowers during their visits, while smaller insects usually remained outside the ring of stamens. The relative prevalence of bees in strawberry fields in 1970 was: Apidae 35%, Andrenidae 14%, Halictidae 52%, and Megachilidae 1%. The distribution in 1971 was: Apidae 31%, Andrenidae 20%, and Halictidae 49%.

Maximum bee activity on strawberry flowers was observed between 10 a.m. and 3 p.m., at average temperatures ranging from 65 to 79°F., and at low wind speeds. 'Midway 2' and 'Midway 1' attracted the greatest number of bees and flies while 'Sunrise' and 'Redchief' were less attractive. Both 'Midway 1' and 'Midway 2' were good pollen producers, based upon pollen collection by honey bees, while 'Sunrise' and 'Redchief' were poorer. Plants competing with strawberry flowers for honey bee pollen collection were: choke cherry (Prunus spp.), apple (Pyrus malus), dandelion (Taraxacum officinale), mustard (Brassica sp.), yellow rocket (Barbarea vulgaris), and willow (Salix spp.). When overall pollinator populations were low in large fields, the pollinators aggregated along the edges of the field. Strong wind exposure in open fields during bloom decreased bee populations, limiting foraging to areas protected from wind. Fields surrounded by cultivated soil and orchards had fewer native bees than fields surrounded by uncultivated land; likewise, honey bees were present in greatest numbers in those fields where colonies were present within or adjacent to the strawberry field. Finally, insecticide use during flowering seriously reduced numbers of insect pollinators, which consequently reduced the level of achene set.

The author recommends that horticulturalists developing new strawberry cultivars work with entomologists to evaluate the pollination needs of each new release, providing each new cultivar with fair evaluation under optimum pollination conditions.

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INTRODUCTION

Continual study and review of the pollination mechanisms and requirements of agricultural crops are needed to keep abreast with new cultivars, changing economics of production, and new cultivation and harvest techniques. In Michigan, such studies have been conducted on blueberry pollination (Dorr and Martin, 1966; Brewer, Dobson, and Nelson, 1969a, 1969b; and Brewer and Dobson, 1969a, 1969b), and on cucumber pollination (Connor and Martin, 1970, 1971; and Collison and Martin, 1970). Because commercial strawberries grown in Michigan lacked such a review, the author surveyed the status of strawberry pollination to isolate the major components of pollination of strawberries. By isolating these mechanisms it was possible to develop a system to evaluate strawberry pollination in commercial fields. Variations in this system were investigated to provide better understanding of strawberry pollination mechanisms.

LITERATURE

Most commercial strawberry flowers are self-pollinated, and to understand the mechanisms of strawberry pollination, we must first understand the morphology of the flower. Modern strawberry cultivars are the result of man's selection from the genetic material of 3 species of wild strawberries, *Fragaria* spp. Two of these species were transported to Europe in the American colonial period. There is circumstantial evidence that they were grown together in gardens and chance seedlings resulted from their accidental hybridization. The hybrids were the progenitors of a new type of strawberry with large berries. These two species were *Fragaria virginiana* L., of Eastern North America, and *F. chiloensis*, native to the Pacific coast of North and South America. *Fragaria ovalis* was also incorporated into some cultivars (Darrow, 1966).

The first cultivars were generally dioecious, possessing separate staminate and pistillate plants. Hermaphroditic selections were not productive in the early days of the industry, and only set a small percentage of the flowers on each inflorescence. However, through plant breeding, hermaphroditic cultivars have been obtained which give nearly 100% berry set (Darrow, 1966).

Floral Hierarchy

There is a predictable hierarchy on flower stems which dictates the order of flowering, the number of pistils per flower, and the relative size of the berry. Typically there are one primary, two secondary, 4 tertiary, and 8 quaternary berries per inflorescence (Darrow, 1966). Because this pattern varies either with multiple or with incomplete branching on the stem, varying numbers of flowers are possible on a inflorescence (Janick and Eggert, 1968). The primary flower of an inflorescence is the largest, has the most pistils, and opens first. Secondary flowers are somewhat smaller, and open next in order. Later, the still smaller tertiary and quaternary flowers follow.

Floral Morphology

Strawberry flowers are typically 5-merous with white petals subtending 20 to 35 stamens in 3 whorls. The stamens differ in size and length within the same flower. Anthers are a deep golden yellow when they contain pollen, but turn pale as pollen is released. Undeveloped stamens, called staminodia, occasionally appear on the same flower with good stamens, while other flowers have only staminodia (Darrow, 1966).

Inside the circle of stamens is a cone-shaped structure called the receptacle. This is an extension of the stem and is covered with a few to over 500 pistils arranged in a spiral pattern. Pistils are long and narrow with rough sticky stigmas. At the base of the pistil is an ovary containing an ovule. The true fruit is an achene; the aggregate of achenes on the fleshy receptacle forms the commercial berry. Fertilization occurs in 24 to 48 hours following pollination;

the seeds are mature before the berries reach full size and become red (Darrow, 1966).

There is a direct relationship between the number of developed achenes and berry weight (Gardner, 1923; Robbins, 1932; and Nitsch, 1950, 1952). Fertilization of ovules releases growth substances which stimulate receptacle growth: unfertilized ovules remain small and are surrounded by undeveloped flesh. When a large number of achenes are unfertilized, a noticeable shrunken 'knot' or depression appears and the berry is poorly shaped.

Pollination Mechanisms

Strawberry pollen matures prior to anthesis and is released when the anthers open along lateral slits. Sometimes the heavy, sticky pollen is under tension and is thrown out on the adjacent pistils and petals (Knuth, 1906). Later it dries and may become airborne (Darrow, 1927). However, strawberry flowers are not considered wind-pollinated within the accepted definition because their pollen does not travel far into the air. The stigmas are small and pollen production is limited when compared to true wind-pollinated species. However, a minimal amount of wind pollination may occur in hermaphroditic flowers (Faegri and van der Pijl, 1966). Strawberry flowers benefit from the closeness of the anthers to adjacent pistils. Thus, some self-pollination is possible in hermaphroditic cultivars, but seldom provides for complete pollination of all pistils on a flower. For example, Swarbrick and Thompson (1933) obtained more complete pollination when pollen was brushed over the entire receptacle of the flower than when the flowers were undisturbed. And Allen and Gaede (1963), using greenhouse plants, reported 20% normal berries from undisturbed flowers, 77% normal berries from wind-pollinated flowers, and 97% from brush pollinated flowers. Finally, Way (1968) noted that berries grown in a greenhouse without wind were more misshapen than berries grown in the open.

Insect Pollination Studies

Insect pollinators were essential for the pollination of early types of strawberries and necessary in the pollination of pistillate cultivars popular several decades ago (Darrow, 1966). Fletcher (1917) considered insects responsible for over 90% of all strawberry pollination. Recently, many studies have been conducted with insect pollinators, all indicating that insects increase yield: either increased berry set, increased berry weight, increased achene set, or decreased nubbins (Table 1).

Insect Activity on Strawberry Flowers

Nearly all previous reports of insect activity on strawberry flowers dealt with observations on the honey bee, *Apis mellifera* L. They visit strawberry flowers to collect pollen and/or nectar. Nectar collectors touch both pistils and stamens on nearly every visit: they often landed on the side of the flower and walk over the stigmas; pollen collectors often stood on the pistil-covered receptacle and pivoted on the flower or circled around the stamens scrabbling for pollen (Free, 1968b). Honey bees vary in the length of time spent on individual flowers ie., 7 seconds (Petkov, 1965), 7.6 to 10.6 seconds (Free, 1968b). Free (1968b) noted that honey bees worked 12 to 14% of

TABLE 1.--References comparing yields with and without insect pollination.

REFERENCE	OBSERVATIONS
Strebtsova (1957)	Found by regulating the number of honey bee visits to flowers that berry set increased up to 11 to 16 visits, while the quality and weight of individual berries increased up to 60 visits.
Hughes (1961)	Extremely misshapened berries of unmarketable quality in screen cages with no bees.
Petkov (1965)	Flowers isolated in screen cages set 31 - 39% vs. 55 to 60% in open plots. In screen cages berry deformity was equal to 60 to 65%, vs. 14 - 18% in uncovered plots.
Rajput and Singh (1967b)	Insect pollinator exclusion reduced fruit set 8 to 18% in 1962 and 2 to 8% in 1963.
Moore (1969)	Pollinator exclusion increased the percent of poorly formed berries, and delayed ripening of 2 out of 3 cultivars.
Mommers (1961)	Improved berry weight and berry quality when insect pollinators were present.
Free (1968a)	Greater berry set, larger, better shaped berries.
Free (1968b)	Yields without bees in cages resulted in lower berry set, lower average berry weight and lower percentage of well formed berries.
Couston (1966)	Open plots gave a higher proportion of marketable fruits than in cage plots.

the exposed flowers as they visited. Pollen collection by honey bees peaked from 11 a.m. to 2 p.m. (Free, 1968b) and ranged from 39% (Free, 1968b) to 48 to 78% (Petkov, 1965) pollen collection by honey bees.

Mitchell (1960) cited numerous bee species as visitors to Fragaria, particularly from the families Andrenidae and Halictidae. However, the role of these insects as pollinators was unknown in Michigan. Also, the hover flies, Eristalis and Syrphus, were noted by the Horticultural Educational Association, (1961). Free (1968b) reported that Bombus spp. rarely visited strawberry flowers.

Environmental Influences

Cool temperatures influence both insect visits to strawberry flowers and flower development. Kronenberg et al (1959) found that cultivars differed in their responses to temperature: ie., they found that 'Deutsch Evern' produced berries at temperatures lower than 'Jacunda'. Greater exposure to wind increased the number of poorly shaped berries or nubbins when compared to well protected fields (Kronenberg, et al 1959). Although cool temperatures prolonged the period of receptivity of pistils (Moore, 1964) more malformed berries were produced in wet and cool weather. Furthermore, cold temperatures reduced pollen formation, fertility, germination and receptacle development, as well as the ratio of number of achenes to berry weight (Thompson, 1971). Heavy rainfall reduced achene development and increased the frequency of malformed berries: repeated drops of water in newly opened flowers prevented berry set or produced very abnormal berries (Marshall, 1954).

Cultivar Preferences by Bees and Flies

Strawberry cultivars are extremely variable in their pollen production (Darrow, 1966), and honey bees collect much more pollen from some cultivars than others (Free, 1970). Skrebtsova (1957) found that bees visited the cultivar 'Misouka' more frequently than either 'Krasavitsa sagoria' or 'Komsomolka' at rates of 578, 429, and 328 visits respectively. Skrebtsova found that 'Misouka' had larger anthers, produced more pollen, and secreted more nectar than 'Krasavitsa sagoria'.

Pesticide Influence on Strawberry Pollination

Pesticides applied to strawberries in bloom may reduce or eliminate native bee and honey bee pollinators from those fields. Some pesticides also cause additional harm because of their phytotoxicity to strawberry pollen (Eaton and Chen, 1969; Bennet, 1968; Lockart, 1967). The Michigan Fruit Spraying Calendar (Thompson et al, 1972) recommends insecticide use at or before 10% king (primary) bloom to control plant bug and fungicide applications several times during bloom. By following this program, growers may deleteriously affect both insect pollination and pollen fertility (Eaton and Chen, 1969).

METHODS AND MATERIALS

Cage Studies

Different style cages were used in 1969, 1970 and 1971 to isolate the components of strawberry pollination, to measure the relative contribution of each component to the overall pollination of the flower, and to seek differences in the pollination requirements of different cultivars. The 1969 plots were located at the Fruit Haven farm in Kaleva, Michigan where 16 plots of Midway 2 plants were divided into 4 treatments:

1. Brass window screen cages (4) measuring 2 x 4 x 1.5 ft were placed over plots and covered with clear plastic to restrict wind movement through the cages, thus measuring the level of self-pollination;

2. Brass window screen cages (4) of the above dimensions were placed over plots and used to measure any increase in yield resulting from wind-motion pollination;

3. Brass window screen cages (4) of the same dimensions were placed over plots supplied with queenless, one-pound nuclei of honey bees in cardboard containers. Weather conditions were poor and the nuclei remained alive for 7 days.

4. Open pollinated checks (4), without any covering, were used to measure the production of berries in a commercial field where native bee and fly pollinators were present.

Although slits were cut into the plastic sheeting to allow air flow, temperatures increased in the cages and caused condensation and leaf enlargement. There were no visible changes in the flowers or the flower stems, except that petal-fall was slow because of incomplete pollination and absence of wind. Ripe berries were harvested on June 26 and July 2 and berries weighed in grams and graded according to the percent of malformed berries.

In 1970, 8 x 12 x 6 ft cages allowed the use of larger nuclei of honey bees in 2 of the 5 treatments and to give the bees better flight conditions. A commercial field of Midway 2 plants in Hartford, Michigan was used, with each of the 5 treatments replicated twice. The treatments were:

1. Plastic-covered screen cages. Four-mil thick plastic sheeting covered screen cages and these were used to measure yields resulting from self-pollination;

2. Screen cages, used to measure the changes in yield resulting from wind-motion pollination;

3. Plastic-covered screen cages containing honey bees, used to measure the increase in production from honey bees but without help from wind-motion pollination;

4. Screen cages containing honey bees, used to measure the change in yields due to honey bees and wind motion pollination;

5. Open pollination checks, used to compare cage yields. One small 6-frame colony was placed near the cages to supplement the moderate native bee population present in the field.

Colonies in the cages were provided water and fed pollen cakes. The plastic covering on the corresponding cages was slit at the top to allow heat to escape, although again some tempterature buildup was noted. However, the temperature did not seriously change bee behavior or plant growth. Each plot was harvested twice, the average weight per berry determined, and the percent achene set rated for individual berries. The percent achene set was much more precise in determining the level of pollination than the percent malformed berries, as done in 1969.

In 1971, 11 cultivars were tested for self-, wind-motion, and open pollination using smaller cages than in 1970. Because of heat buildup experienced in 1969 and 1970, white muslin cloth was sewn into cages for one set of treatments to restrict both wind and insect activity, but to allow air flow. Cages measured 18 x 48 x 15 in and were used in 2 of the 3 treatments:

1. Cloth-covered plots were used to check the level of self pollination;
2. Screen covered plots were used to determine the amount of pollination resulting from both self pollination and wind-motion pollination through the screen;
3. Open pollinated plots were used to measure the combined level of self, wind-motion, and insect pollination.

By estimating the percent achene set to the nearest 10% on the primary, 2 secondary, 2 tertiary and 2 quaternary flowers per inflorescence, berries on 25 flower stems were evaluated for extent of pollination from each plot. In addition, the percent berry set was calculated for each plot.

Each year, cage differences were tested with the analysis of variance, and when differences were found at the 5% probability level, the Student-Newman-Keul multiple comparison test (Sokal and Rohlf, 1969) was used to separate means. The estimated percent achene set was transformed prior to statistical analysis by using the arcsin function; data in the Results section appear as untransformed percentages, data in Appendix II contain both transformed and untransformed data.

Stamen Height Comparisons

In conjunction with the 1971 cage study, the length of stamens were measured in mm, in primary, secondary, tertiary and quaternary flowers for each cultivar tested, using the longest stamens in each flower (noticeable within-flower variation was evident). The mean values for each cultivar were correlated with the percent achene set obtained in the cloth-covered and screen covered cages, in an effort to determine the importance stamen height had on the pollination of strawberry flowers. These data were also separated by primary, secondary, tertiary and quaternary flowers for purposes of analysis.

Greenhouse Study

Ten cultivars were started in the greenhouse in January, 1971 and grown in the same room until the appearance of the first flowers. Then 35 plants were arranged in each of two rooms for each cultivar tested. A randomized block arrangement with 7 groups of 5 plants each were grouped to equalize microclimate differences in the rooms. Plants were watered directly into the pot to avoid disturbing the flowers. Automatic equipment maintained temperature at a 75°F minimum, and a 16 hour photoperiod. When berries were ripe they were individually harvested, weighed and the percent achene set determined. In the room without bees achene set was determined by counting the actual number of enlarged achenes and dividing by 200, an arbitrary estimate, while in the room with bees, the increased numbers of achenes necessitated the estimation of percent achene set to the nearest 10%.

To determine the effect of insect pollination on the length of time of individual flower bloom, the time of flowering was recorded in both rooms. The corresponding time intervals were compared with analysis of variance. Flowers were also observed for changes in overall appearance during flowering.

Insect Pollinator Studies

The density of insect pollinators in different commercial strawberry fields was estimated by using a standard 15 inch insect sweep net. From 200 to 500 sweeps, the number depending upon field dimensions, were made over single rows of commercially growing plants. Cultural, climatic and spray information were recorded at the time of sampling. At an early stage, when mostly primary and secondary berries were ripe, rows adjacent to those swept were sampled to provide an estimate of the level of pollination present in that field. A rating system used by Kronenberg et al (1959) was modified and the percent achene set estimated to the nearest 5% or 10%. Samples consisted of from 5 to 25 flower stems and their berries; they were rated immediately or frozen until rated. On each stem, the primary, 2 secondary, 2 tertiary, and 2 quaternary berries were rated, or 7 berries representing the serial progression in blooming were used. The percentage berry set was recorded by counting the number of flowers and the number of developed berries. Data were analyzed using analysis of variance and the Student-Newman-Keul multiple comparison test. Correlations were attempted between pollinator density and the level of achene set found in different fields; similar comparisons were made between pollinator density and the level of achene set due to insect pollinators found in the 1971 cage study discussed earlier. In both cases, the percent achene set values were transformed by the arcsin function.

In 1970 and 1971 insect pollinators were collected in 4 Michigan counties using a sweep net. Immediately after collection, the insects in the samples were killed in cyanide jars and honey bees sorted by the presence or absence of pollen pellets on their corbiculae. Although nectar collecting bees collected pollen incidently, if a bee had a pollen pellet of any size, it was classified as a pollen collector. Other bee and fly species were preserved and used for comparing pollinator populations in different areas of Michigan.

Observations were made on the behavior of different insects as they worked strawberry flowers, and some of their activities recorded on Super-8 movie film. From these observations the author identified different groups based upon pollinator efficiency.

Relative pollinator densities were compared for different times of day, temperature, wind speed and location by using the sweep net collections. Over 200 samples were made under various conditions to make the above comparisons and to compare aspects of wind protection, pesticide applications, and cultivar attractiveness. In making such comparisons, only similar conditions were used: for example, comparisons of cultivar attractiveness were only made under favorable flight conditions, and all cultivars were examined under the same factors. Sweep net collections were replicated within fields whenever possible.

Insect pollinators were visually counted on equal length rows (approximately 250 feet) to verify observations concerning cultivar attractiveness. A large field on the Fruit Haven Farm, Kaleva, Michigan, was particularly suitable in that it had several cultivars growing under nearly identical conditions in several sections of the field.

