

The Role of Honey Bees in Macadamia Nut (*Macadamia integrifolia* Maiden and Betche) Production in Hawaii¹

Gordon T. Shigeura, James Lee and James A. Silva²
University of Hawaii, Honolulu

Abstract. Honey bees from commercial apiaries placed in a macadamia nut orchard increased nut yields in 2 of 3 cultivars tested.

THE pollination activities of honey bees, *Apis mellifera* L., in the production of agricultural crops have been studied by many workers employing various experimental procedures. McGregor et al. (5) showed a significant increase in cotton lint and seed production due to bee activity in plastic screen cages. Hawthorne et al. (3) using colonies of honey bees in caged carrot plots showed seed production significantly increased over that of open pollinated plots. Weaver and Wheihing (12) demonstrated that seed production was inadequate in *Trifolium* plots when bees were excluded from caged plots. Sholdt and Mitchell (10) found wind and insects were the principal pollinating agents in coconut, wind being most effective under conditions of self pollination. Nishida (6) found that feral honey bees were the major pollinators of passion fruit, *Passiflora edulis* var. *flavicarpa*, in the Hilo area of Hawaii. On the other hand, Yamane and Nakasone (14) found that honey bees apparently were not attracted to blossoms of acerola, *Malpighia glabra* L.

Urata (11) using waxed tissue paper pollinating cylinders and basing conclusions on initial nut-set count on macadamia found partial self-incompatibility in the majority of the cultivars studied with a few clones being almost completely self-compatible. Shigeura (9) working with a feral bee population in a macadamia nut orchard found statistically significant differences in nut set of cultivars and a significant increase in nut set in cultivar 246 when planted adjacent to cultivar 508. This indicates a possible cross pollination effect.

The present study is an extension of the work previously reported (9) and its objective was to determine whether or not introduction of honey bees from commercial apiaries into an orchard area will increase macadamia flower pollination and thus increase nut set.

METHOD

The 3-year study was carried out from 1966 through 1968 in an orchard located at 100' elevation in an area of relatively unweathered aa lava with little organic matter accumulation. The mineral nutritional status of the soil was low and relatively uniform, but adequate fertilization resulted in good, uniform tree growth.

The 195 experimental trees, 9 years old in 1966, were rigidly selected for uniformity in leaf color, tree size, and branching habit to reduce yield variability due to these factors. These experimental trees were selected from a total of 1200 trees planted in blocks by cultivars. An unequal number of trees of each cultivar was available, therefore, data collected were from 100 trees of cultivar 333, 75 trees of cultivar 246, and 20 trees of cultivar 508.

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²Department of Horticulture, Department of Animal Science and Department of Agronomy and Soil Science, respectively.

The weekly average maximum temperature, usually at about 2 P.M., was between 74 and 81° F, and the weekly average minimum just before daybreak was between 61 and 67° F (Fig. 1). Yearly rainfall of 90 inches was adequate and, more often than not, rains during the night did not seem to hinder bee activity and pollination to any great extent. Tradewinds, very seldom exceeding 10 miles an hour, also did not appear to hinder bee activity.

Nut set data, corrected for tree-size by conversion to nuts/cm² of the cross sectional area of tree trunk 2 feet above ground, were collected by actual count of nuts in late July of each year after the premature June drop of nuts and just prior to the harvest season.

The nut count data collected in 1966 were considered the control in this study since no commercial honey bee hives were placed in the orchard and pollination depended entirely on feral bees. In 1967 and 1968, 20 honey bee hives were placed in the orchard each year so that no experimental tree was more than 200 feet away from the hives. Thus the bee population in the orchard was greatly increased. The data collected in these 2 years reflected the effects of commercial bees on pollination and nut set.

The use of 1966 as the control year and 1967 and 1968 as the treatment years requires justification since year and treatment effects are statistically confounded in the analysis. However, the authors feel this procedure is justified in this study for the following reasons:

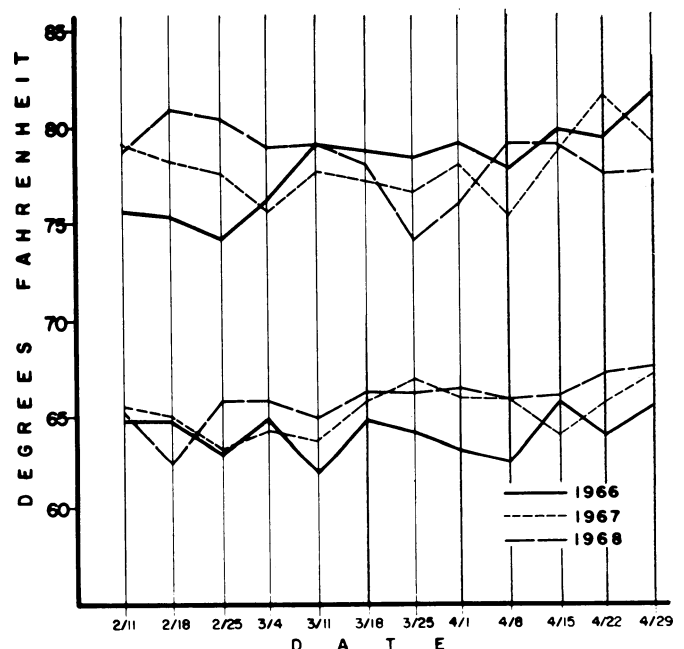


Fig. 1. Maximum and minimum air temperatures during pollination periods.

