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ROLE AND EFFECTIVENESS OF *Elaeidobius kamerunicus, Thrips hawaiiensis* AND *Pyroderces sp.* IN POLLINATION OF MATURE OIL PALM IN PENINSULAR MALAYSIA

Keywords: *Elaeidobius kamerunicus; Thrips hawaiiensis; Pyroderces* sp.; *Elaeis guineensis*; oil palm; insect pollination; pollinator force.

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A study on the pollination of seven-year old palms in a plantation in Selangor, Malaysia was made between 1983 and 1987 to determine the relative roles of three types of pollinators, Elaeidobius kamerunicus *(Coleoptera: Curculionidae),* Thrips hawaiiensis *(Thysanoptera) and* Pyroderces sp. *(Lepidoptera: Cosmopterygidae) as well as to examine their effects on oil palm bunches.*

Samples were collected monthly from anthesising male inflorescences to provide information on the actual and potential populations of pollinators. The activities of pollinators on anthesising female inflorescences were measured by pan-trapping. All anthesising female inflorescences at the time of population sampling were marked and the fruit bunches which formed were later harvested for analysis.

The weevil Elaeidobius kamerunicus *had not displaced* T. hawaiiensis *and* Pyroderces sp. *as was evident from their co-existence. Their pollination activities had sustained the fruit set and fruit to bunch ratios above 60 per cent. Nevertheless,* E. kamerunicus *had become the most important pollinator, even during the wet season. During dry periods,* T. hawaiiensis *played a more important role than* E. kamerunicus *in pollination.*

The critical threshold of weevil numbers required for pollination could not be determined because the fruit set had not declined to low levels. Furthermore, a high population was not necessarily beneficial because it resulted in the

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lowering of fruit set.

During the period after the introduction of the weevil into Malaysia, there was no significant change on bunch parameters, with one exception: oil to bunch ratio showed a marked depression in 1985, three years after the introduction of the weevil. Three explanations have been suggested, the most important of which was related to a marked increase in the moisture content of the fruit bunches.

INTRODUCTION

The weevil *Elaeidobius kamerunicus* Faust. was introduced into Malaysia in early 1982 to overcome the inconsistencies of oil palm pollination (Syed *et al.*, 1982). With the weevil carrying out the role of pollination, the previous practice of manually assisted pollination has been discontinued from oil palm management in most parts of the country. A long-term monitoring study on the populations of the weevil at 22 field sites throughout Malaysia between 1983 and 1986 indicated that in most localities the weevil population had stabilized: the stable levels in the West and East coast areas of Peninsular Malaysia averaged 26.1 and 29.0 adult weevils per spikelet respectively and those in Sabah and Sarawak averaged 31.5 adults per spikelet. That study confirmed the long-term establishment of the weevil (Basri *et al.*, 1987).

Kevan *et al.*(1986) suggested the idea of quantifying the weevil population as a pollinator force, which was a measure of the total number of adults per unit area. They also introduced the idea of a critical pollinator force, which was the minimum level of population required for adequate pollination. Some efforts to quantify these concepts were reported by Syed and Salleh (1987), Dhileepan (1994) and Donough *et al.* (1996). Syed and Salleh (1987) estimated that 3000 weevils per female inflorescence need to be present for a pollination of 70% or more. They suggested the critical threshold as 700 weevils per female inflorescence. However, their results were not conclusive because the weevil populations had always been above the critical level. Dhileepan (1994) found that the potential pollinator force was always above 5000 weevils per hectare per day and gave no estimate on the critical level. Donough *et al.* (1996) believed that at least 20 000 weevils per hectare would be required for a fruit set of 55%.

An important factor in assessing the pollination efficiency of the weevil is the fruit set subsequently resulting on the bunches. Some information is available for Malaysia. Prior to the introduction of the weevil, the average fruit set was in the region of 49% to 52% (Syed *et al.*, 1982). After the introduction, Basri *et al.* (1987) reported that the fruit set attributed to a weevil population in Selangor ranged from 62.3% to 89.6 per cent. In Lower Perak, the average fruit set brought about by another weevil population was 67% (Tan, 1982). Because of the satisfactory performance of the weevil, no attempt has been made, prior to the work reported here, to study the relationship between weevil population and pollination efficiency in Peninsular Malaysia. Also there has been no information on the relative abundance and performance of the local pollinator, *Thrips hawaiiensis,* in the post-weevil era. The objective of this paper is to shed more light on these two aspects of pollination. We also report some information on the activities of *Pyroderces* sp. in relation to the other pollinators because its role in pollination has already been noted. (Tan and Basri, 1985).