Pollen traps, of the style used by Kremer (1949), were placed in front of strong colonies of honey bees in 2 commercial fields to compare the relative attractiveness of strawberry pollen from 2 cultivar groups. One field consisted of entirely 'Redchief', while the second consisted of 75% 'Midway 1' and 'Midway 2', and 25% 'Sunrise', 'Surecrop', 'Redchief' and several miscellaneous cultivars present in small amounts. The resulting pollen pellet samples were identified to plant species by Larry G. Olsen[1] providing information regarding pollen collection by honey bees from the two fields. In addition, useful information was gathered concerning the plants which compete with strawberry flowers for honey bee visits.

Finally, land surrounding each commercial field was assessed as either cultivated, orchard, woodlot, unused, etc., with concern for possible sites for ground-nesting native bees. Observations were also made to see if honey bee colonies were located near the field. The resulting bee density was then compared with these observations.

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[1]Graduate assistant, Department of Entomology, Michigan State University.

RESULTS

Cage Studies

In 1969 and 1970 average berry weights were similar for the different treatments, and estimates of berry quality followed the same trend (Table 2). Plastic covered cages, which eliminated both wind motion and insect activity from strawberry flowers, produced the lowest yields, followed by the screen covered plots which allowed wind motion but no insect pollination. Both the plastic and screen covered plots without bees produced berries of approximately the same weight, while there was slightly better shape and percent achene set in berries from the wind-motion pollinated plots. The addition of honey bees into plastic or screen cages improved yield considerably, closely approaching or equalling the yields found in uncovered, open pollinated plots. While open pollinated checks out-yielded plots caged with bees in 1969, they failed to do so in 1970. This may have been because the bee nuclei died within 7 days in 1969, and survived in 1970.

Two significant facts were observed in the 1971 cage trials: first the level of achene set for all 11 cultivars increased from cloth-covered cages (53%) to screen covered cages (67%) to open pollinated plots (91%) (Table 3), indicating that wind motion improved percent achene set over self-pollinated flowers, while open pollinated plots out-yielded either self- or wind-motion pollination. Secondly, there

TABLE 2.--Yields from 1969 and 1970 cage studies on Midway 2 plants. Plots located in Kaleva, Michigan in 1969 and in Hartford, Michigan in 1970.

CAGE DESIGN	1969			1970		
	No. berries	Weight/ berry	Percent malformed	No. berries	Weight/ berry	Percent achene set
PLASTIC COVERED SCREEN	388	4.6a	92%a	755	5.5a	51%
SCREEN	351	7.0ab	33b	310	5.8a	62
PLASTIC + BEES	0	--	--	617	7.2b	68
SCREEN + BEES	397	7.5b	20c	294	7.7b	71
OPEN CHECK	485	9.1c	9d	447	7.3b	80

Means in each column followed by the same small letter are not significantly different at the 5% probability level (Student-Newman Keul multiple comparison test).

TABLE 3.--Contribution of self-, wind-motion and insect pollination to strawberry set and achene set in 11 cultivars from 6 Michigan fields. 1971.

Cultivar	Percent Berry Set			Percent Achene Set		
	Cloth Cage	Screen Cage	Open Plot	Cloth Cage	Screen Cage	Open Plot
Guardian	47%	93%	95%	35a	53 b	80a
Surecrop	96	99	100	48 b	61 cd	98 e
Earlidawn	90	100	99	48 b	46a	76a
Sunrise	87	97	100	49 bc	65 de	75 cd
M 828	95	99	99	49 bc	90 g	96 d
Redchief	91	97	99	51 bc	61 cd	95 cd
Midway 2	80	93	99	53 bc	70 ef	91 c
M 788	84	92	99	54 bc	73 f	95 cd
M 772	43	66	93	61 c	64 d	99 e
M 766	88	96	97	62 c	56 bc	88 b
Midway 1	93	96	100	78 d	97 h	100 f
Mean	81	93	98	53	67	91

Percentages in each of the 3 percent achene set columns denote no statistical difference at the 5% probability level when followed by the same small letter.

were significant differences between results of self and wind motion pollination, attributable to the differences in the 11 cultivars. For example, cloth covered plots of Guardian produced 35% achene set, while Midway 1 produced 78%; similarly in screen covered plots, Earlidawn produced 46% achene set, compared to 97% in Midway 1. Differences were also found in the open pollinated plots, but these were largely due to differences in pollinator densities present in the different fields. Differences in the percent berry set also increased from cloth-covered (81%), to screen covered plots (93%) to open pollinated plots (98%), but the variation was not as large as those for percent achene set (Table 3).

Stamen Height Comparisons

The average stamen height for the 11 cultivars varied from 2.4 to 5.2 mm, although 9 of the 11 cultivars ranged from 3.0 to 4.0 mm (Table 4). There was a great deal of variation within each cultivar; for example, cultivar 'Guardian' had 1.9 mm stamens in primary flowers, but 4.6 mm stamens in quaternary flowers. Three cultivars were examined in more than one field, but none showed any statistical differences due to field location. Thus there was one 'short' stamened cultivar, 9 'intermediate' stamened cultivars, and one 'long' stamened cultivar. Correlations of stamen height and percent achene set were statistically significant at the 5% level for both self-pollinated flowers ($r = 0.657$, $n = 44$) (Figure 1), and for wind-motion pollinated flowers ($r = 0.599$, $n = 44$) (Figure 2). By dropping the values from the 'short' and the 'long' stamened cultivars, thereby testing only the intermediate length

TABLE 4.--Average stamen height of cultivars used in 1971 cage study. 10 flower measurements/sub-sample, 40 total/sample. In mm.

GROWER	CULTIVAR	PRIMARY	SECONDARY	TERTIARY	QUARTENARY	AVERAGE	SIGNIFICANCE 5% level
Culby	Sunrise	2.5	3.6	3.8	4.0	3.48	n.s.
Piggott	Sunrise	3.2	3.2	3.8	3.7	3.48	
Hassel	Sunrise	3.4	3.6	4.0	3.7	3.68	
Lutz	Sunrise	3.2	4.4	3.9	3.7	3.90	
AVERAGE	SUNRISE	3.2	3.7	3.9	3.8	3.63	
Culby	Midway 2	3.6	4.1	4.1	3.7	3.85	n.s.
Piggott	Midway 2	2.9	3.3	4.4	4.6	3.80	
Radewald	Midway 2	3.8	3.9	4.3	3.7	3.93	
Lutz	Midway 2	2.6	4.6	4.1	4.5	3.95	
AVERAGE	MIDWAY 2	3.2	4.0	4.2	4.1	3.88	
Radewald	Redchief	2.5	3.8	3.9	4.1	3.58	n.s.
Hassel	Redchief	2.3	3.6	4.2	4.1	3.55	
Lutz	Redchief	2.8	3.6	3.7	3.3	3.35	
AVERAGE	REDCHIEF	2.5	3.7	3.9	3.8	3.49	
Lutz	Surecrop	1.9	1.9	3.2	2.6	2.40	a
Piggott	Earlidawn	2.4	2.9	3.3	3.6	3.05	b
Hassel	Guardian	1.9	3.5	4.6	2.5	3.13	b
Lutz	Midway 1	5.0	5.5	5.2	5.0	5.18	c
MSU	M788	3.0	3.2	3.9	3.0	3.28	a
MSU	M828	2.7	3.8	3.9	3.4	3.45	ab
MSU	M772	3.8	3.7	3.4	3.7	3.65	b
MSU	M766	3.0	4.6	4.0	4.2	3.95	c

MEAN OF ALL CULTIVARS	2.97	3.73	3.98	3.94	3.55	

Total values followed by the same small letter are not significantly different at the .05 probability level. Each group tested separately.

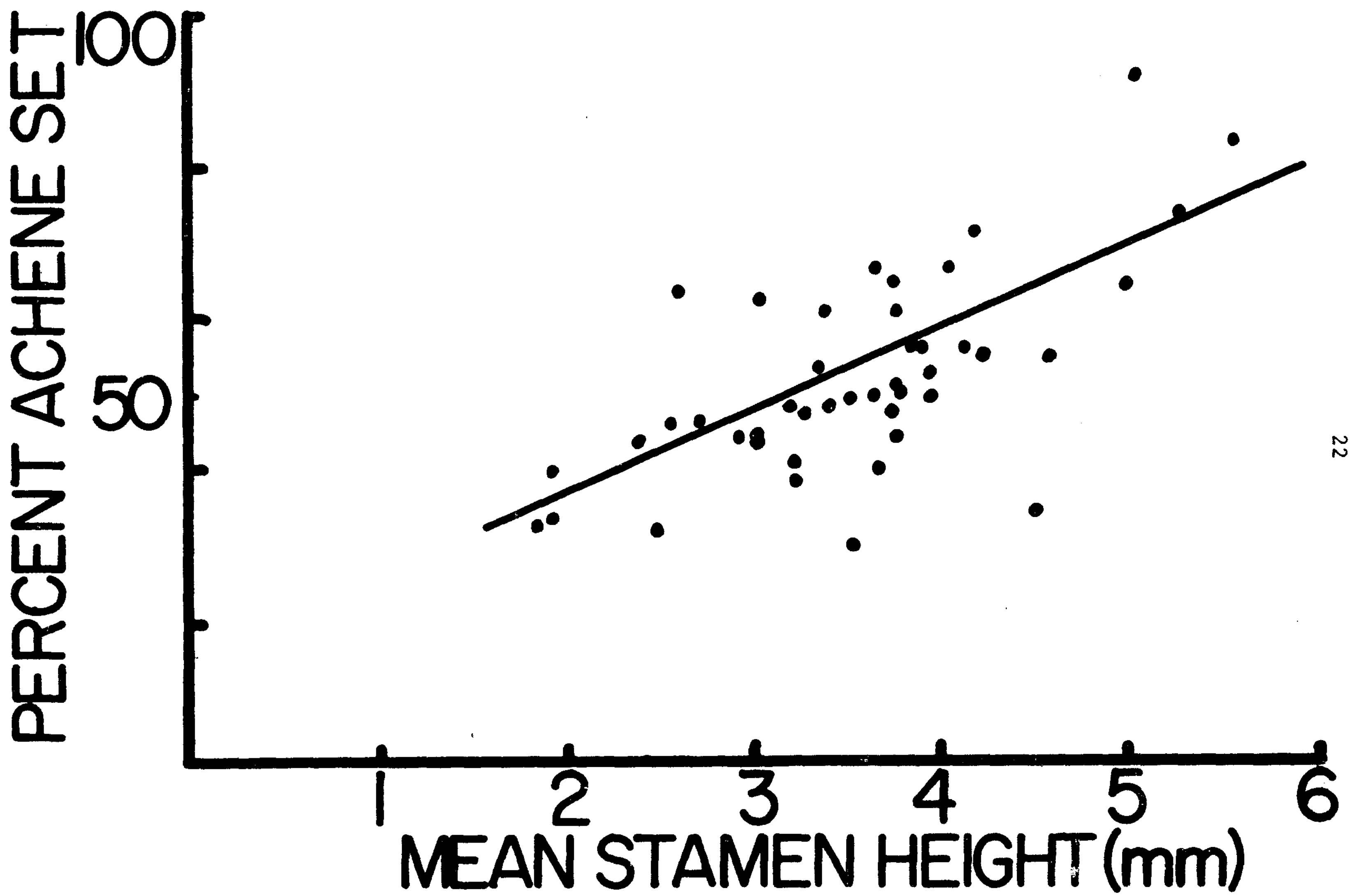

Figure 1.--Correlation of percent achene set in self pollinated plots with average stamen height in each of primary, secondary, tertiary, and quaternary flowers.

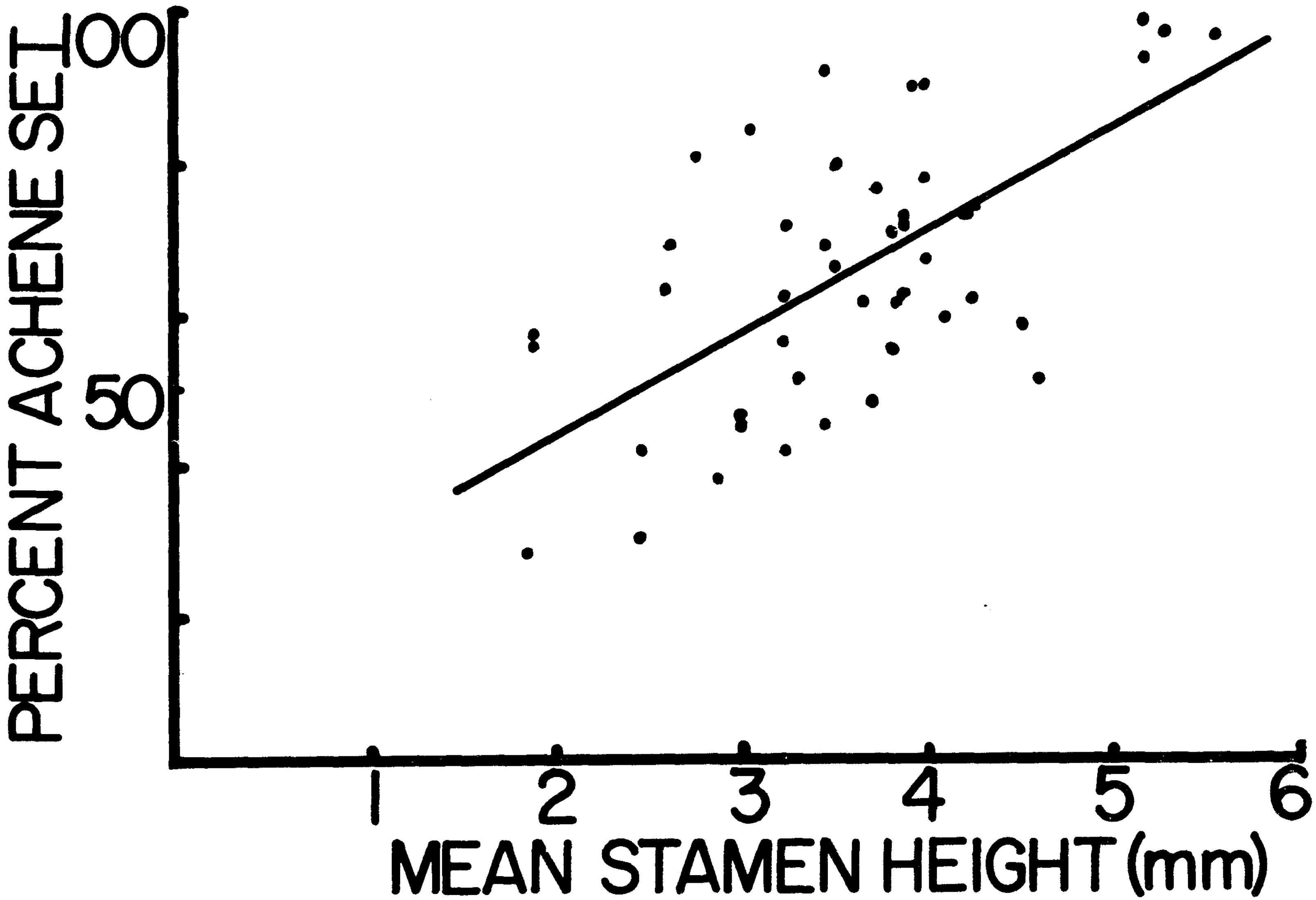

Figure 2.--Correlation of percent achene set in wind-motion pollinated plots with average stamen height in each of primary, secondary, tertiary, and quaternary flowers.

cultivars, the results of the correlations were still significant at the 5% level, but the 'r' values were smaller: self pollination $r = 0.455$, $n = 36$; wind-motion pollination $r = 0.431$, $n = 36$.

Correlation of the percent achene set between each of the primary, secondary, tertiary and quaternary flower groups resulted in statistical significance only in the primary and secondary flowers for the self pollinated plots, and only the primary berries in the wind-motion pollination plots (Table 5).

Greenhouse Study

The results of the greenhouse study may be examined two ways: differences between rooms resulting from the presence or absence of honey bees, and differences between the cultivars located in the same room. Without honey bees, self pollination produced berries averaging 1.0 g in weight and possessing only 5% pollinated achenes, while with honey bee pollination berries averaged 4.5 g in weight and had 69% achene set (Table 6). In the room lacking bees, the differences between cultivars was considerable: ranging from 0.2 to 1.8 g in weight and from 2% to 9% achene set. The presence of bees did not eliminate differences in weight yields, because of genetically controlled differences, but the percent achene set was more uniform, ranging from 55% to 82% achene set. In addition, honey bee pollination decreased the average flowering period from 64 hours to 43 hours (Table 7). Also, one may note that the longer a cultivar had flowers in bloom, the greater the percent achene set which resulted in the self pollinated treatment.

TABLE 5.--Correlation coefficients for self- and wind-motion pollinated plots of 11 cultivars and the corresponding levels of achene set.

GROUP TESTED	NO. DATA POINTS	MEAN STAMEN HEIGHT "X"	MEAN % ACHENE SET "Y"	r	b (slope)	a (intercept)	STATISTICAL SIGNIFICANCE
SELF POLLINATED FLOWERS							
Primary	11	2.96	46.62	0.8469	15.78	-0.15	.01
Secondary	11	3.68	50.07	.7783	12.11	5.50	.01
Tertiary	11	3.96	55.60	.2849	5.25	34.83	n.s.
Quaternary	11	3.61	59.75	.3882	4.15	44.78	n.s.
ALL FLOWERS	44	3.55	53.01	.6572	10.35	16.23	.01
ALL FLOWERS EXCEPT MIDWAY 1 & SURECROP	36	3.50	55.26	.4554	3.53	-4.45	.01
WIND MOTION POLLINATED FLOWERS							
Primary	11	2.96	52.68	.6760	16.27	4.47	.05
Secondary	11	3.68	63.27	.5095	9.97	26.55	n.s.
Tertiary	11	3.96	70.99	.5547	13.36	18.16	n.s.
Quaternary	11	3.61	75.77	.3660	5.39	56.33	n.s.
ALL FLOWERS	44	3.55	65.68	.5989	12.89	19.90	.01
ALL FLOWERS EXCEPT MIDWAY 1 & SURECROP	36	3.50	62.79	.4343	11.82	21.42	.01

n.s. = no statistical significance at .05 probability level.

TABLE 6.--Weight/berry and percent achene development with and without honey bees in separate greenhouse rooms--1971 greenhouse study.

CULTIVAR	MEAN WEIGHT PER BERRY In grams		LEVEL OF ACHENE DEVELOPMENT % achene development	
	WITHOUT	WITH BEES	WITHOUT BEES*	WITH BEES
NJ 267	0.0 n.s.	5.8 e	0%	58%a
133-6733	.2	1.6a	2 a	70 cd
GUARDIAN	.9	5.8 e	4 b	82 e
TIOGA	.9	4.2 bcd	3 ab	59 ab
SEQUOIA	1.1	4.7 cde	4 bc	55 a
7-6736	1.1	5.2 de	4 bc	75 d
REDCHIEF	1.3	3.8 bcd	6 cd	74 cd
SURECROP	1.4	4.5 bcde	6 cd	79 d
STOPLIGHT	1.5	3.4 b	7 d	76 d
MIDWAY	1.8	3.6 bc	9 e	66 bc
MEAN	1.0	4.5	5	69

*Adjusted values calculated by dividing the actual number of achenes by 200, an 'average' potential number of achenes per berry.