- 1). The temperature conditions were essentially similar during the 3 experimental years (Fig. 1). The minimum temperatures, apparently more important than maximum temperatures, prevalent in the experimental area in all 3 years were decidedly above the minimum necessary for bee activity reported by Phillips (7), Woodrow (13), Brittain (2), Lindauer (4), and Richardson and Alvarez (8).
- 2). Blooming period of the 3 cultivars was essentially the same in all three years.
- 3). The experimental procedures were carried out in a manner to reduce errors inherent in the experimental material and in the collection and expression of data.

RESULTS AND DISCUSSION

Mean nut set data for the 3 experimental years and the number of trees of each cultivar are given in Table 1. Nut set during the two pollination years, 1967 and

Table 1. Mean nut set per tree expressed as number of nuts/cm² of cross sectional area of tree trunk and number of trees by cultivar.

Cultivar	No. of trees	Nuts/cm ² *			1967-1968 Means
		1966	1967	1968	
333.....	100	7.99b	9.08a	8.60a	8.84
246.....	75	5.02b	8.52a	8.48a	8.50
508.....	20	11.53a	11.20a	11.92a	11.56
All cultivars means...		8.18b	9.08a	8.90a	

*Means in the same row followed by the same letter do not differ significantly at the 5% level.

1968, was found not to be significantly different by use of the "t" test for each of the 3 cultivars and for all the cultivars combined. The lack of significant differences between the two pollination years lends support to the assumption that confounding year and treatment effects was justified. In view of this uniformity in nut production, the data for 1967 and 1968 were combined and compared to the control values obtained in 1966. An analysis of variance for unequal subclass numbers (15) was made (Table 2). A highly significant difference in nut production was found between the control and the pollination years and also between cultivars. The highly significant treatment × cultivar interaction calls for further examination of the data. Means in Table 1 suggest that this interaction is due to the relatively high yields of cultivars 333 and 246 in 1967 and 1968 compared to their yields in 1966 while cultivar 508 had essentially the same yield in all three years. This suggests that nut set in cultivars 333 and 246 is dependent on bee population level in the orchard while nut set in cultivar 508 is essentially unaffected by bee population level. This response pattern may be due to cultivars 333 and 246 being relatively self-incompatible while cultivar 508 is relatively self-compatible. Data to sup-

Table 2. Analysis of variance for nut set data.

Source of variation	d.f.	Mean square
Pollination vs. control.....	1	500*
Cultivar.....	2	510**
Treatment × cultivar.....	2	121**
Rows in treatment (experimental error).....	111	11**
Trees in rows in treatment (sampling error).....	468	6.6

**P<0.005.

port this hypothesis are not presently available for cultivars 333 and 508, but preliminary data for cultivar 246 indicate that this cultivar is relatively self-incompatible³ (9). The nearly identical yields of cultivar 508, which was unaffected by bee population level, in all three years (Table 1), further supports the assumption that year effects on nut set were unimportant. Thus, the yield differential of cultivars 333 and 246 in 1966 vs. 1967-1968 may be attributed primarily to the presence or absence of commercial bees in the orchard. The highly significant Rows in Treatment term (experimental error) suggest that there was greater variation between rows than among trees within rows. This may be due to some soil or environmental factor causing variation in yield between rows.

A test of homogeneity of variance (1) in nut production was performed between the control and bee pollination years for each cultivar separately and for all cultivars combined (Table 3). It is apparent from these

Table 3. Test of homogeneity of variance of macadamia nut production among trees between control and bee pollination years.

Class	Degrees of freedom	Mean square	Individual cultivar (F)	All classes (χ^2) ^a
Cultivar 333				
Control.....	99	4.26		
Bee pollination....	199	9.06	2.1**	19.9**
Cultivar 246				
Control.....	74	5.84		
Bee pollination....	149	8.42	1.4**	
Cultivar 508				
Control.....	19	6.42		
Bee pollination....	39	6.87	1.1 ^{ns}	

^aDegrees of freedom = 5.