Because the introduced pollinator, *E. kamerunicus*, shares a common food resource (male inflorescences) with the other two pollinators, a question arises as to whether interspecific competition occurs between the three. Earlier, Kang and Zam (1982) expressed concern over the possible displacement of the local pollinators by *E. kamerunicus*. The general principles of the subject were discussed by Price (1984), who stated that competing species could co-exist indefinitely in a number of ways, including differing patterns of resource availability, creation of new empty habitats for colonization through natural catastrophes, and the occurrence of several generations in a year, whereby each generation may be exposed to different environmental conditions. Although interspecific competition amongst the pollinators has not been examined specifically in the current study, some comments are made as they are pertinent to this subject.

MATERIALS AND METHODS

The ten-hectare study area was located in the plantation of Universiti Putra Malaysia (UPM) at Serdang, Selangor where the palms were planted in 1976. The study was made between October 1983 and December 1987. Ten per cent of the palms were selected permanently by marking every tenth one, giving a total of nearly 150 palms for sampling. The sampling of anthesising male inflorescences was conducted in the middle of each month. During the day of sampling, the total number of anthesising male and female inflorescences on all marked palms was determined and the stage of anthesis for male inflorescences was recorded as 25%, 50%, 75%, or full bloom. From the total number of anthesising male inflorescences, only 10 inflorescences rated between 25% to 75% were randomly sampled for study. In instances where the number of anthesising male inflorescences was less than 10, sampling was confined to the number available.

From each of the sampled inflorescences, three spikelets were taken from the top, three from the middle and three from the bottom of each inflorescence, then the number of thrips and adult weevils on each spikelet was determined. (Since the weevils became more active towards midday, the sampling was preferably completed in the early morning). From these data, the mean weevil and thrips densities were determined.

All anthesising female flowers at the time of census were marked and the fruit bunches derived from them were harvested about 4-7 months later, for the determination of fruit set. This involved weighing each bunch and, chopping it into individual spikelets, and weighing the stalk. All fruits in the spikelets were categorized as parthenocarpic or fertile (that is, with fruit set) and the numbers were recorded. The percentage of flowers that set fruit in each bunch and the average for each month was determined.

From all the anthesising male inflorescences that were sampled, the spikelets were counted and the number recorded. The average number of spikelets per male inflorescence was then calculated. The pollinator force per hectare (of weevils) was a product of mean weevil density, mean number of spikelets and the number of anthesising male inflorescences.

A week after sampling spikelets from anthesising male inflorescences, nine spikelets were taken from the same inflorescences, air-dried for two days, and then placed in individual containers. Within two weeks, the weevil progenies emerged: they were counted and the average number was determined for each inflorescence. The number of anthesising female flowers amongst the marked palms during this time was also determined. The potential pollinator force was a product of mean number of weevils emerging per spikelet, mean number of spikelets per male inflorescence, and mean number of anthesising male inflorescences per hectare (Kevan *et al.*, 1986).

The activities of both thrips and weevils within anthesising female inflorescences were determined by using pan traps at the time of full emergence of the weevil progeny, that is about three weeks after the monthly census. Five to ten anthesising female inflorescences were used depending on their availability. A pan trap (which consisted of a Petri dish 9 cm in diameter containing a layer of emulsifiable blend of oil fractions - 'Tenac sticker' from Shell) was placed about 15 cm above each female inflorescence early in the morning. The traps were replaced at the end of the day and the number of weevils and thrips captured after one day was counted. Captures of *Pyroderces* were recorded the following morning. Trappings for activity were continued for up to four days depending on the duration of anthesis of the female flowers.

All anthesising female inflorescences at the time of complete emergence of the weevil progencies were also marked and later harvested for the determination of fruit set as described earlier. All harvested bunches were subjected to normal bunch analysis according to the method described by Rao *et al.* (1983).

RESULTS

I. Density of pollinators.

The variation in population densities of weevils and thrips from August 1984 to August 1987 and its effects on oil palm pollination is shown in *Figure 1*. The overall mean of weevil population density was 20.5 weevils/spikelet, with a range of 5.6 to 44.7. Lower levels were recorded in June, August and September 1985 than in other months. A significant correlation was found between weevil density and the number of anthesising female inflorescences per hectare at census time (df=44; r=0.466; $p<0.01$) (*Figure 2*). No relationship could be found between weevil density and the number of anthesising male inflorescences.