**Value in each column followed by the same small letter are not significantly different at the 5% probability level.

TABLE 7.--Period of blooming of individual flowers of 9 cultivars growing in the greenhouse with and without honey bees. January and February, 1971.

CULTIVAR	N flowers	ROOM WITHOUT BEES (Hours)	N flowers	ROOM WITH BEES (Hours)	DIFFERENCE and SIGNIFICANCE (Hours)
7-6736	123	46a	8	28 n.s.	18*
TIOGA	10	51a	3	30	21 n.s.
133-6733	96	59a	39	49	10*
GUARDIAN	29	62a	8	31	31**
SEQUOIA	45	63a	8	57	16 n.s.
STOPLIGHT	41	68a	5	44	24*
REDCHIEF	16	72a	4	35	37 n.s.
SURECROP	63	73a	30	55	18**
MIDWAY	23	81 b	18	54	27**
MEAN		64		43	21

Means in columns followed by the same small letter are not significantly different at the .05 probability level.

Differences indicated are marked * for .05 level and ** for .01 level of significance.

After pollination, a conspicous change was evident in strawberry pistils: yellow-green at the start of anthesis, pollinated pistils were a dark brown at petal-fall, giving partially pollinated receptacles a mottled appearance. In their activity, bees stripped the anthers of pollen and often knocked the anthers off the filaments, while self-pollinated flowers possessed large pollen-laden anthers that persisted throughout berry development. Morphological differences were noted in the appearance of the flowers of different cultivars, particularly in the length of the stamens, the angle of the filament arising from the base of the receptacle, and the size of the anthers.

Insect Pollinators of Strawberries

Strawberry flowers in commercial fields were visited by a variety of bee species, with the ratio varying significantly from field to field and from the 2 areas of the state the author surveyed (Table 8). Honey bees comprised 32% of the bee population in 1970, and 25% in 1971, with 21% pollen collectors in 1970 and 13% in 1971. The ground nesting bee families of Andrenidae and Halictidae comprised 14% and 52% respectively in 1970, and 20% and 49% in 1971 and were a major part of the pollinating fauna. *Ceratina* spp. (1% in 1970 and 5% in 1971); Megachilidae (0% in 1970 and 1% in 1971); and *Bombus* spp. (2% in 1970 and 1% in 1971) were also captured.

Manistee and Leelanau counties in Northern Michigan had proportionately more halictines than Berrien and Van Buren counties in Southern Michigan. *Ceratina* spp. was only present in fields where hollow stemmed plants such as raspberry were available for nesting (Table 8).

TABLE 8.--Breakdown, by percentage, of bees collected in commercial strawberry fields in 4 Michigan counties in 1970 and 1971, with summaries by county.

LOCALITY AND COUNTY	HONEY BEES % POLLEN COLLECTORS	HONEY BEES % NECTAR COLLECTORS	HONEY BEES % TOTAL	% BOMBUS	% ANDRENIDAE	% HALICTIDAE	% *CERATINA* SPP.	% MEGACHILIDAE	% TOTAL NATIVE	TOTAL NO. BEES COLLECTED
					1970*					
BERRIEN CO.										
Benton Harbor	3	53	56	2	10	32	1	0	44	102
Niles	1	27	28	3	25	42	1	0	72	110
VANBUREN CO.										
Hartford	19	17	35	0	24	38	1	2	65	230
Keeler	23	11	35	0	23	36	5	1	65	162
AVERAGE, SOUTHERN COUNTIES	14	23	37	1	21	37	2	1	63	607**
MANISTEE CO.										
Kaleva	18	5	23	1	17	59	0	0	77	732
Copemish	17	3	20	1	18	59	0	0	80	260
LEELANAU CO.										
Suttons Bay	60	18	78	1	0	20	0	1	22	95
Lake Leelanau	29	7	35	0	4	60	0	1	65	539
AVERAGE, NORTHERN COUNTIES	23	6	29	1	12	57	0	0	71	1626**
1970 AVERAGE	21	11	32	2	14	52	1	1	68	2230
					1971*					
BERRIEN CO.										
Benton Harbor	33	12	44	0	5	36	15	0	56	61
Niles	44	17	61	17	6	11	6	0	39	18
VAN BUREN CO.										
Keeler	18	9	28	0	12	34	26	0	72	65
AVERAGE SOUTHERN COUNTIES	28	11	39	2	8	32	19	0	61	144**
MANISTEE CO.										
Kaleva - Only Northern Co.	8	13	21	1	24	54	0	0	79	462**
1971 AVERAGE	13	12	25	1	20	49	5	0	75	606

Chi-square comparison of yearly (*) and area (**) results were highly significant (.01 probability level).

Honey bees worked strawberry flowers for both pollen and nectar. Pollen gathers 'scrabbled' over the flowers and contacted a large surface area of the stigmas and the stamens, running rapidly in a circular fashion, making 2 or 3 circles per flower. Such pollen gatherers were most often observed during the period of maximum pollen production, occurring from 10 a.m. to 12 p.m. Nectar collectors landed on the top of the flowers and pivoted on the receptacles searching for nectar. Generally, they held one foreleg on a receptacle and the other foreleg on a petal, moving in a circular manner. Honey bees averaged 8.8 flower visits per minute, moving from row to row in a 2 or 5 row limit on a single foraging trip. They visited an average of 11.7 flowers per row.

Of the remaining species of bees visiting strawberry flowers, size was the key factor in influencing pollination behavior (Table 9). The families Andrenidae and Halictidae were divided into 2 groups on the basis of size: the first group was approximately the size of a honey bee worker or slightly smaller, while the second group consisted of all smaller bees. Of the andrenines collected, 85% were in the larger group while 15% of the halictines were in the larger class. Larger bees of both families contacted the stigmas and styles of the flower on the same foraging trip, while the smaller bees often remained outside the wall of stamens on intermediate or long stamened flowers and manipulated the anthers for pollen. Short stamened flowers allowed the smaller bees to contact the stigmas and styles on the same visit. Gererally, the small bees were less likely to cross over the top of the receptacle while the larger bees often did.

TABLE 9.--Identity* and efficiency of strawberry flower pollinators.

INSECT	NUMBER COLLECTED	EFFICIENCY AS POLLINATORS**
Family Colletidae		
Colletes nudus Robertson	3	high
Family Andrenidae		
Andrena alleghaniensis Viereck	8	intermediate
Andrena crataegi Robertson	58	high
Andrena perplexa Smith	3	high
Andrena rugosa Robertson	1	intermediate
Andrena lata Viereck	3	intermediate
Andrena miserabilis bipunctata Cresson	71	intermediate
Andrena forbesii Robertson	5	high
Andrena fragariana Graenicher	6	low
Andrena nasonii Robertson	137	intermediate
Andrena wilkella Kirby	80	high
Andrena carlini Cockerell	3	high
Andrena vicina Smith	68	high
Family Halictidae		
Halictus confusus Smith	786	low
Halictus ligatus Say	44	intermediate
Halictus rubicundus (Christ)	35	high
Halictus parallelus Say	2	high
Lasioglossum zonolum Smith	7	intermediate
Lasioglossum fuscipenne Smith	1	intermediate
Lasioglossum forbesii Robertson	43	intermediate
Evylaeus pectoralis Smith	111	low
Evylaeus divergens Lovell	9	low
Evylaeus foxii Robertson	29	low
Dialictus lineatulus Robertson	113	low
Dialictus pictus Crawford	11	low
Dialictus illinoiensis Robertson	23	low
Dialictus perpunctatus Ellis	170	low
Dialictus anomalus Robertson	19	low
Dialictus tegularis Robertson	14	low
Dialictus nymphaerarum Robertson	2	low
Dialictus pilosus Smith	322	low
Dialictus nymphaearum Robertson	131	low
Dialictus albipennis Robertson	15	low
Dialictus cressonii Robertson	15	low
Dialictus reticulatus Robertson	5	intermediate
Dialictus vierecki Crawford	28	low
Dialictus inconspicuus Smith	18	low
Agapostemon virescens (F)	1	high
Agapostemon texanus texanus Cress	24	high
Agapostemon splendens (Ler)	11	high
Agapostemon radiatus (Say)	9	high
Augochlorella striata (Provancher)	83	low
Augochloropsis metallica fulgida (Smith)	1	intermediate
Augochlora pura pura (Say)	3	intermediate
Family Xylocopidae		
Ceratina dupla dupla (Say)	38	intermediate
Ceratina calcarata Robertson	43	intermediate
Xylocopa virginica virginica L	1	high
Family Apidae		
Bombus impatiens Cresson	16	high
Bombus bimaculatus Cresson	5	high
Bombus borealis Kirby	5	high
Bombus affinis Cresson	2	high
Apis mellifera Linnaeus	866	high

*Determined by Roland L. Fischer, Department of Entomology, Michigan State University.

**Efficiency determined by amount of contact of both pistils and stamens during foraging.

Other insects observed visiting strawberry flowers included: syrphid flies, anthomyiid flies, other flies, plant bugs, lady bird beetles, weevils and other beetles, butterflies and crab spiders. The larger hairy syrphid flies appeared to be helpful in strawberry pollination; the remaining insects were not considered to be of any importance in moving pollen on the flower from stamens to stigmas.

The impact of different bee populations found in various commercial strawberry fields on the resulting achene set shows a significant correlation between honey bee density (Figure 3). In fields of short and intermediate length stamened cultivars, there was a significant relationship ($r = 0.537$, $n = 22$), but when data from tall stamened cultivars was included in the analysis, there was no significance ($r = 0.219$, $n = 26$). Similar results were found by comparing the density of bee pollinators found in commercial fields where cages were located, and the amount of achene set due to insect pollination in the field ($r = 0.587$, $n = 14$) (Figure 4). These data were obtained by subtracting the percent achene set in the screen covered cages from the percent achene set found in the open pollinated plots.

Honey bees and native bees were collected in strawberry fields in peak numbers from 10 a.m. to 12 noon, after which they decreased in density until 1 p.m., and then increased in density from 2 to 3 p.m. (Figure 5). In the period from 8 a.m. to 1 p.m., 75% of the honey bees possessed pollen pellets, while from 1 p.m. to 6 p.m. only 52% possessed pollen pellets. This suggests that the greatest pollen release was in the late morning, which was confirmed by visually examining the flowers.

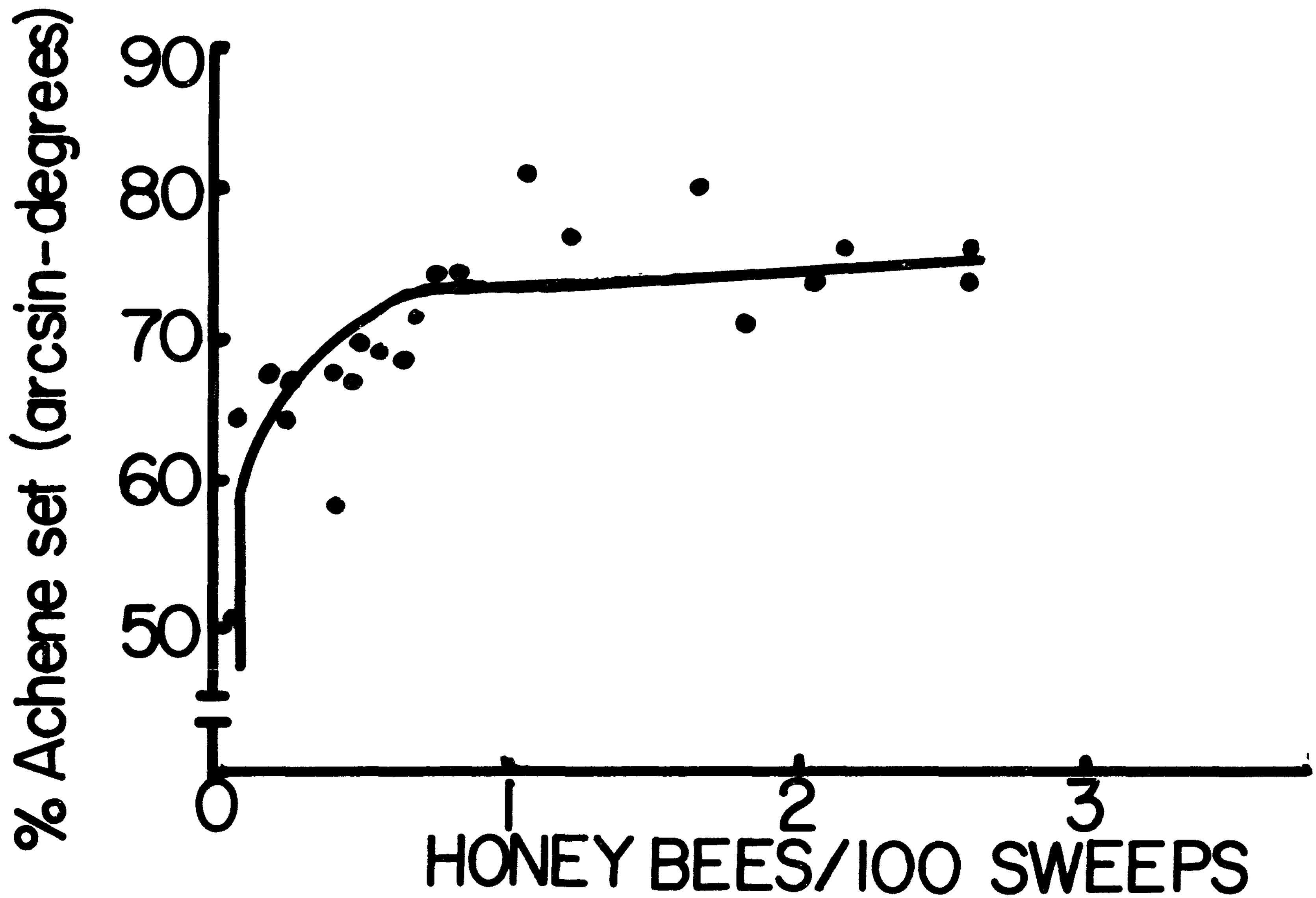

Figure 3.--Relationship between number of honey bees per 100 sweeps in different commercial strawberry fields and the percent achene set (arcsin transformed % values). Curve hand-fitted.

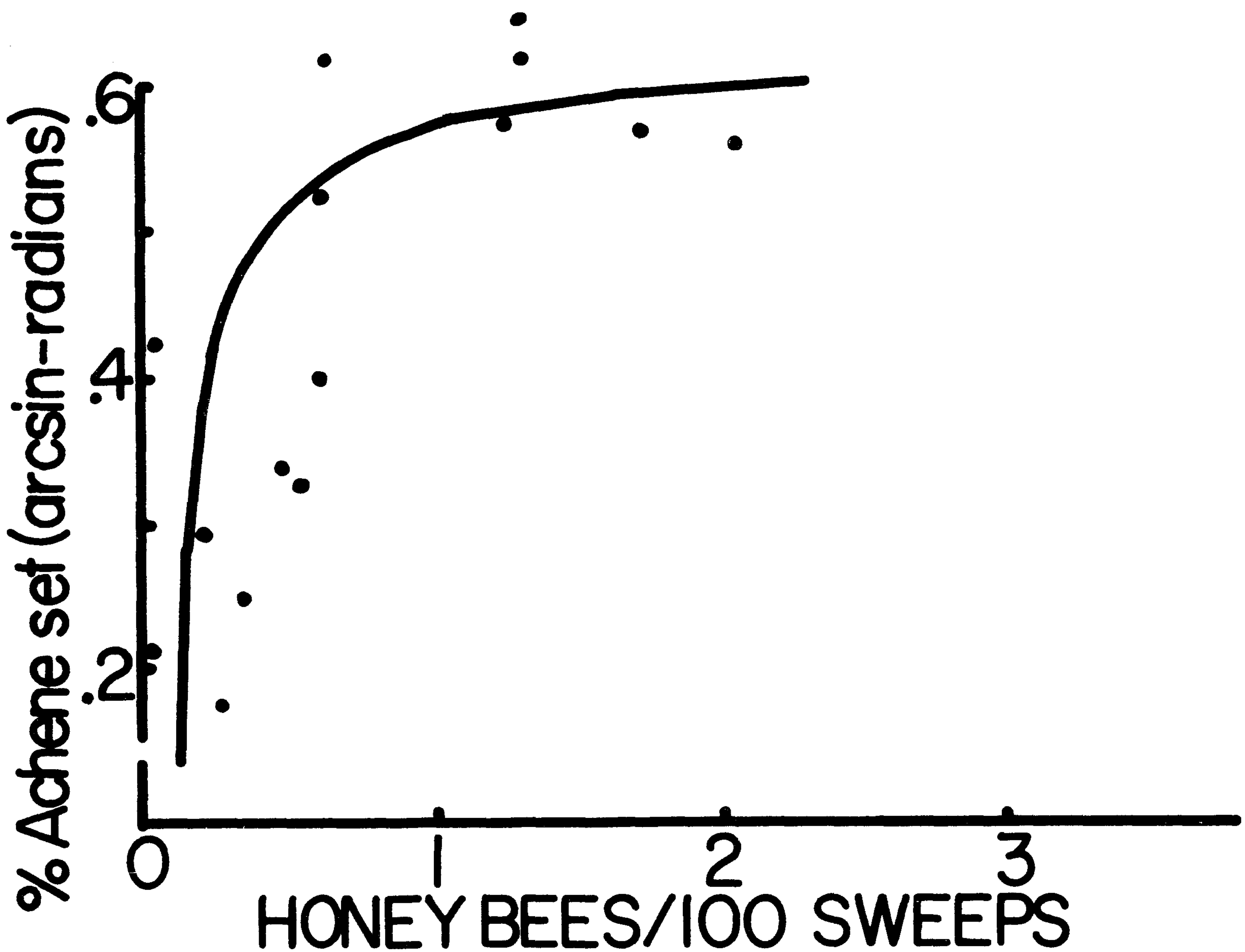

Figure 4.--Relationship between the percent achene set due to insect pollination in the 1971 cage study (calculated as difference between open plots and screen cages) and pollinator density in the different fields (arcsin transformed % values). Curve hand-fitted.