** (P<0.01).

results that the variability in nut production was significantly greater in the pollination years than in the control years for cultivars 333 and 246. On the other hand, cultivar 508 showed no difference in variability in the 2 sets of years. The increase in variability in nut production among trees in cultivars 333 and 246 in the pollination years may have been due to a variable pattern of effective bee activity, or due to conditions not now apparent. Cultivar 508, which did not respond to bee pollination, showed no increase in variability among trees in the pollination years, again supporting the assumption that confounding year and treatment effects was justified in this test.

³P. J. Ito, in personal communication.

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Effects of Cycocel, Moisture Stress and Pinching on Growth and Flowering of F₁ Hybrid Geraniums (*Pelargonium x hortorum* Bailey)¹

John W. White²

The Pennsylvania State University, University Park

Abstract. Cycocel applied as a 5000 ppm soil drench 31 days after sowing reduced height 8 to 10 cm and caused 8 to 16 days earlier flowering of F₁ geranium 'Carefree Scarlet' when compared with plants which had not been treated with Cycocel. Manually irrigated plants were shorter, flowered earlier, and were more compact, as measured by fresh weight, than automatically irrigated plants for this Cycocel treatment. Pinched plants were short and well branched but so much delayed in flowering that this method of height reduction would not be acceptable for commercial use.

OUR objective was to produce a short, compact, well-branched, flowering geranium in a four-inch pot in the shortest possible time. G. M. Campbell³ suggested to Dr. Richard Craig the possibility of using Cycocel⁴ (CCC) for height retardation and earlier flowering of the geranium cultivar 'Nittany Lion Red'. Height retardation of several F₁ hybrid cultivars treated with Cycocel was reported by White in a Geo. J. Ball, Inc. staff report (1) and by Holcomb and White (7). These findings were confirmed by the Geo. J. Ball, Inc. staff, and by Boodley, Payne, Larson, and several commercial growers (2).

Lindstrom (9) reported considerable height reduction but no delay in flowering of seedlings sown November 28 and pinched March 1. Wilkins and Widmer (14) found that plants sown December 15 and January 15 and pinched were delayed in flowering. Craig and Walker (4) showed that flowering of seedling geraniums was delayed by 21 to 48 days when the terminals were removed (pinched).

White and Wick (13) demonstrated that several inbred geranium lines were taller, heavier, and flowered earlier as fertility levels were increased from none to 500 grams of Osmocote⁵ 14-14-14 per bushel of soil mix. According to Holcomb and White (8) internode elongation of poinsettias was retarded by allowing plants to wilt—creating a moisture stress before irrigating.

Halevy (6) found that growth retardant-treated plants were more drought resistant than control plants. Plaut,

et al. (11) reported that Cycocel reduced transpiration rate per unit leaf area. Gohlke and Tolbert (5) showed that Cycocel treated plants required less water than control plants.

MATERIALS AND METHODS

Seeds of 'Carefree Scarlet', 'Carefree White', 'New Era Scarlet', and 'New Era Deep Scarlet' were shown in Jiffy 7⁶ peat pots on February 1, 1968. Light was supplied at 1000 ft candles for 16 hours per day by a combination of warm white, cool white fluorescent and incandescent lamps from February 3 to February 22. Carbon dioxide levels were 1000 to 1300 ppm from February 14 to February 22. Seedlings were transplanted on February 28 into 4 inch clay pots. They were grown in a 50% soil, 25% sphagnum peat, and 25% perlite medium to which had been added 4 oz of Osmocote⁵ 14-14-14, 4 oz dolomitic limestone, 4 oz pulverized limestone, and 6 oz 20% superphosphate per 1.25 cu. ft. of medium. One-half of the plants were irrigated and fertilized through a Chapin⁷ small-bore, plastic irrigation system which was actuated by a time clock opening a solenoid valve. A fertilizer solution containing 150 ppm N, supplied from 15-15-15, was applied with each irrigation from February 22 to March 19; the concn was reduced to 100 ppm N from March 20 to June 4. One and one-half oz of solution was applied daily to each pot from February 22 to February 27, 2 oz daily until March 5, 3 oz daily until March 24, 5 oz daily until April 15, 5 oz twice per day until April 29 and 7 oz three times per day until harvest, June 4.

The other half of the plants were irrigated manually with a hose as needed. These plants were irrigated daily except on days with a thick cloud cover for most

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²Assistant Professor, Department of Horticulture.

³Campbell, G. M. 1966. Personal correspondence from Univ. of Tennessee with R. Craig. July 19, 1966.

⁴Cycocel (2-chloroethyl trimethyl ammonium chloride) supplied by American Cyanamid Company.

⁵Osmocote—a slow-release, resin-encapsulated fertilizer supplied by Sierra Chemical Company, 37650 Sycamore St., Newark, California.

⁶Jiffy 7—expandable peat pots made in Norway and distributed by Jiffy Pot Corporation of America.

⁷Chapin Watermatics Inc., 368 N. Colorado Ave., Watertown, N. Y.