There were greater fluctuations of the thrips population and generally high levels were recorded in July, August and September in three successive years (*Figure 1*). The overall average was 47.6 thrips/spikelet, with a range of 3.2 to 211.2. Significant negative correlations were found between density of thrips and the number of anthesising male inflorescences (df=33; r=-0.445; $p<0.05$) (*Figure 3*) and between thrips density and rainfali (df=33; r=-0.359; $p<0.05$) (*Figure 4*).

Three types of pollinators, *E. kamerunicus*, *T. hawaiiensis* and *Pyroderces* sp. visited anthesising female inflorescences (*Figure 5*). Thrips exhibited higher activity during the middle of the year and lower activity around the end and beginning of the year. The weevils were generally active throughout the year but with slightly more activity towards the end and beginning of the year. Significant correlations were found between weevil activity and fruit set (df=33; r=0.460; $p<0.01$) (*Figure* 6), and also between weevil activity and rainfall (df=33; r=0.339; $p<0.05$) (*Figure 7*). No significant correlation could be found between the

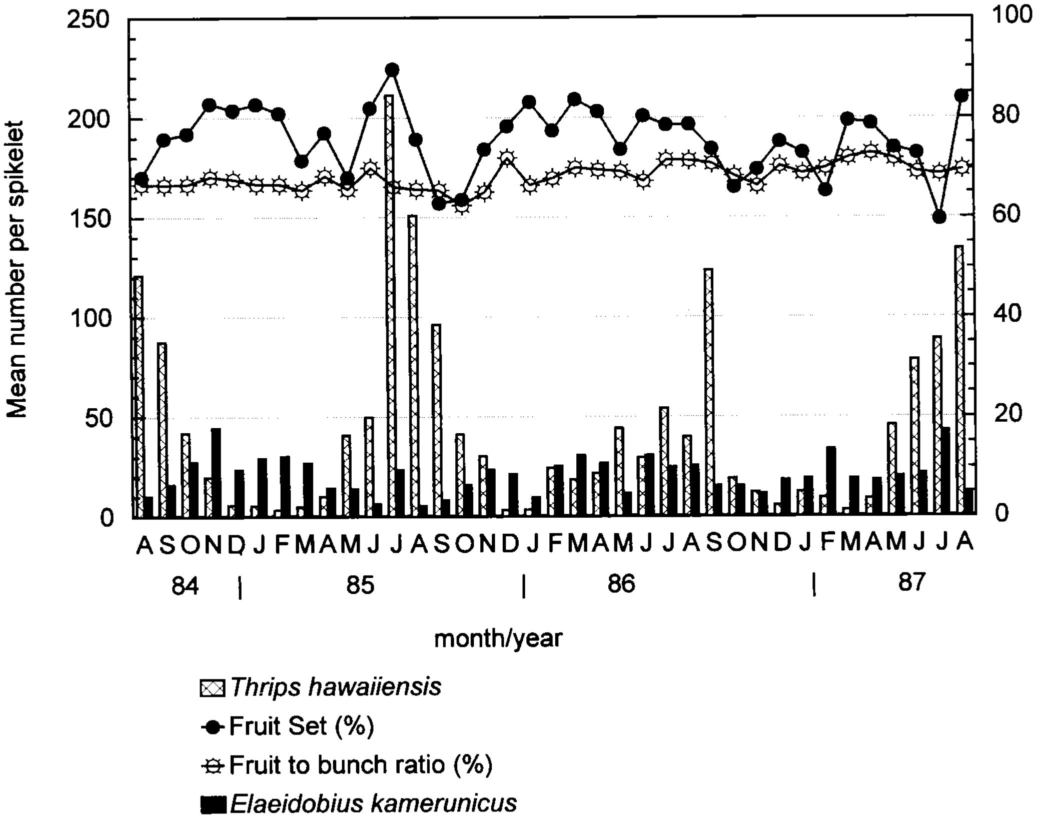


Figure 1. Fluctuations in population densities of Elaeidobius kamerunicus *and* Thrips hawaiiensis *at UPM plantation in Serdang*