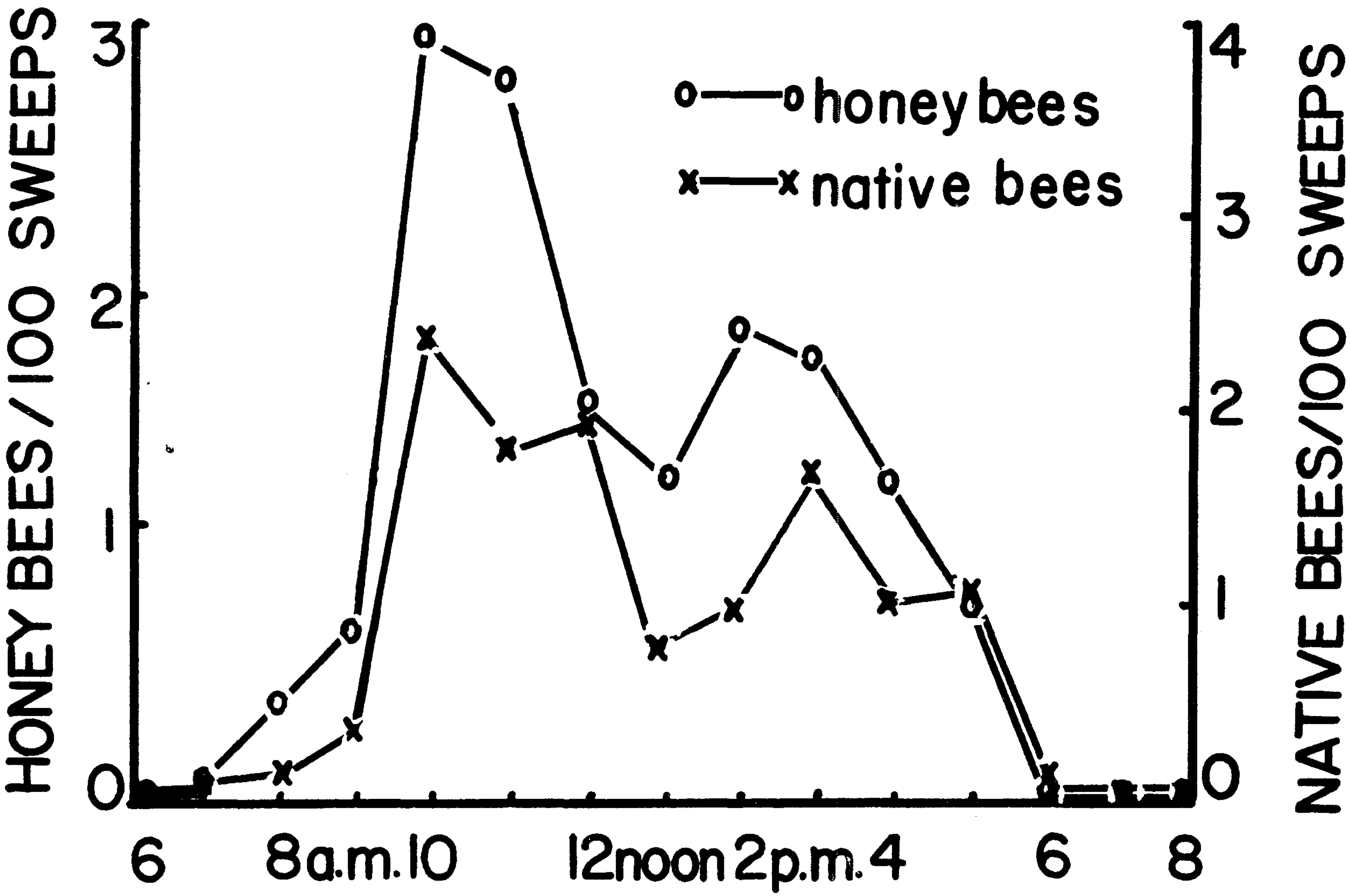

Figure 5.--Influence of time of day on honey bee and native bee density in commercial strawberry fields as determined by repeated sweep net collections in 4 Michigan counties in 1970 and 1971.

Bee activity was linked to pollen and nectar availability, as indicated above, but both were influenced by temperature (Figure 6). Strong bee activity was observed first from 65 to 69°F., agreeing with Percival's (1955) observation that the minimum temperature of strawberry anthesis was 62°F. Honey bee and native bee density peaked in the temperature range of 65 to 79°F. Above 80°F, bee activity was reduced, apparently due to a reduction in pollen and nectar supplies.

Honey bees were active in strawberry fields at wind speeds up to 19 mph: above this level flight activity was reduced. Native bee activity was highest at low wind speeds with density decreasing proportionately to the amount of wind activity (Figure 7).

When bee density was low in commercial fields, the bees remained along the edges of the fields and avoided the center: this fact is supported by the reduced achene set found in the center of fields of short and intermediate length stamened cultivars (Table 10). These differences were greatest in the primary flowers. Cultivar 'Redchief' demonstrated a 20% decrease in achene set between center and edges of the field. Similarly, 'Midway 2' showed a 3 to 12% difference and 'Sunrise' showed a 5% reduction. In 6 other fields with more than 5 bees per 100 sweeps, which represented a high pollinator density, there was no evidence of an edge effect in distribution of bees within the field or achene set.

Two commercial fields surveyed in 1971 were protected from strong winds along one border by large trees. The greatest number of insect pollinators was found in the area protected from wind. A field of

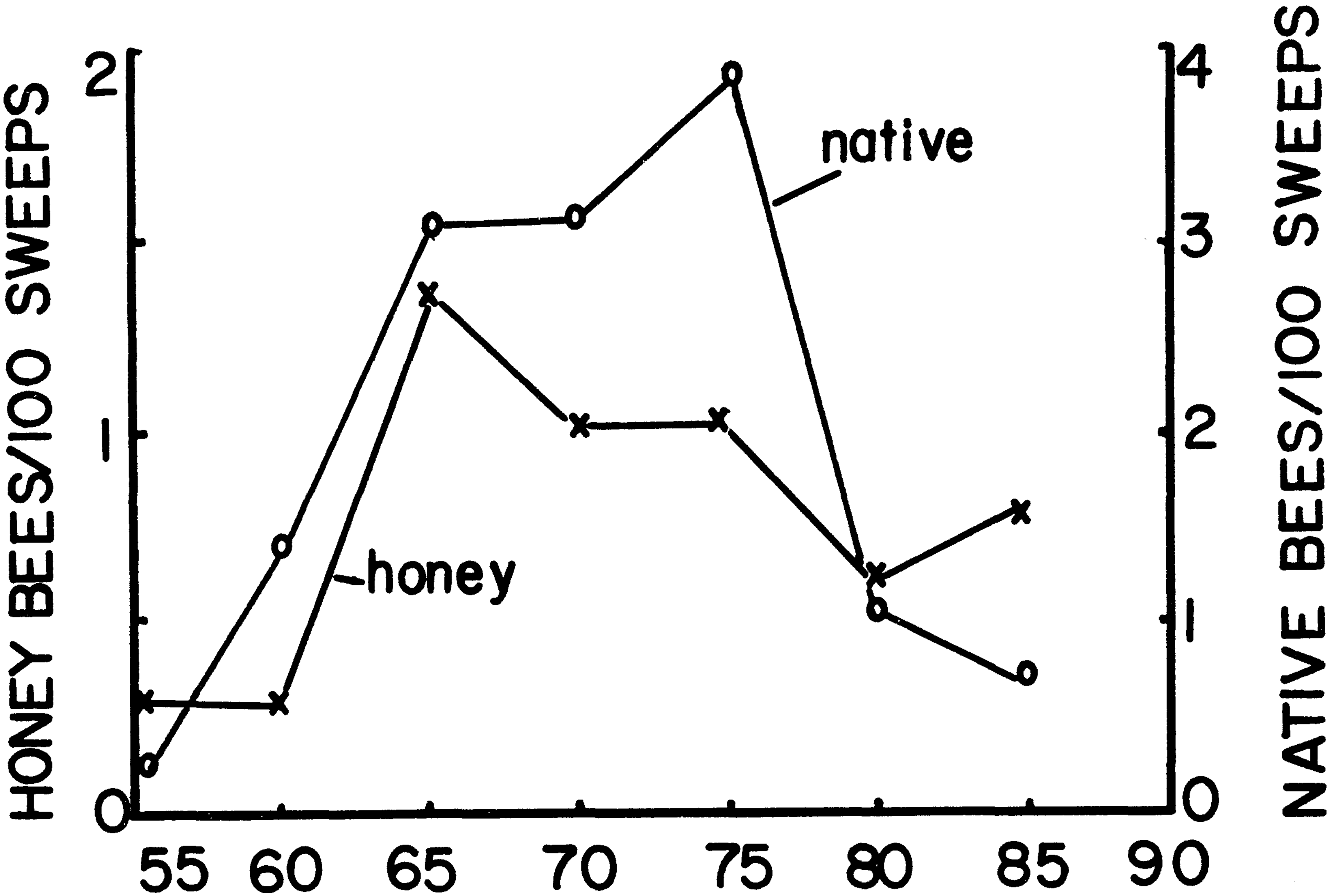

Figure 6.--Influence of temperature (°F) on honey bee and dative bee density in commercial strawberry fields as determined by repeated sweep net collections in 4 Michigan counties in 1970 and 1971.

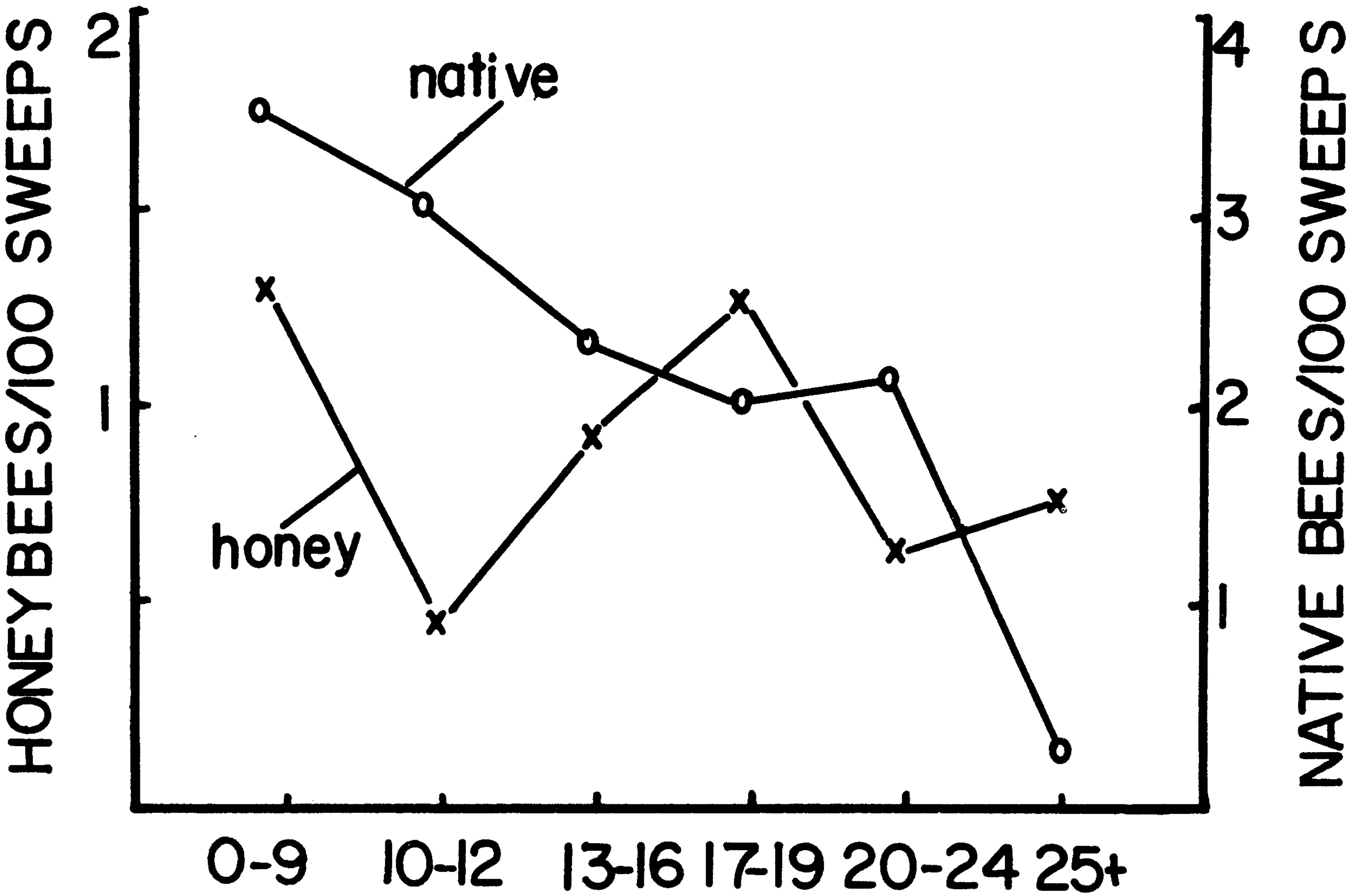

Figure 7.--Influence of wind speed (mph) on honey bee and native bee density in commercial strawberry fields as determined by repeated sweep net collections in 4 Michigan counties in 1970 and 1971.

TABLE 10.--Concentration of bees along edges of commercial strawberry fields with low bee density, and the resulting percent achene set.

FIELD SIZE & CULTIVAR	BEES/100 SWEEPS EDGE	BEES/100 SWEEPS CENTER	PERCENT ACHENE SET - EDGE	PERCENT ACHENE SET - CENTER	DIFFERENCE IN YIELD
25 Acres Midway 2	1.63	0.86	91.25%	88.50%	2.75%
30 Acres Redchief	3.30	1.40	84.00	64.50	19.50
8 Acres Midway 2	0.50	0.00	87.50	76.00	11.50
10 Acres Sunrise	1.35	0.80	87.50	82.50	5.00

'Midway 2' plants had a 4% difference in achene set between the protected and unprotected areas.

Concerning cultivar attractiveness to pollinators, 'Midway 2' and 'Midway 1' attracted more insect pollinators than any other cultivar, with greater numbers of pollen collectors appearing in sweep net collections (Figure 8A) and in row counts (Figures 8B and 8C). 'Sunrise' did not attract large numbers of pollen collectors, but did attract a moderate number of nectar collectors. 'Redchief' attracted the lowest numbers of nectar and pollen collectors. Pollen traps yielded only 2.4% strawberry pollen from colonies located in 'Redchief' fields, compared to 57% in a large field of predominately 'Midway 1' and 'Midway 2' (Table 11). The following flowering plants competed with strawberry flowers for honey bee activity: choke cherry (Prunus sp.), dandelion (Taraxacum officinale), yellow rocket (Barbarea vulgaris), Brassica sp., sweet cherry (Prunus avium), apple (Pyrus malus), and willow (Salix sp.).

The impact of pesticides on bee density in commercial strawberry fields can be determined from sprayed fields. In one field sampled under similar conditions prior to and the day of a Thiodan application, there was a decrease from 1.8 to 0.4 honey bees per 100 sweeps, and 2.3 to 1.5 native bees per 100 sweeps. In a second field there were 0.4 bees per 100 sweeps immediately after a Guthion spray, and 2.9 bees per 100 sweeps 48 hours later. A third field doubled its bee population in 48 hours after a Guthion spray, from 0.5 to 1.0 bees per 100 sweeps. In a fourth field, at 0, 1, 2 and 11 days after a Guthion spray, there were 1.6, 2.1, 3.7 and 3.5 bees per 100 sweeps. Finally, in a fifth

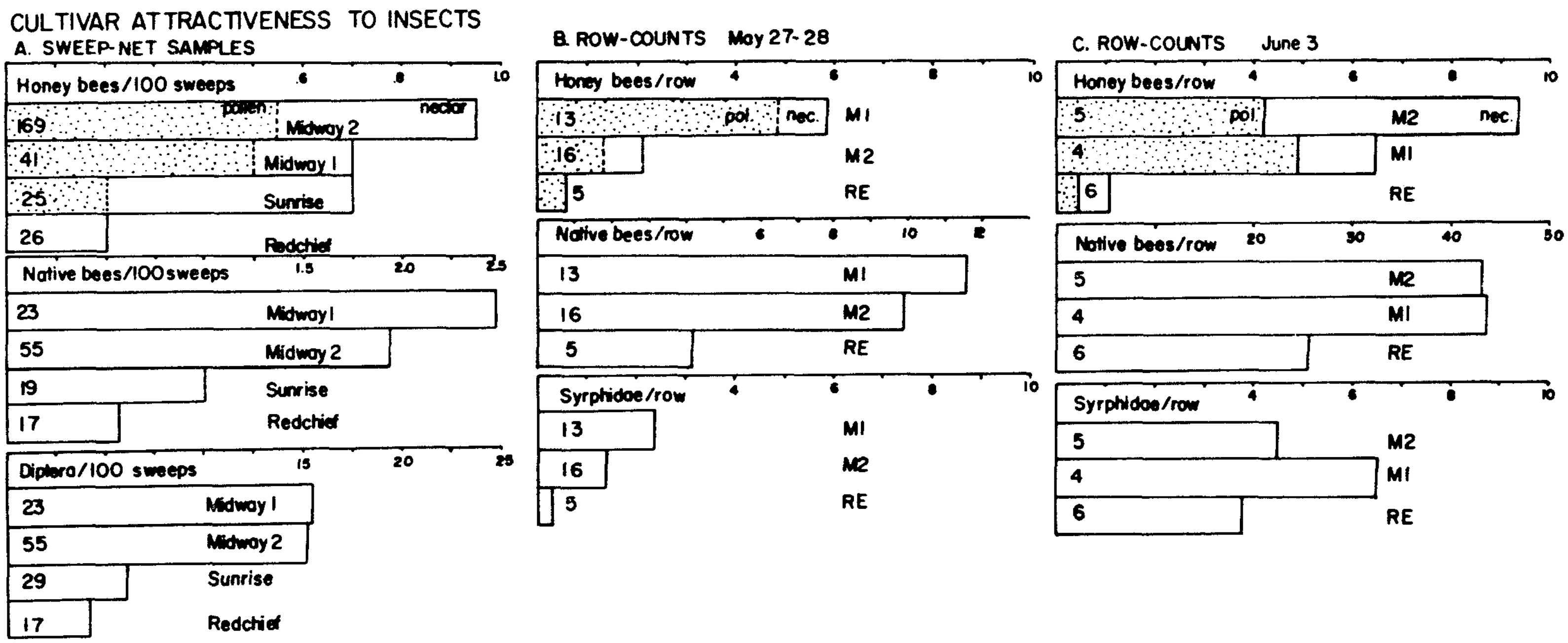

Figure 8.--Cultivar attractiveness to insects of four cultivars grown in Michigan, band upon sweep net collections (A) and row counts (B and C). Numbers at left of each bar represent the number of sweep collections (A) or rows (B and C) included in the mean value.

TABLE 11.--Plant source of pollen pellets returned to colonies of honey bees located in 2 commercial strawberry fields consisting of different cultivars.

PELLET SOURCE	REDCHIEF		MIDWAY 1 AND MIDWAY 2	
	No. samples with this pollen	Percent (mean)	No. samples with this pollen	Percent (mean)
Fragaria	2	2.4	19	57.1
Choke cherry	4	71.7	13	25.2
Sweet cherry	0	0.0	7	8.5
Apple	3	5.3	9	21.0
Dandelion	2	7.9	11	13.9
Yellow Rocket	2	6.9	5	13.9
Brassica sp.	1	0.6	9	16.8
Willow	3	18.9	2	1.9
OTHERS	2	0.5	10	1.2
TOTAL NO. SAMPLES	4		19	

field sprayed twice during bloom, pollinator density never exceeded 2.1 bees per 100 sweeps.

In addition to pesticide applications, native bee density was greatly influenced by the type of use of surrounding land. Commercial strawberry fields surrounded by non-cultivated soil provided the highest native bee density, while fields surrounded by cultivated land or orchards had very low native bee densities. This variation can be explained by the greater availability of nesting sites for native bees in non-cultivated areas. Cultivated land provided fewer places for bees to build nests (Figure 9).

Honey bee density was similarly influenced by the closeness of samples fields to the colony: In 11 fields located within approximately 1/4 mile of colonies of honey bees, there were 1.2 honey bees per 100 sweeps based upon 103 sweep net samples. This is compared to 9 fields lacking honey bee colonies within 1/4 mile from the field: there were 0.5 honey bees per 100 sweeps based upon 99 samples. These data do not include any fields of Redchief which proved to be relatively unattractive to honey bees irrespective of the closeness of the colonies.

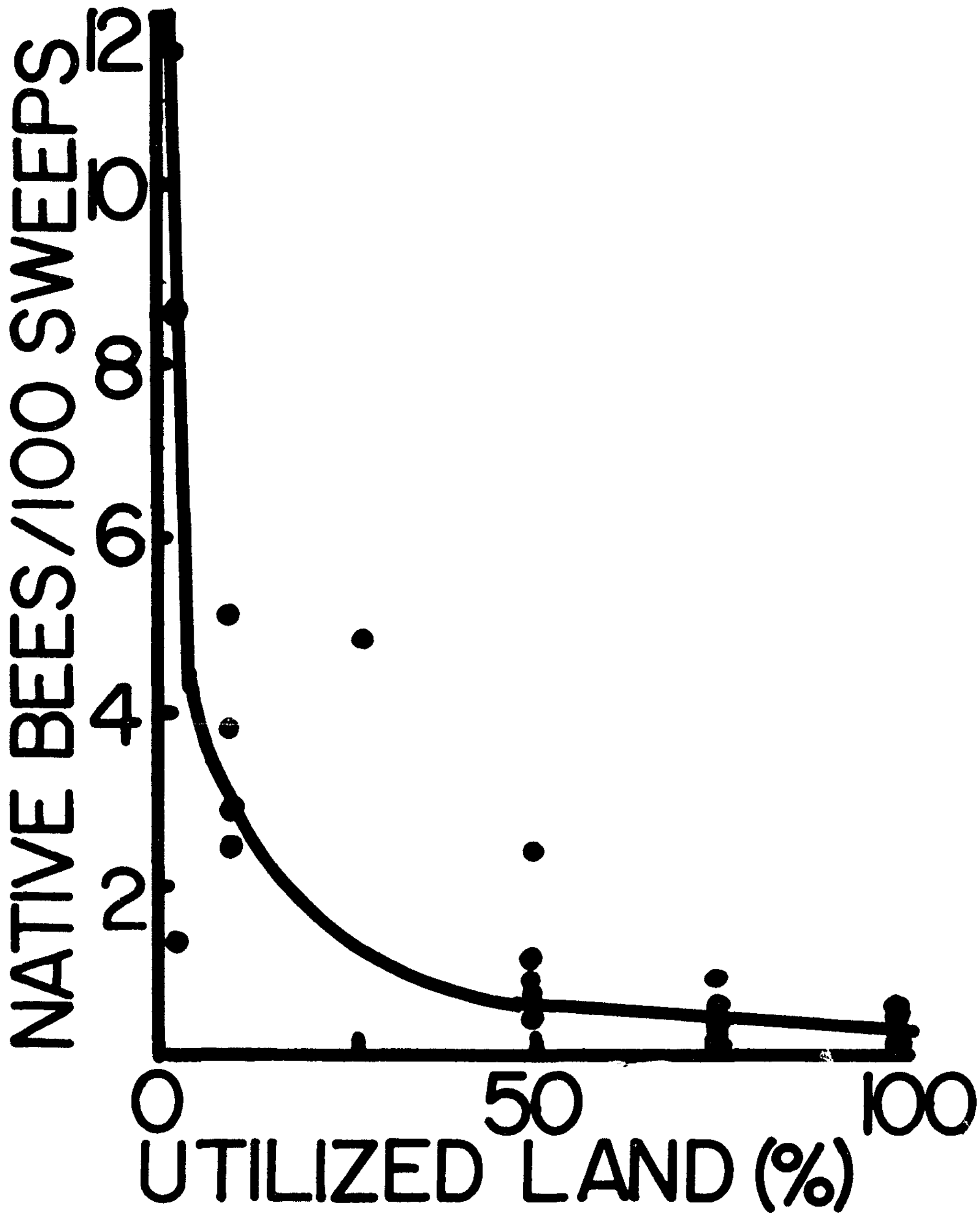

Figure 9.--Native bee density in commercial strawberry fields as influenced by the percent of surrounding land in agricultural use.

DISCUSSION

Commercially-grown strawberry flowers were pollinated through the interaction of three mechanisms: self-pollination, wind-motion pollination and insect pollination. These mechanisms were controlled by two major components, a 'flower-factor' and an 'insect-factor' (Figure 10). The flower-factor controlled the level of pollination resulting from the flower itself, and included both self-pollination and pollination due to the motion of the wind. It was determined by various morphological aspects of the flower, especially the relationship between the height of the stamen and the receptacle. Different ratios found in different cultivars influenced the percent achene set in various plot treatments. Analysis of the data revealed significant correlations between stamen height and achene set for those berries produced early in the season, but not in later berries. Because stamens were longer on flowers produced later in the season, and the height of the receptacle decreased, the percent achene set increased from the primary to the quaternary flowers. Thus, primary flowers often had tall receptacles with short stamens, while tertiary and quaternary flowers had shorter receptacles and taller stamens. Thus, stamen height relative to receptacle height together determine the achene set more than stamen height alone.

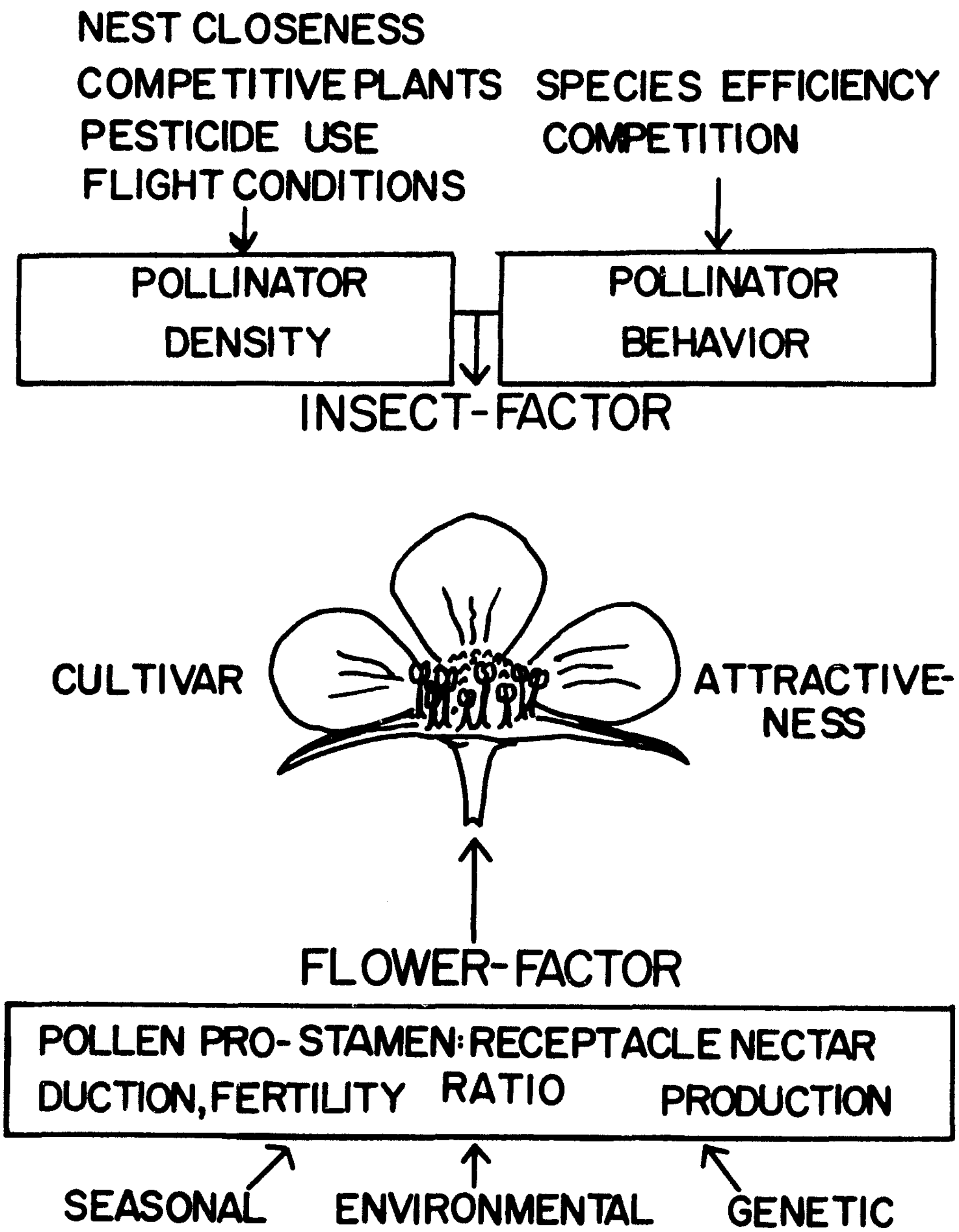

Figure 10.--A conceptual picture of the strawberry pollination system observed in Michigan strawberry fields.

Other aspects of floral morphology potentially influence the flower-factor, including the angle of the filaments supporting the anthers, the size of the anthers, and the shape of the receptacle. Cultivars may differ in the amount of pollen they produce, the viability of that pollen and the length of receptivity of the pistils. For example, pistils at the tip of flowers of some cultivars were receptive to pollination after petal fall while the remaining pistils were no longer receptive in greenhouse studies. Any and all of these factors potentially influenced the amount of achene set and are collectively included in the flower-factor. Thus, there is considerable variation in the importance of the flower-factor both in different cultivars and within the same cultivar at different stages of flowering. Cultivars also appeared to differ in nectar production and attractiveness to insects, a fact which ultimately influenced the total number of insect pollinators and the amount of insect pollination. A combination of short stamens, tall receptacles, and unattractiveness to insects attributed to an average 62% achene set in primary berries of the cultivar 'Redchief', while smaller receptacles and taller stamens in quaternary flowers resulted in 96% achene set. The 'Redchief' flowers were unattractive to insect pollinators throughout bloom when compared to other cultivars.

As a result of the flower-factor, six commercial strawberry cultivars set from 46% to 70% of their achenes and four Michigan State University selections set from 56% to 90%. Insect pollination increased achene set to 90% or better in these cultivars. There was one exception:

'Midway 1' set 97% of its achenes without help from insects. Thus, insect pollination of 'Midway 1' was not important to the grower.

Theoretically, the amount of pollination the flower-factor failed to accomplish was completed by the insect activity on the flowers. This second pollination component is called the 'insect-factor'. But insect species varied in their behavior on the flowers, and consequently, their pollination efficiency. Larger bee species, including the honey bee, contacted the stigmas and the stamens of a flower at the same time, so that the bee's movement resulted in pollination. Smaller bee species demonstrated a tendency to remain outside the tall stamens, and only occasionally touched the stigmas. Several species of Andrenidae and Halictidae were excellent pollinators of strawberry flowers and deserve continued study. Cultivars with short stamens permitted the small bees to contact stigmas and styles on the same visit. Various fly species appeared to differ from being occasionally pollinators to being of no value as pollinators of strawberry flowers.

Pollinator density in commercial fields affected achene set. Honey bees were most numerous when colonies were located within or close to the field. Likewise, native bee species, most of which are ground nesting, were abundant only when nearby nesting sites were undisturbed. Andrenine and halictine populations were low in commercial fields surrounded by cultivated land unsuitable for nesting sites. Furthermore, if a field of strawberries had a low population of pollinators, the insects worked along the edges of the field, avoiding the middle, a fact supported by reduced levels of achene set in the center of these fields. Pollinator insect populations were reduced during cold weather, rain, overhead irrigation, or periods of high wind. When other conditions were favorable to insect foraging except high wind, the insects foraged in areas protected by fence rows, woods, orchards, etc.

Insecticide applications during bloom significantly reduced pollinator density, often for days. Insect control is important in Michigan strawberry production, but further study should be given to possible elimination of sprays during bloom. Loss of pollinating insects at bloom may be more serious than insect damage incurred during bloom. If insecticides are essential, sprays least toxic to bees should be applied when bees are not flying. For example, late afternoon and early evening application of an insecticide with less than overnight residual effect could almost totally prevent bee kill.

The author worked in commercial fields where pollinator density was extremely low, yet there was no pollination problem. For growers had selected cultivars which did not need a great deal of insect pollination for good berry production. In such cases elimination of pollinators by insecticides had little effect on final yield. But growers who practiced spraying in bloom could not be successful with cultivars which required insect pollination. Several growers in Van Buren and Berrien counties mentioned to the author that they had problems with either poor berry set or rough looking berries, both of which were a result of poor pollination indicated by low achene set attributed to low insect density. Usually these fields were sprayed in bloom, sometimes twice; also, the fields were surrounded by cultivated land which restricted nesting sites for native bee species, and there were few colonies of honey bees within 1/4 mile of the field. Thus, when cultivars of the type benefited by bees were planted, a poor quality crop resulted.

In addition to the danger of reduced pollinator density due to the use of insecticides, fungicides applied during bloom may have a deleterious effect on strawberry pollen fertility and germination. Some fungicides are phytotoxic to strawberry pollen (Eaton and Chen, 1968a, 1968b).

As mentioned earlier, stamen height on different flowers increased throughout the season, while receptacle height decreased, resulting in proportionately higher achene set without the help of insects. For example, one field averaged 70% achene set in the primary flowers, 84% in the secondary flowers, 91% in the tertiary flowers, and 94% in the quaternary flowers. Because berries with 70 or 84% achene set had noticeable unpollinated areas and were less than perfect in shape, it was evident that the greatest need for supplemental pollination was during the bloom of these early flowers, while the need for insect pollination greatly decreased in the tertiary and quaternary flowers. In fields needing supplemental insect pollination, rental colonies of honey bees should be introduced at the first stage of bloom, but might be safely removed during the later stages, especially if an insecticide is to be applied.

This research underscores the need for cooperation between plant breeders and entomologists in considering the pollination aspects of new cultivars. During past decades, strawberry breeders have striven for highly productive, hermaphroditic cultivars which set nearly 100%

of all the flowers on the stem. Generally, they have sought high yields, irregardless of the pollination requirements of the cultivar. In the process they may have rejected genetic stock because it failed to produce high yields where pollinator populations were low. Theoretically, it is possible that breeders may have had good and poor pollen producing lines growing in small trial plots, with cross pollination from the viable pollen line increasing yield of the poor pollen line. In such a case, the problem of inadequate pollen production would not appear until the cultivar was grown in large acreages. When insect pollinators were excluded from trial plots, lines with poor morphological features but good yield and quality potential might be discarded. Finally, with the evolution of mechanical harvesters for strawberry production, cultivars will be required which concentrate flowering and ripening in order to optimize yield. In the greenhouse study it was evident that cultivars that remained in bloom longer set more achenes through self pollination; furthermore, the lines selected for concentrated ripening were open for shorter periods of time. This suggests that a short flowering period would greatly reduce self pollination in lines selected for concentrated ripening and increase the need for insect pollination. Pollination studies could help plant breeders become aware of the pollination requirements of new cultivars at the time of their release. Pollination requirements could then be specified for the growers benefit.

Worthwhile research might consider the possibility of interplanting good pollen cultivars in the fields with cultivars lacking adequate pollen. Similar work could also be conducted investigating the possibility of using pollen dispensors on colonies of honey bees to improve yields. Based upon counts of honey bees collecting pollen on different cultivars, there is a great difference in the level of pollen production or attractiveness of different lines. Controlled studies in greenhouse and field plots may provide additional information about these lines.

To simplify the evaluation of strawberry pollination needs for growers, county agents, horticulturalists, beekeepers, and entomologists, a flow-chart is presented in Figure 11. This chart is a summation of the author's research and available literature. It provides a means of quickly checking the status of pollination in specific fields. Checking the height of the stamens relative to the receptacle is the key point in assessing pollination problems. Pollinator density is normally only a factor when stamens are shorter than the receptacle. An important part of the flow-chart is the change in appearance of the strawberry pistil after fertilization--changing from a green-yellow to a dark brown in color. Completely pollinated flowers show pistils of an uniform dark brown color at the end of anthesis, while incompletely pollinated flowers have a mottled appearance.

In this research, fields of cultivars like 'Midway 1' seemed to have little or no need for insect pollinators for high yield of good quality. Fields with intermediate length stamens benefited from insect pollination but could not be said to warrant the expense of introducing honey bee colonies unless the local bee population was very low. Thus, only in cultivars with short stamens would this research suggest that supplemental pollinators be introduced on a regular basis.

STRAWBERRY POLLINATION SYSTEM EVALUATION FLOW-CHART

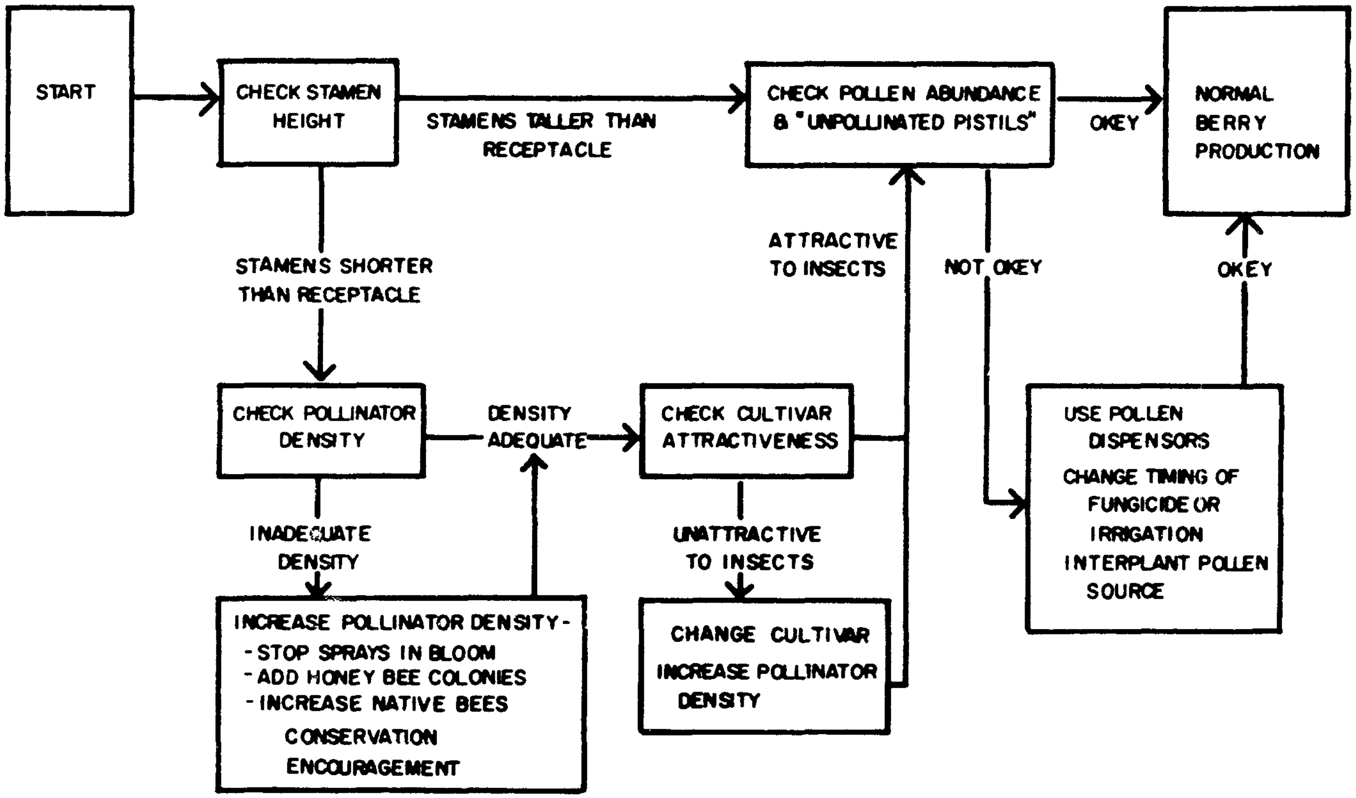

Figure 11.--Flow-chart designed to allow growers, beekeepers, horticulturalists and entomologists to evaluate the level of pollination in specific fields. Remedial procedures are then suggested.

This analysis of strawberry pollination is far from complete: the complexities of flower morphology, pollinator behavior, pollinator density, etc., are interrelated with cultivar peculiarities, seasonal changes, climatic conditions, insecticidal applications, and cultural practices. However, the author hopes that this research has clarified the components of strawberry pollination and identified some of the more essential features.

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Figure 12.--Various aspects of floral morphology of strawberry flowers. A--'Redchief', with tall receptacle and shorter stamens; B--'Guardian', also with stamens shorter than receptacle; C--Honey bee on flowers with stamens approximately equal in length to stamen height; D--'Midway 1' flowers with stamens taller than receptacle; E--honey bee on flower with stamens equal in length to stamen height; and F--flower at the end of anthesis, loosing petals, with pollinated pistils darkening.

Figure 13.--Various degrees of pollination. A--Only 2 or 3 pollinated and enlarged achenes; B--about 10 enlarged achenes producing nubbin or button shape, note small size of unfertilized ovules. C--Random achene enlargement from self-pollination; D--Nearly complete pollination, with only a few unpollinated ovules in creases and at berry tip; E--Pistillate 'NJ 264'; hand pollinated after petals had fallen, showing pistil receptivity only at tip of receptacle (berry); F--'Guardian' berries resulting from self-pollination, with characteristic nubbin or button appearance.

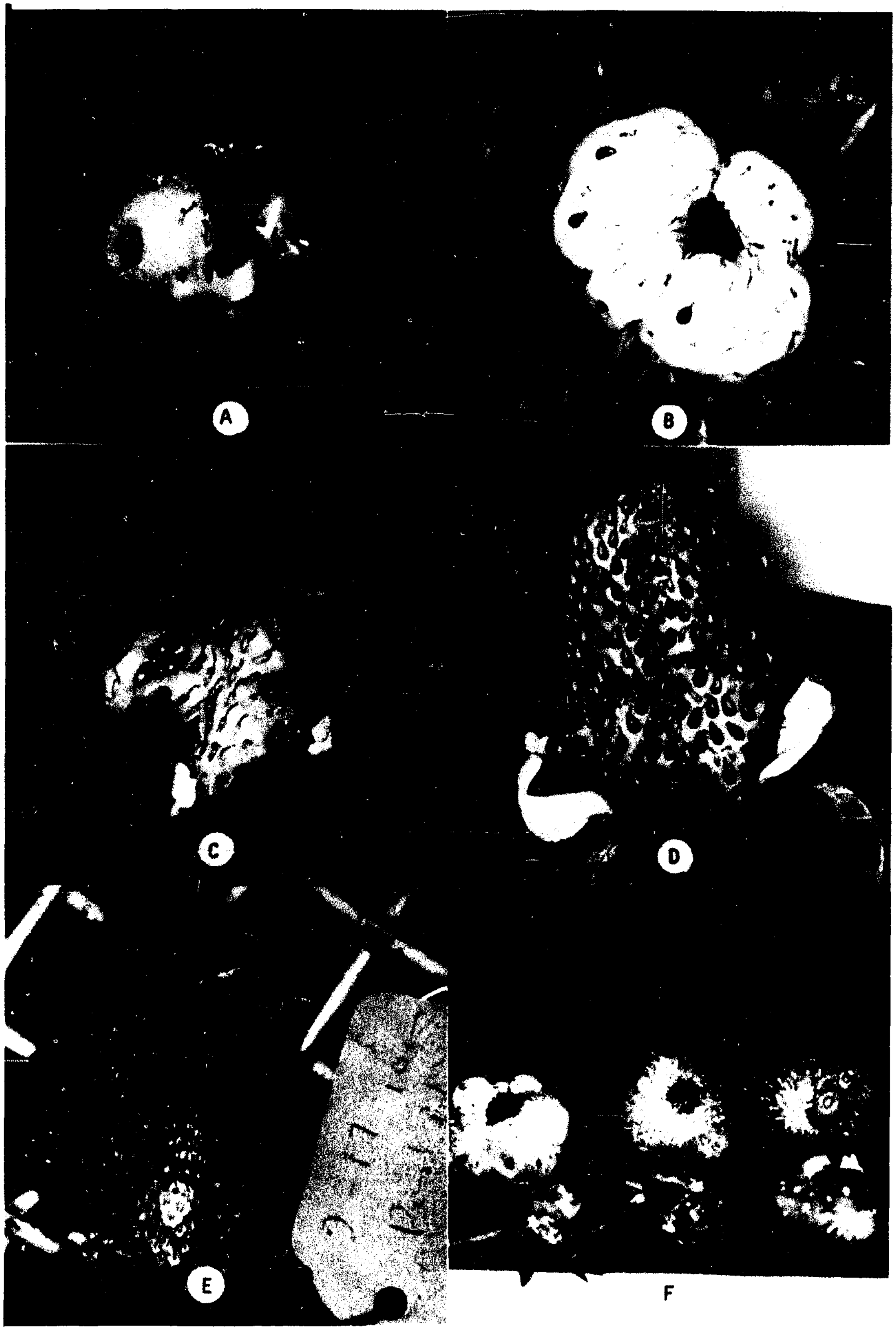

A
B
C
D
E
F

Figure 14.--Honey bee activity on strawberry flowers. A, B, and C--shows a single bee visit to a flower with bee following a clockwise direction. The bee is centered over the top of the receptacle during much of the visit. D and E--honey bee touching pistil and stamens during same visit. F--Honey bee on pistillate flower, seeking nectar.

Figure 15.--Several native bees on strawberry flowers. A and B--Andrenine on top of receptacle. C and D--Halictines working anthers from outside of 'wall' of stamens, eliminating most contact with pistils and thus minimizing pollination.

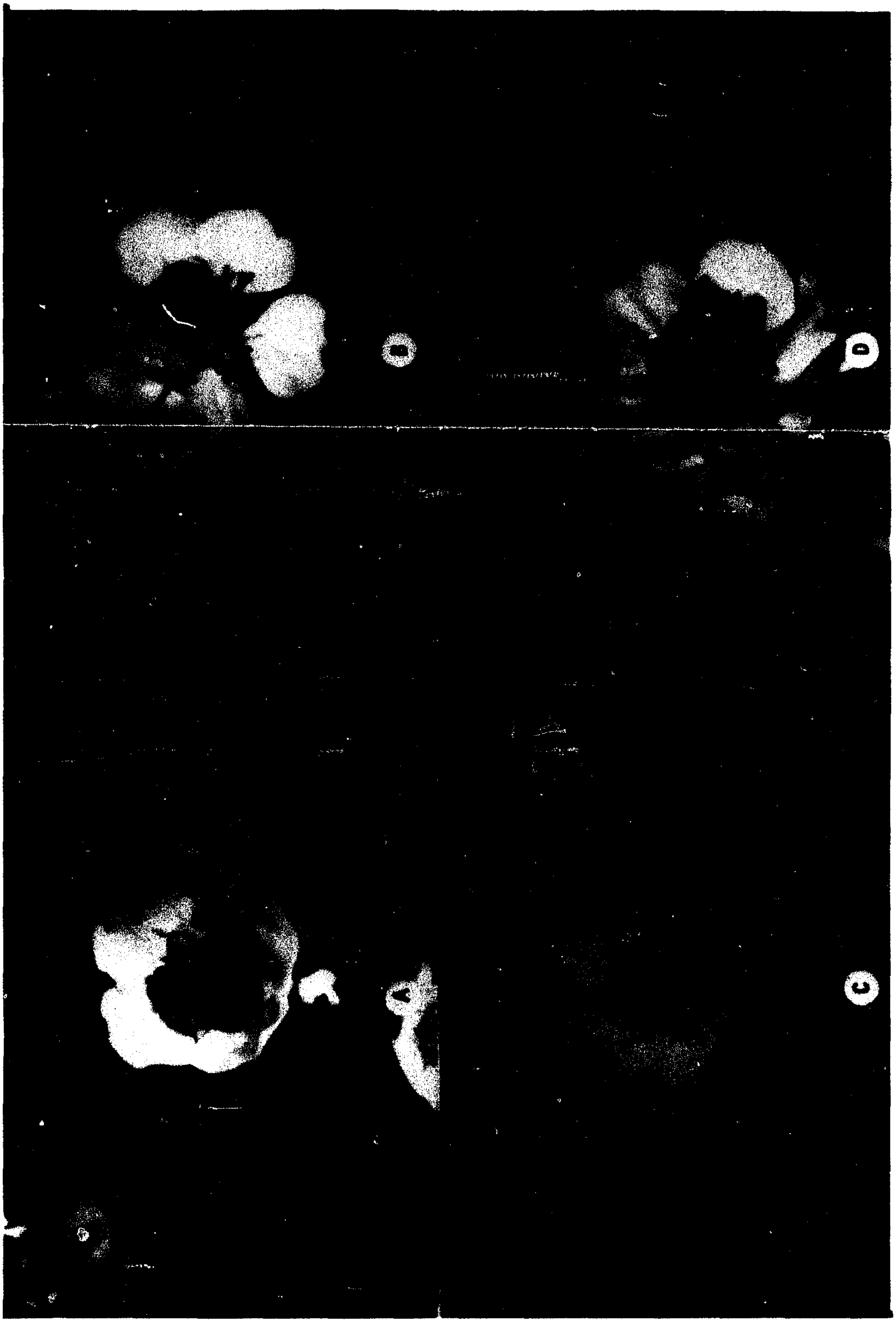


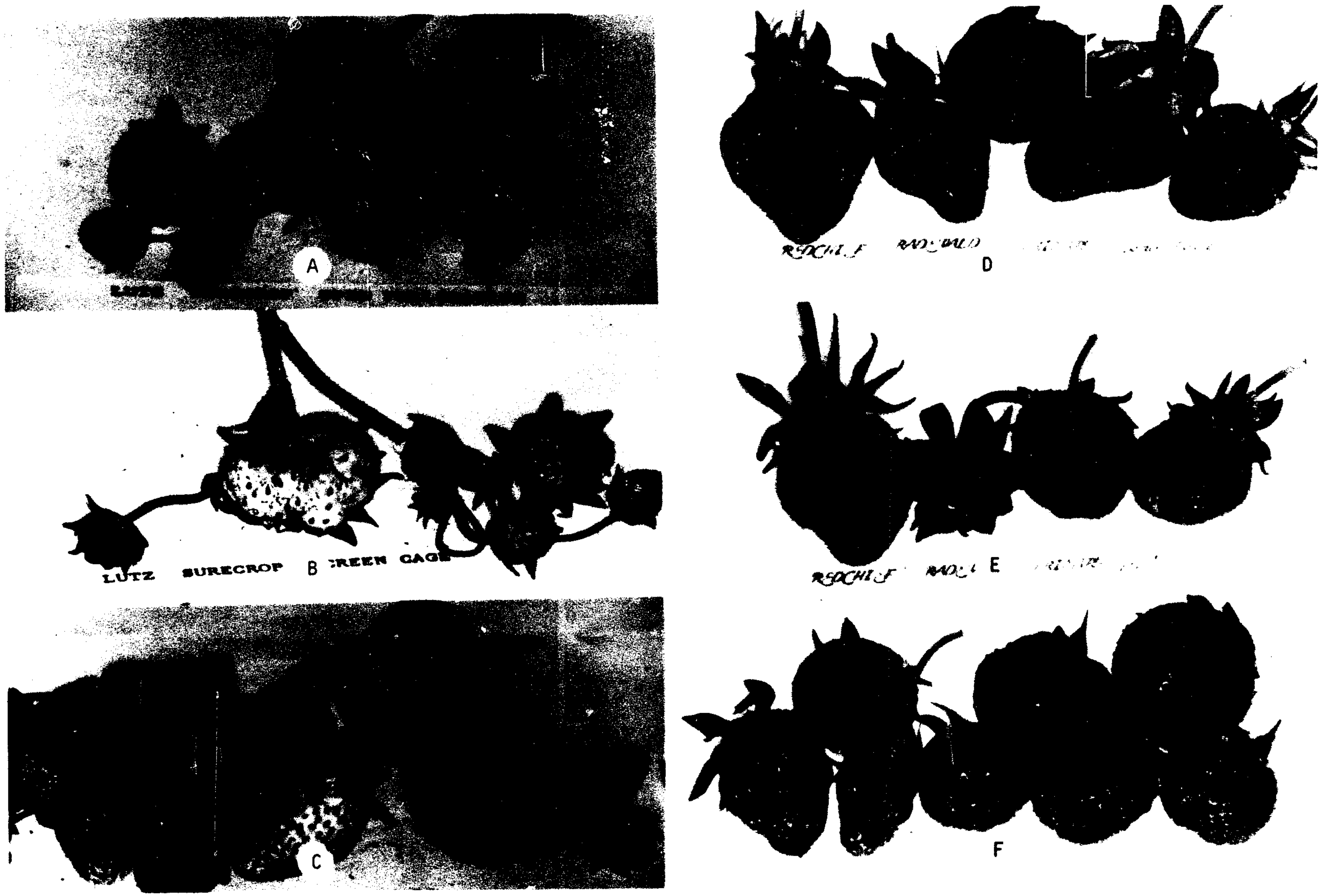
Figure 16.--Typical flower stems from open pollinated plots, screen covered plots, and cloth covered plots, representing insect, self and wind-motion pollination respectively. A, B, C--'Sunrise': open screen, cloth cages, respectively; D, E, F--'Midway 2' open, screen, cloth respectively.


A
B
C
D
E
F

Figure 17.--Similar to Figure 16, with 'Redchief' A, B, C--open pollination, screen cages, and cloth cages respectively; D, E, F--open pollination, screen cages, and cloth cages for 'Guardian', respectively.


A
B
C
D
E
F

Figure 18.--Short stamened 'Surecrop' yield in open pollination plots (A) and screen covered plots (B) compared to cloth covered cage of tall stamened 'Midway 1' (C). In D, E, F, Primary berries of 'Redchief' that were harvested at 0, 75 and 150 feet from the edge of a field with low pollinator density, showing poorer berry quality in the center of the field. There was a 20% decrease in the level of achene set from the edge to the center of this field.


A
LUTZ
SURECROP
B
C
D
E
F

APPENDICES

APPENDIX I

Cultivars, field locations, and dates of cage placement and removal for 1971 cage study.

COUNTY	GROWER	CULTIVAR	REPLICATION	CAGES PLACED	CAGES REMOVED
Berrien	Culby	Sunrise	2	May 6	June 11
Berrien	Culby	Midway 2	2	May 6	June 11
Berrien	Piggott	Sunrise	2	May 6	June 7
Berrien	Piggott	Earlidawn	2	May 6	June 7
Berrien	Piggott	Midway 2	1	May 6	June 11
Berrien	Radewald	Redchief	2	May 6	June 15
Berrien	Radewald	Midway 2	2	May 6	June 11
Van Buren	MSU Hort. Dept.	M 828	2	May 13	June 24
Van Buren	MSU Hort. Dept.	M 788	2	May 13	June 24
Van Buren	MSU Hort. Dept.	M 766	2	May 13	June 24
Van Buren	MSU Hort. Dept.	M 772	2	May 13	June 24
Van Buren	Hassell	Sunrise	2	May 6	June 11
Van Buren	Hassell	Redchief	2	May 6	June 11
Van Buren	Hassell	Guardian	2	May 6	June 15
Manistee	Lutz	Surecrop	2	June 2	June 25
Manistee	Lutz	Redchief	2	June 2	June 25
Manistee	Lutz	Sunrise	2	June 2	June 25
Manistee	Lutz	Midway 1 (Early Midway)	2	June 2	June 25
Manistee	Lutz	Midway 2 (Reg. Midway)	2	June 2	June 25

APPENDIX II

CULTIVAR GROWER		PRIMARY BERRIES				SECONDARY BERRIES				TERTIARY BERRIES				QUATERNARY BERRIES				TOTAL OF ALL BERRIES				PERCENT BERRY SET
		No. berries	mean % achene set	mean arcsin % achene set	Standard error	No. berries	mean % achene set	mean arcsin % achene set	Standard error	No. berries	mean % achene set	mean arcsin % achene set	Standard error	No. berries	mean % achene set	mean arcsin % achene set	Standard error	No. berries	mean % achene set	mean arcsin % achene set	Standard error	
Guardian Hassell	Cloth	30	33.74	.620	.041	61	30.87	.589	.027	41	36.07	.644	.033	19	47.21	.757	.059	151	34.83	.631	.018	46.63
	Screen	42	26.99	.546	.031	95	45.58	.741	.021	94	58.92	.875	.018	78	69.49	.986	.013	309	53.17	.817	.013	92.51
	Open	49	82.16	1.135	.030	98	82.75	1.143	.017	92	77.83	1.080	.014	68	75.99	1.059	.015	307	79.76	1.104	.009	95.22
	Average	121	51.74	.803	.031	254	57.38	.859	.019	227	62.97	.917	.015	165	69.84	.989	.013	767	60.91	.895	.010	78.53
Surecrop Lutz	Cloth	36	41.57	.701	.062	86	36.80	.652	.027	86	49.90	.784	.022	66	64.91	.937	.021	274	48.31	.769	.016	96.39
	Screen	45	56.80	.854	.052	99	58.01	.866	.028	94	63.35	.921	.030	71	64.06	.928	.034	309	60.87	.895	.017	98.54
	Open	48	96.17	1.374	.031	100	97.49	1.412	.021	87	98.55	1.450	.018	48	98.85	1.464	.011	283	97.92	1.426	.011	100.00
	Average	129	71.22	1.005	.037	285	70.16	.993	.024	267	75.18	1.049	.022	185	76.95	1.070	.024	866	73.36	1.028	.013	98.26
Earlidawn Piggott	Cloth	45	43.17	.717	.036	84	44.39	.729	.030	74	53.09	.816	.030	47	50.64	.792	.031	250	47.92	.765	.016	89.59
	Screen	47	28.98	.568	.038	94	38.78	.672	.030	81	51.68	.802	.025	51	67.58	.965	.026	273	46.23	.748	.017	99.71
	Open	49	53.73	.823	.037	95	64.70	.935	.025	75	74.16	1.037	.026	42	72.12	1.015	.027	261	66.74	.956	.015	99.00
	Average	141	41.92	.704	.023	273	49.57	.781	.018	230	59.75	.883	.017	140	63.47	.922	.018	784	53.70	.822	.010	96.14
Sunrise Piggott	Cloth	41	26.74	.543	.045	89	34.32	.626	.032	94	49.04	.776	.030	82	57.02	.856	.028	306	43.73	.723	.017	89.85
	Screen	48	20.88	.475	.026	95	39.06	.675	.030	91	56181	.854	.025	74	69.13	.982	.021	308	48.49	.770	.017	99.74
	Open	49	73.25	1.027	.035	98	84.02	1.160	.024	95	89.59	1.242	.022	75	91.46	1.274	.026	317	86.26	1.191	.014	100.00
	Average	138	40.64	.691	.030	282	54.25	.828	.022	280	67.05	.959	.019	231	73.67	1.032	.019	931	61.15	.898	.012	96.48
Sunrise Culby	Cloth	47	34.82	.631	.039	95	47.46	.760	.027	90	55.56	.841	.030	66	60.96	.896	.032	298	50.89	.794	.016	91.80
	Screen	45	35.79	.641	.037	93	65.65	.945	.026	91	73.79	1.033	.023	68	78.59	1.090	.027	297	67.02	.959	.016	93.39
	Open	48	91.12	1.268	.044	100	95.03	1.346	.025	96	95.98	1.369	.019	79	95.84	1.365	.020	323	95.03	1.346	.013	98.37
	Average	140	56.72	.853	.034	288	72.88	1.023	.021	277	78.38	1.087	.019	213	81.94	1.132	.020	918	74.52	1.042	.012	94.49
Sunrise Hassell	Cloth	39	51.47	.800	.052	88	54.20	.827	.038	86	61.67	.903	.039	59	68.03	.970	.042	272	59.25	.878	.021	86.32
	Screen	49	37.99	.664	.038	99	62.75	.914	.024	93	74.52	1.042	.020	67	79.68	1.103	.017	308	66.55	.954	.015	96.71
	Open	32	93.84	1.320	.048	81	98.82	1.462	.019	79	97.37	1.408	.021	59	97.21	1.403	.026	251	97.53	1.413	.013	99.32
	Average	120	59.72	.883	.036	268	75.36	1.051	.023	258	80.04	1.108	.021	185	83.78	1.156	.021	831	76.77	1.068	.012	93.85
Sunrise Lutz	Cloth	30	42.98	.715	.045	74	40.10	.686	.024	50	37.72	.661	.029	10	42.18	.707	.084	164	40.02	.685	.017	78.09
	Screen	40	74.49	1.041	.066	95	87.69	1.212	.027	83	85.84	1.185	.031	20	83.57	1.153	.054	238	84.71	1.169	.020	97.33
	Open	50	95.28	1.352	.047	100	99.61	1.508	.014	94	99.94	1.547	.009	57	99.69	1.515	.028	301	99.44	1.496	.012	100.00
	Average	120	78.54	1.089	.039	269	85.31	1.177	.024	227	88.16	1.219	.026	87	94.72	1.339	.038	703	86.59	1.196	.015	92.56
M828 - MSU	Cloth	46	47.22	.758	.039	96	50.56	.792	.025	88	48.65	.772	.024	67	49.71	.782	.034	297	49.30	.778	.015	94.51
	Screen	44	81.21	1.122	.043	97	90.62	1.260	.026	95	91.44	1.274	.027	69	92.05	1.285	.036	305	90.06	1.250	.016	99.16
	Open	25	85.59	1.181	.050	50	95.80	1.364	.026	50	96.61	1.386	.025	38	97.97	1.428	.028	163	95.52	1.358	.016	99.08
	Average	115	69.83	.989	.031	243	79.12	1.096	.022	233	80.09	1.108	.023	174	81.25	1.123	.029	765	78.60	1.090	.013	97.34
Redchief Redmmald	Cloth	35	19.24	.454	.027	81	23.86	.510	.021	90	37.54	.660	.024	77	53.65	.822	023	283	35.24	.636	.014	87.66
	Screen	42	34.48	.628	.030	96	44.82	.733	.021	92	67.12	.960	.020	74	78.03	1.083	019	304	58.67	.873	.014	99.76
	Open	37	78.09	1.084	.051	96	91.53	1.275	.031	96	96.92	1.394	.022	91	98.69	1.456	020	320	94.78	1.340	.016	97.92
	Average	114	43.71	.722	.033	273	57.22	.858	.024	278	71.96	1.013	.022	242	82.57	1.140	.021	907	67.45	.964	.013	95.25
Redchief Hassell	Cloth	23	32.01	.601	.050	79	44.42	.729	.032	96	61.31	.899	.026	90	78.80	1.093	018	288	60.35	.890	.017	84.17
	Screen	19	18.46	.444	.031	82	35.76	.641	.024	100	58.82	.874	.019	97	73.16	1.026	.016	298	54.66	.832	.015	92.29
	Open	38	76.87	1.069	.031	78	87.18	1.205	.024	78	93.12	1.305	.020	71	92.86	1.300	.023	265	89.48	1.240	.013	100.00
	Average	80	50.08	.786	.038	239	56.85	.856	.022	274	71.33	1.006	.017	258	81.41	1.125	.013	851	68.85	.979	.011	91.43
Redchief Lutz	Cloth	23	48.27	.768	.055	83	53.64	.822	.026	100	57.86	.864	.019	85	64.43	.032	.017	291	57.86	.864	.012	100.00
	Screen	49	73.28	1.028	.049	100	67.41	.963	.024	99	68.23	.972	.019	81	70.03	.991	.018	329	69.20	.982	.013	100.00
	Open	14	98.11	1.433	.044	41	99.78	1.524	.018	49	99.96	1.551	.011	46	99.92	1.543	.014	150	99.83	1.530	.009	100.00
	Average	86	72.98	1.024	.048	224	72.02	1.013	.022	248	74.63	1.043	.020	212	78.38	1.087	.019	770	74.76	1.044	.011	100.00
Midway 2 Culby	Cloth	41	43.81	.723	.031	96	56.56	.851	.023	87	57.18	.857	.023	57	60.77	.894	.028	281	55.76	.843	.013	83.42
	Screen	41	58.98	.876	.033	81	73.71	1.032	.016	72	80.10	1.108	.021	54	82.86	1.144	.018	248	75.48	1.053	.012	88.40
	Open	33	85.02	1.173	.029	66	85.93	1.186	.016	61	87.52	1.210	.017	47	88.66	1.227	.022	207	86.90	1.200	.010	100.00
	Average	115	62.02	.907	.025	243	71.04	1.003	.014	220	74.13	1.037	.016	158	77.65	1.078	.018	736	72.10	1.014	.009	89.45
Midway 2 Piggott	Cloth	24	48.57	.771	.052	45	70.75	.999	.028	38	68.11	.971	.024	21	63.63	.923	.043	128	64.80	.936	.019	77.04
	Screen	45	64.21	.929	.029	98	70.42	.996	.016	80	71.83	1.011	.015	60	71.36	1.013	.022	283	70.37	.994	.010	92.93
	Open	49	83.96	1.159	.031	100	89.26	1.237	.017	87	89.66	1.243	.017	59	92.23	1.290	.022	295	89.23	1.236	.010	98.60
	Average	118	70.12	.992	.024	243	79.07	1.096	.013	205	79.61	1.102	.014	140	80.88	1.118	.019	706	78.18	1.085	.008	92.10
H788 MSU	Cloth	40	44.84	.734	.050	90	48.49	.770	.031	86	57.99	.866	.032	60	63.51	.922	.039	276	54.23	.838	.018	83.52
	Screen	46	44.31	.728	.035	99	71.21	1.004	.028	86	79.13	1.096	.031	61	84.64	1.168	.027	292	72.81	1.022	.017	91.99
	Open	19	79.31	1.099	.044	40	92.61	1.296	.033	39	97.62	1.416	.033	37	99.30	1.487	.028	135	95.42	1.355	.020	99.44
	Average	105	51.20	.797	.029	229	67.42	.963	.022	211	76.22	1.061	.024	158	83.28	1.149	.026	703	71.70	1.010	.013	90.06
Midway 2 Lutz	Cloth	36	32.88	.611	.040	75	39.21	.677	.027	77	43.48	.720	.027	53	46.40	.749	.035	241	41.17	.697	.016	78.92
	Screen	48	51.45	.800	.045	93	57.87	.864	.019	88	66.51	.954	.018	56	73.56	1.031	.034	285	62.70	.914	.014	96.67
	Open	42	95.12	1.348	.037	100	97.50	1.412	.018	95	99.37	1.485	.016	61	99.12	1.477	.020	298	98.29	1.440	.011	99.70
	Average	126	64.12	.928	.036	268	72.37	1.016	.023	260	77.67	1.079	.023	170	79.68	1.103	.029	824	74.41	1.040	.013	91.77

APPENDIX II
continued

CULTIVAR GROWER		PRIMARY BERRIES No. berries	mean % achene set	mean arcsin % achene set	Standard error	SECONDARY BERRIES No. berries	mean % achene set	mean arcsin % achene set	Standard error	TERTIARY BERRIES No. berries	mean % achene	mean arcsin % achene set	Standard error
Midway 2 Radewald	Cloth	43	39.21	.677	.034	88	47.65	.762	.023	74	56.44	.850	.020
	Screen	49	55.57	.841	.033	97	69.12	.982	.017	90	76.30	1.062	.015
	Open	49	84.58	1.167	.026	99	90.59	1.259	.020	88	91.70	1.280	.021
	Average	141	61.78	.904	.025	284	71.73	1.010	.017	252	77.45	1.076	.015
M772 MSU	Cloth	18	51.23	.798	.050	51	61.00	.896	.025	49	62.17	.908	.031
	Screen	41	55.06	.836	.030	82	61.76	.904	.021	63	67.17	.961	.025
	Open	22	97.53	1.413	.039	48	99.36	1.491	.024	45	99.54	1.503	.025
	Average	81	69.36	.984	.036	181	75.89	1.057	.024	157	79.41	1.100	.026
M766 MSU	Cloth	40	44.09	.726	.039	88	56.74	.853	.020	92	67.27	.962	.023
	Screen	77	78.55	.837	.034	143	65.28	.941	.023	135	72.34	1.017	.021
	Open	77	78.55	.837	.034	143	65.28	.941	.023	135	72.34	1.017	.021
	Average	108	51.06	.796	.026	231	62.07	.907	.017	227	70.32	.995	.016
Midway 1 Lutz	Cloth	25	93.60	1.317	.048	61	83.69	1.155	.035	72	76.87	1.069	.026
	Screen	32	98.58	1.451	.035	83	96.50	1.383	.022	90	97.57	1.414	.022
	Open	50	97.17	1.402	.028	100	99.78	1.524	.012	93	99.91	1.542	.012
	Average	107	97.00	1.397	.021	244	96.54	1.384	.016	255	95.75	1.363	.017

CULTIVAR GROWER		QUATERNARY BERRIES No. berries	mean % achene set	mean arcsin % achene set	Standard error	TOTAL OF ALL BERRIES No. berries	mean % achene set	mean arcsin % achene set	Standard error	PERCENT BERRY SET
Midway 2 Radewald	Cloth	59	59.52	.881	.018	264	51.40	.799	.012	81.49
	Screen	71	78.60	1.091	.018	307	71.54	1.008	.011	92.74
	Open	51	96.04	1.370	.027	287	91.20	1.270	.012	98.48
	Average	181	79.53	1.101	.018	858	73.62	1.031	.009	90.53
M772 MSU	Cloth	21	66.06	.949	.046	139	60.94	.896	.017	43.27
	Screen	38	70.06	.992	.030	224	63.53	.922	.013	66.39
	Open	35	99.50	1.500	.028	150	99.27	1.405	.016	93.27
	Average	94	84.88	1.171	.032	513	77.76	1.080	.014	63.86
M766 MSU	Cloth	63	70.18	.993	.031	283	61.52	.902	.016	87.96
	Screen	77	78.55	1.089	.030	423	68.55	.975	.013	96.12
	Open	77	78.55	1.089	.030	423	68.55	.975	.013	96.12
	Average	140	74.90	1.046	.022	706	65.77	.946	.010	92.57
Midway 1 Lutz	Cloth	57	64.74	.935	.033	215	78.34	1.087	.018	93.26
	Screen	73	94.37	1.331	.027	270	96.67	1.387	.013	96.09
	Open	74	99.99	1.562	.006	317	99.73	1.519	.007	100.00
	Average	204	93.06	1.304	.022	810	95.58	1.359	.009	96.55

APPENDIX III

Source and description of 10 cultivars used in 1971 greenhouse evaluations.

SOURCE	CULTIVAR	COMMENTS:
Denison, Iowa	Stoplight	High level of concentrated ripening.
Denison, Iowa	133-6733	Higher level of concentrated ripening than Stoplight.
Denison, Iowa	7-6736	Highest level of concentrated ripening.
Smith, Rutgers	NJ 264	Pistillate selection
Moulton, MSU	Midway*	A leading Michigan producer.
Moulton, MSU	Guardian	USDA release, disease resistant
Moulton, MSU	Sequoia	California
Moulton, MSU	Surecrop	Commercially available, disease resistant,but not a leading line.
Moulton, MSU	Redchief	USDA release, disease resistant
Moulton, MSU	Tioga	Good producer in California

*Midway was not designated either Midway 1 or Midway 2 by Moulton's supplier, but appeared to by Midway 2.

APPENDIX IV

Parameters concerning sweep net collections made in 1969 - 1971. Materials, preserved and stored at the Department of Entomology, Michigan State University, may be identified by year of collection and sample number.

SAMPLE	CULTIVAR	DATE	TIME (EST)	OWNER	TEMPERATURE °F	WIND MPH	PERCENT SUN	NUMBER SWEEPS
				1969				
1	Wild	04 May	1200	Connor	75	05	100	n/r*
2	Wild	04 May	0200	Connor	75	05	75	n/r
3	Mixture	06 May	0115	Hort Farm	75	25	75	n/r
4	Wild	16 May	1115	Apiary	78	05	100	n/r
5	Mixture	16 May	0200	Lott	83	n/r	100	n/r
6	Mixture	23 May	0300	Hort Farm	62	25	25	n/r
7	Mixture	24 May	0230	Hort Farm	72	25	100	n/r
8	Mixture	24 May	0330	Lott	72	25	100	n/r
9	Unknown	26 May	1200	Kayes	65	00	90	n/r
10	Midway 1	26 May	0130	FosterBrs.	70	20	90	n/r
11	Mixture	26 May	0300	Connor	70	15	90	n/r
12	Mixture	26 May	0330	Beauchamp	70	20	90	n/r
13	Mixture	27 May	1200	Alfonso	75	25	70	n/r
14	Mixture	28 May	0100	Lutz	85	20	100	n/r
15	Mixture	28 May	0115	Lutz	85	20	100	n/r
16	Mixture	28 May	0130	Lutz	85	20	100	n/r
17	Mixture	28 May	0145	Lutz	85	20	100	n/r
18	Mixture	28 May	0200	Lutz	85	20	100	n/r
19	Mixture	28 May	0215	Lutz	85	20	100	n/r
20	Mixture	28 May	0230	Lutz	85	20	100	n/r
21	n/r	29 May	0900	Grant	60	25	00	n/r
22	n/r	29 May	0900	Grant	60	25	00	n/r
23	n/r	29 May	1000	Grant	62	25	25	n/r
24	n/r	29 May	1000	Grant	62	25	25	n/r
25	n/r	29 May	1000	Grant	64	25	75	n/r
26	n/r	29 May	1000	Grant	64	25	75	n/r
27	n/r	29 May	1100	Lather	66	30	100	n/r
28	n/r	29 May	1100	Lather	66	30	100	n/r
29	n/r	29 May	1130	Lather	66	30	100	n/r
30	n/r	29 May	0200	Lutz	78	25	100	n/r
31	n/r	06 Jun	0115	Grant	63	25	100	n/r
32	n/r	06 Jun	0200	Lather	60	25	100	n/r
33	n/r	06 Jun	0400	Lutz	58	25	70	n/r
34	n/r	31 May	0200	Collison	82	n/r	100	n/r
35	n/r	10 Jun	1100	Hort Farm	68	20	100	n/r

Appendix IV (cont'd)

SAMPLE	CULTIVAR	DATE	TIME (EST)	OWNER	TEMPERATURE °F	WIND mph	PERCENT SUN	NUMBER SWEEPS
				1970				
1	Earlidawn	15 May	1045	Piggott	69	12	80	n/r
2	Sunrise	15 May	1100	Piggott	69	12	80	n/r
3	Sunrise	15 May	1145	Piggott	69	12	80	n/r
4	Earlidawn	15 May	1200	Piggott	69	12	80	n/r
5	Midway 2	15 May	1200	Piggott	69	12	80	n/r
6	Redchief	15 May	0145	Radewald	72	18	50	500
7	Redchief	15 May	0155	Radewald	72	18	50	500
8	Redchief	15 May	0205	Radewald	72	18	50	500
9	Wild	17 May	1200	Connor	58	18	80	n/r
10	Midway 2	18 May	0300	Dowd	70	18	100	n/r
11	Midway 2	18 May	0315	Dowd	70	18	100	340
12	Midway 2	18 May	0325	Dowd	70	18	100	340
13	Midway 2	18 May	0340	Dowd	73	18	100	350
14	Midway 2	18 May	0345	Dowd	73	18	100	350
15	Midway 2	18 May	0355	Dowd	73	10	100	350
16	Midway 2	18 May	0405	Dowd	73	18	100	350
17	Midway 2	18 May	0415	Dowd	73	18	100	350
18	Midway 2	18 May	0440	Dowd	75	20	100	300
19	Midway 2	18 May	0445	Dowd	75	20	100	300
20	Midway 2	18 May	0500	Dowd	75	20	100	360
21	Midway 2	18 May	0505	Dowd	75	20	100	360
22	Midway 2	19 May	0915	Dowd	75	23	100	500
23	Robinson	19 May	0945	FosterBrs.	75	23	100	500
24	Midway 2	19 May	1000	FosterBrs.	75	23	100	500
25	Midway 2	19 May	1015	FosterBrs.	75	23	100	500
26	Midway 2	19 May	1030	FosterBrs.	75	23	100	500
27	Midway 2	19 May	1100	Baiers	78	28	100	500
28	Midway 2	19 May	1100	Baiers	78	28	100	500
29	Midway 2	19 May	1100	Baiers	78	28	100	500
30	Midway 2	19 May	1130	Scherer	80	23	100	500
31	Midway 2	19 May	1145	Scherer	80	23	100	500
32	Midway 2	19 May	1215	Baiers	82	23	100	500
33	Midway 2	19 May	1230	Baiers	82	23	100	500
34	Midway 2	19 May	0100	Baiers	82	23	100	500
35	Midway 2	19 May	0115	Scherer	82	23	100	500
36	Midway 2	19 May	0145	Hassel	82	23	100	500
37	Midway 2	19 May	0200	Hassel	84	23	100	500
38	Midway 2	19 May	0245	Dowd	84	23	100	500
39	Midway 2	19 May	0330	Radewald	85	25	100	500
40	Midway 2	19 May	0345	Radewald	85	25	100	500
41	Midway 2	19 May	0400	Radewald	85	25	100	500
42	Redchief	19 May	0430	Radewald	85	25	100	500
43	Earlidawn	19 May	0500	Piggott	80	20	100	500

Appendix IV (cont'd)

SAMPLE	CULTIVAR	DATE	TIME (EST)	OWNER	TEMPERATURE °F	WIND mph	PERCENT SUN	NUMBER SWEEPS
44	Sunrise	19 May	0505	Piggott	78	20	100	500
45	Midway 2	19 May	0530	Piggott	75	20	100	500
46	Midway 1	20 May	0230	Collins Rd.	78	13	95	n/r
47	Midway 2	20 May	0230	Collins Rd.	78	13	95	n/r
48	Midway 2	21 May	1030	Dowd	79	18	95	500
49	Midway 2	21 May	1045	Dowd	79	18	95	500
50	Midway 2	21 May	1055	Dowd	79	18	95	500
51	Redchief	21 May	1225	Radewald	85	16	95	400
52	Redchief	21 May	1215	Radewald	85	16	95	400
53	Redchief	21 May	1235	Radewald	85	16	95	400
54	Redchief	21 May	1245	Radewald	85	16	95	400
55	Redchief	21 May	1255	Radewald	85	16	95	400
56	Midway 2	21 May	0115	Radewald	85	16	95	500
57	Midway 2	21 May	0130	Radewald	85	16	95	500
58	Midway 2	21 May	0145	Radewald	85	16	95	500
59	Midway 2	21 May	0155	Radewald	85	16	95	500
60	Sunrise	21 May	0230	Culby	86	18	100	500
61	Midway 1	21 May	0300	Culby	86	18	100	500
62	Midway 2	21 May	0315	Culby	86	18	100	500
63	Earlidawn	21 May	0315	Piggott	85	20	100	500
64	Sunrise	21 May	0340	Piggott	85	20	100	500
65	Midway 2	21 May	0355	Piggott	85	20	100	500
66	Midway 1	May	0900	Collins Rd.	72	18	50	n/r
67	Midway 2	May	0900	Collins Rd.	72	18	50	n/r
68	Midway 1	May	1030	Collins Rd.	74	18	50	n/r
69	Midway 2	May	1030	Collins Rd.	74	18	50	n/r
70	Midway 1	May	0300	Collins Rd.	75	25	75	n/r
71	Midway 2	May	0300	Collins Rd.	75	25	75	n/r
72	Midway 2	28 May	1245	Collins Rd.	65	23	100	n/r
73	Midway 2	29 May	1045	Dowd	75	18	85	500
74	Midway 2	29 May	1100	Dowd	75	18	85	500
75	Midway 2	28 May	1130	Dowd	79	18	85	500
76	Midway 2	29 May	1130	Dowd	79	18	85	500
77	Midway 2	29 May	1145	Dowd	79	18	85	500
78	Midway 2	29 May	1215	Dowd	79	18	85	500
79	Midway 2	29 May	1230	Dowd	79	18	85	500
80	Midway 2	29 May	0130	Foster Br.	83	28	90	500
81	Midway 2	29 May	0145	Foster Br.	83	28	90	500
82	Midway 2	29 May	0200	Foster Br.	83	28	90	500
83	Midway 2	29 May	0215	Foster Br.	83	28	90	500
84	Midway 2	29 May	0230	Baiers	83	30	90	500
85	Midway 2	29 May	0245	Baiers	83	30	90	500

Appendix IV (cont'd)

SAMPLE	CULTIVAR	DATE	TIME (EST)	OWNER	TEMPERATURE °F	WIND mph	PERCENT SUN	NUMBER SWEEPS
1970 (cont'd)								
86	Midway 2	29 May	0245	Scherer	85	30	85	500
87	Midway 2	29 May	0245	Scherer	85	30	85	500
88	Midway 2	29 May	0330	Baiers	85	30	90	500
89	Midway 2	29 May	0345	Baiers	85	30	90	500
90	Midway 2	29 May	0415	Scherer	73	28	10	500
91	Midway 2	4 June	1030	Lutz	69	05	100	500
92	Midway 2	4 June	1030	Lutz	69	05	100	500
93	Midway 1	4 June	1030	Lutz	69	05	100	500
94	Midway 2	4 June	1030	Lutz	69	05	100	500
95	Midway 1	4 June	1100	Lutz	69	05	100	500
96	Midway 1	4 June	1100	Lutz	69	05	100	500
97	Midway 2	4 June	1115	Lutz	70	05	100	500
98	Midway 2	4 June	1115	Lutz	70	05	100	500
99	Midway 2	4 June	1130	Lutz	70	05	100	500
100	Midway 2	4 June	1130	Lutz	70	05	100	500
101	Midway 2	4 June	0130	Lutz	70	08	100	500
102	Midway 1	4 June	0130	Lutz	70	08	100	500
103	Surecrop	4 June	0200	Lutz	70	08	100	500
104	Midway 1	4 June	0200	Lutz	70	08	100	500
105	Sunrise	4 June	0210	Lutz	72	12	100	500
106	Paymaster	4 June	0210	Lutz	72	12	100	500
107	Midway 2	4 June	0220	Lutz	72	12	100	500
108	Midway 2	4 June	0220	Lutz	72	12	100	500
109	Midway 1	4 June	0250	Lutz	72	12	100	500
110	Midway 2	4 June	0250	Lutz	72	12	100	500
111	Midway 2	4 June	0300	Lutz	72	12	100	500
112	Midway 2	4 June	0300	Lutz	72	12	100	500
113	Midway 2	4 June	0400	Lutz	74	18	100	500
114	Midway 2	4 June	0400	Lutz	74	18	100	500
115	Midway 2	4 June	0415	Lutz	74	18	100	500
116	Midway 2	4 June	0415	Lutz	74	18	100	500
117	Midway 2	4 June	0430	Lutz	74	18	100	500
118	Midway 2	4 June	0430	Lutz	74	18	100	500
119	Midway 1	4 June	0500	Lutz	74	18	100	500
120	Midway 1	4 June	0500	Lutz	74	18	100	500
121	Midway 2	5 June	0800	Lather	55	05	100	500
122	Midway 2	5 June	0800	Lather	55	05	100	500
123	Midway 2	5 June	0830	Lather	55	05	100	500
124	Midway 2	5 June	0830	Lather	55	08	100	500
125	Midway 2	5 June	0850	Lather	55	12	100	500
126	Midway 2	5 June	0900	Ruph	55	10	100	500
127	Midway 2	5 June	0900	Ruph	55	10	100	500
128	Midway 2	5 June	0915	Ruph	58	10	100	500
129	Midway 2	5 June	0915	Ruph	58	10	100	500
130	Midway 2	5 June	0930	Lather	59	15	100	500
131	Midway 2	5 June	0930	Lather	59	15	100	500

Appendix IV (cont'd)

SAMPLE	CULTIVAR	DATE	TIME (EST)	OWNER	TEMPERATURE °F	WIND mph	PERCENT SUN	NUMBER SWEEPS
1970 (cont'd)								
132	Midway 2	5 June	1015	Grant	65	20	100	500
133	Midway 2	5 June	1015	Grant	65	20	100	500
134	Midway 2	5 June	1045	Grant	65	20	100	500
135	Midway 2	5 June	1045	Grant	65	20	100	500
136	Midway 2	5 June	1045	Grant	65	20	100	500
137	Midway 2	5 June	1045	Grant	65	20	100	500
138	Midway 2	5 June	1130	Grant	69	08	100	500
139	Midway 2	5 June	1130	Grant	69	08	100	500
140	Midway 2	5 June	1145	Grant	71	08	100	500
141	Midway 2	5 June	1145	Grant	71	08	100	500
142	Midway 2	5 June	1200	Lather	73	23	100	500
143	Midway 2	5 June	1200	Lather	73	23	100	500
144	Midway 2	5 June	0230	Cudney	75	28	100	500
145	Midway 2	5 June	0230	Cudney	75	28	100	500
146	Midway 2	5 June	0300	Howe	75	28	100	500
147	Midway 2	5 June	0300	Howe	75	28	100	500
148	Midway 2	5 June	0330	Howe	75	28	100	500
149	Midway 1	5 June	0330	Howe	75	28	100	500
150	Midway 1	5 June	0430	Lutz	75	28	100	500
151	Midway 2	5 June	0430	Lutz	75	28	100	500
152	Midway 1	5 June	0430	Lutz	75	28	100	500
153	Midway 1	5 June	0430	Lutz	75	28	100	500
1971				1971				
1	Wild	13 May	1115	So.Haven	60	05	100	n/r
2	Sunrise	13 May	0100	Culby	66	20	100	300
3	Midway 2	13 May	0110	Culby	66	20	100	300
4	Midway 2	13 May	0115	Culby	66	20	100	300
5	Midway 2	13 May	0130	Culby	66	20	100	300
6	Sunrise	13 May	0135	Culby	66	20	100	300
7	Sunrise	13 May	0215	Piggott	66	20	100	300
8	Sunrise	13 May	0230	Piggott	66	20	100	300
9	Sunrise	13 May	0245	Piggott	66	20	100	300
10	Sunrise	13 May	0300	Piggott	66	20	100	300
11	Midway 2	13 May	0305	Piggott	66	20	100	300
12	Midway 2	13 May	0315	Piggott	66	20	100	300
13	Redchief	14 May	1030	Radewald	62	05	100	300
14	Redchief	14 May	1045	Radewald	62	05	100	300
15	Sunrise	14 May	1130	Piggott	63	10	100	300
16	Sunrise	14 May	1145	Piggott	63	10	100	300
17	Sunrise	14 May	1145	Piggott	63	10	100	300
18	Sunrise	14 May	1200	Piggott	63	10	100	50
19	Sunrise	14 May	1200	Piggott	63	10	100	50
20	Sunrise	14 May	1200	Piggott	63	10	100	50
21	Sunrise	14 May	1215	Piggott	63	10	100	300
22	Sunrise	14 May	1215	Piggott	63	10	100	300

Appendix IV (cont'd)

SAMPLE	CULTIVAR	DATE	TIME (EST)	OWNER	TEMPERATURE °F	WIND mph	PERCENT SUN	NUMBER SWEEPS
1971 (cont'd)								
23	Midway 2	14 May	1245	Piggott	63	10	100	300
24	Midway 2	14 May	0200	Culby	65	05	100	300
25	Sunrise	14 May	0330	Hassel	72	10	100	300
26	Sunrise	14 May	0345	Hassel	72	10	100	300
27	Sunrise	14 May	0355	Hassel	72	10	100	300
28	Sunrise	14 May	0410	Hassel	72	10	100	300
29	Midway 2	14 May	0430	Wm Foster	72	05	100	300
30	Midway 2	14 May	0440	Wm Foster	72	05	100	300
31	Midway 1	14 May	0450	Wm Foster	72	05	100	300
32	Midway 1	14 May	0500	Wm Foster	72	05	100	300
33	Midway 2	15 May	0900	Foster Br	65	25	90	200
34	Midway 2	15 May	0900	Foster Br	65	25	90	200
35	Midway 2	15 May	0900	Foster Br	65	25	90	200
36	Midway 2	15 May	0900	Foster Br	65	25	90	200
37	Midway 2	15 May	0930	Foster Br	73	15	90	200
38	Midway 2	15 May	0930	Foster Br	70	15	90	200
39	Midway 2	15 May	0930	Foster Br	70	15	90	200
40	Midway 2	15 May	1000	Foster Br	70	25	90	200
41	Midway 2	15 May	1000	Foster Br	70	25	90	200
42	Midway 2	15 May	1000	Foster Br	70	25	90	200
43	Midway 1	15 May	1045	Wm Foster	75	15	90	300
44	Midway 1	15 May	1045	Wm Foster	75	15	90	300
45	Midway 2	15 May	1045	Wm Foster	75	15	90	300
46	Midway 1	15 May	1130	Wm Foster	75	20	100	300
47	Midway 1	15 May	1130	Wm Foster	75	20	100	300
48	Midway 2	15 May	1130	Wm Foster	75	20	100	300
49	Redchief	15 May	0100	Radewald	80	30	95	300
50	Redchief	15 May	0100	Radewald	80	30	95	300
51	Redchief	15 May	0130	Radewald	80	25	100	300
52	Redchief	15 May	0130	Radewald	80	25	100	300
53	Redchief	15 May	0130	Radewald	80	25	100	300
54	Redchief	15 May	0130	Radewald	80	25	100	300
55	Midway 2	15 May	0230	Radewald	80	25	100	300
56	Midway 2	15 May	0230	Radewald	80	25	100	300
57	Midway 1	17 May	0300	Collins Rd	82	25	80	n/r
58	Midway 1	17 May	0300	Collins Rd	82	25	80	n/r
59	Midway 1	17 May	0300	Collins Rd	82	25	80	n/r
60	Midway 2	18 May	1030	Foster Br	82	20	60	n/r
61	Sunrise	18 May	1130	Hassell	82	20	60	n/r
62	Sunrise	18 May	0200	Piggott	82	20	60	n/r
63	Wild	20 May	1100	So. Haven	60	05	100	n/r
64	Sunrise	20 May	0100	Culby	62	25	95	300
65	Midway 2	20 May	0100	Culby	62	25	100	300
66	Midway 2	20 May	0100	Culby	62	25	100	300
67	Midway 2	20 May	0100	Culby	62	25	100	300
68	Sunrise	20 May	0100	Culby	62	25	100	300
69	Sunrise	20 May	0200	Piggott	65	25	95	300

Appendix IV (cont'd)

SAMPLE	CULTIVAR	DATE	TIME (EST)	OWNER	TEMPERATURE °F	WIND mph	PERCENT SUN	NUMBER SWEEPS
1971 (cont'd)								
70	Sunrise	20 May	0200	Piggott	65	25	95	300
71	Sunrise	20 May	0200	Piggott	65	25	95	300
72	Sunrise	20 May	0200	Piggott	65	25	95	300
73	Midway 2	20 May	0200	Piggott	65	25	95	300
74	Midway 2	20 May	0200	Piggott	65	25	95	300
75	Redchief	20 May	0300	Radewald	65	20	95	300
76	Redchief	20 May	0300	Radewald	65	20	95	300
77	Redchief	20 May	0300	Radewald	65	20	95	300
78	Redchief	20 May	0300	Radewald	65	20	95	300
79	Redchief	20 May	0300	Radewald	65	20	95	300
80	Redchief	20 May	0300	Radewald	65	20	95	300
81	Midway2	20 May	0515	Radewald	65	15	100	300
82	Midway2	20 May	0515	Radewald	65	15	100	300
83	Sunrise	21 May	0300	Hassell	60	25	95	n/r
84	Midway1	27 May	0230	Lutz	60	10	100	n/r
85	Midway1	27 May	0230	Lutz	60	10	100	n/r
86	Midway1	27 May	0230	Lutz	60	10	100	n/r
87	Sunrise	26 May	n/r	Hassell	n/r	n/r	n/r	n/r
88	Midway2	27 May	0100	Lutz	73	10	90	n/r
89	Midway2	27 May	0115	Lutz	73	10	90	n/r
90	Midway2	27 May	0200	Lutz	75	10	95	300
91	Redchief	27 May	0200	Lutz	75	10	95	300
92	Midway1	27 May	0200	Lutz	75	10	95	300
93	Sunrise	3 June	0300	Lutz	75	n/r	n/r	n/r
94	Midway2	7 June	0300	Radewald	88	25	80	250
95	Midway2	7 June	0310	Radewald	88	25	80	250
96	Midway2	7 June	0315	Radewald	88	25	80	250
97	Midway2	7 June	0320	Radewald	88	25	80	250
98	Midway2	9 June	0430	Lutz	68	10	100	250
99	Redchief	9 June	0445	Lutz	68	10	100	250
100	Midway1	9 June	0500	Lutz	68	10	100	250
101	Wild	8 June	0300	So Haven	65	10	0	n/r
102	Midway2	9 June	0520	Lutz	68	10	100	250
103	Midway2	9 June	0530	Lutz	68	10	100	250
104	Midway2	9 June	0535	Lutz	68	10	100	250
105	Midway2	9 June	0545	Lutz	68	10	100	250
106	Midway2	9 June	0555	Lutz	68	10	100	250
107	Midway2	9 June	0605	Lutz	68	10	100	250
108	Midway1	9 June	0615	Lutz	68	10	100	250
109	Paymaster	10Jun	1015	Lutz	69	15	100	200
110	Vesper	10 Jun	1030	Lutz	70	15	100	200
111	Midway1	10 Jun	1040	Lutz	70	15	100	250
112	Midway1	10 Jun	1040	Lutz	70	15	100	250
113	Midway2	10 Jun	0130	Lutz	75	15	100	250
114	Midway2	10 Jun	0130	Lutz	75	15	100	250
115	Redchief	10 Jun	0145	Lutz	75	15	100	250
116	Sunrise	10 Jun	0145	Lutz	75	15	100	250

Appendix IV (cont'd)

SAMPLE	CULTIVAR	DATE	TIME (EST)	OWNER	TEMPERATURE °F	WIND mph	PERCENT SUN	NUMBER SWEEPS
1971 (cont'd)								
117	Midway 1	10 Jun	0200	Lutz	75	15	100	250
118	Midway 1	10 Jun	0200	Lutz	75	15	100	250
119	Surecrop	10 Jun	0215	Lutz	75	15	100	250
120	Midway 2	10 Jun	0245	Lutz	75	15	100	250
121	Midway	10 Jun	0245	Lutz	75	15	100	250
122	Midway 1	10 Jun	0245	Lutz	75	15	100	250
123	Midway 1	10 Jun	0300	Lutz	75	15	100	250
124	Midway 1	10 Jun	0300	Lutz	75	15	100	250
125	Midway 1	10 Jun	0315	Lutz	75	15	100	250
126	Midway 2	10 Jun	0315	Lutz	75	15	100	250
127	Midway 2	10 Jun	0320	Lutz	75	15	100	250
128	Midway 2	10 Jun	0345	Lutz	75	15	100	250
129	Midway 2	10 Jun	0345	Lutz	75	15	100	250
130	Midway 2	10 Jun	0400	Lutz	75	15	100	250