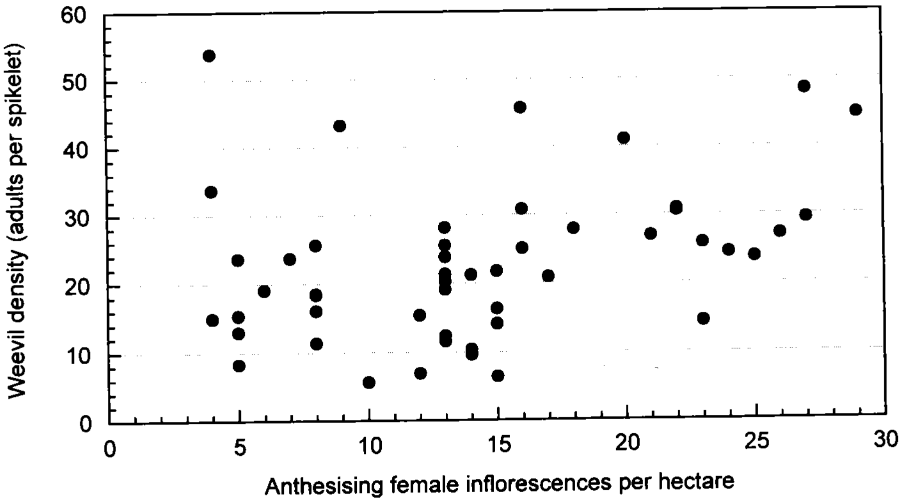


Figure 2. Relationship between weevil density and number of anthesising female inflorescences at time of census

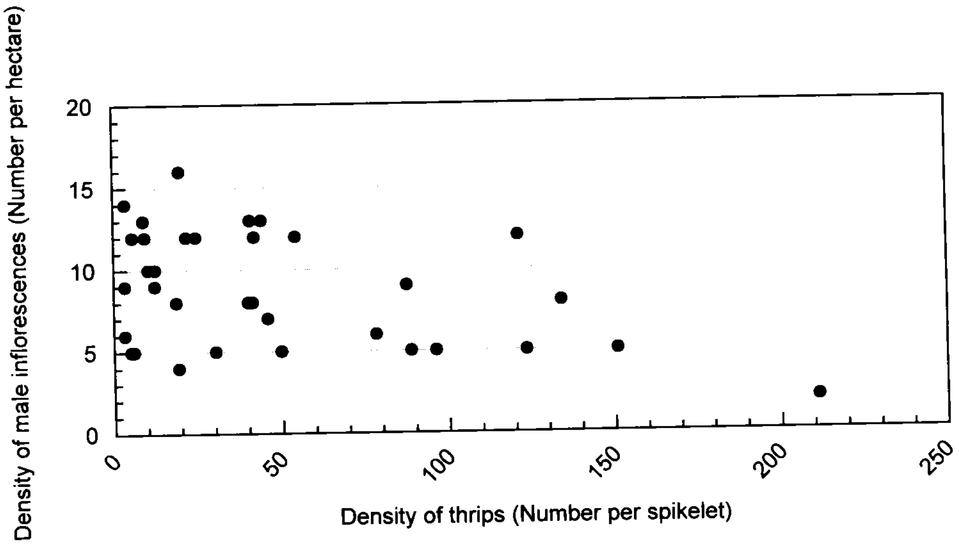


Figure 3. Relationship between density of thrips and density of male inflorescences at UPM plantation in Serdang

activities of thrips and *Pyroderces*, and other factors such as number of anthesising male inflorescences or rainfall.

The average monthly rainfall in the study area was 178.4 mm, with a minimum of 21.1 and a maximum of 466.3 mm/month. June, July and August were generally drier, that is with less than 100 mm/month (*Figure 8*).

II. Pollinator force.

The potential pollinator force averaged 154 422 weevils per hectare, with a range of 13 832 to 632 835, while the actual pollinator force averaged 47 558 weevils per hectare with a range of 4711 to 141 577. No significant correlation could be found between the actual pollinator force per hectare and fruit set (df=46; r=0.100; p>0.05). The fluctuations of these pollinator forces expressed in terms of numbers of weevils per anthesising female inflorescence are shown in *Figure 9*. The average actual pollinator force was 4134 weevils per female inflorescence, with a minimum of 347 and a maximum of 22 420 weevils. Both fruit set and

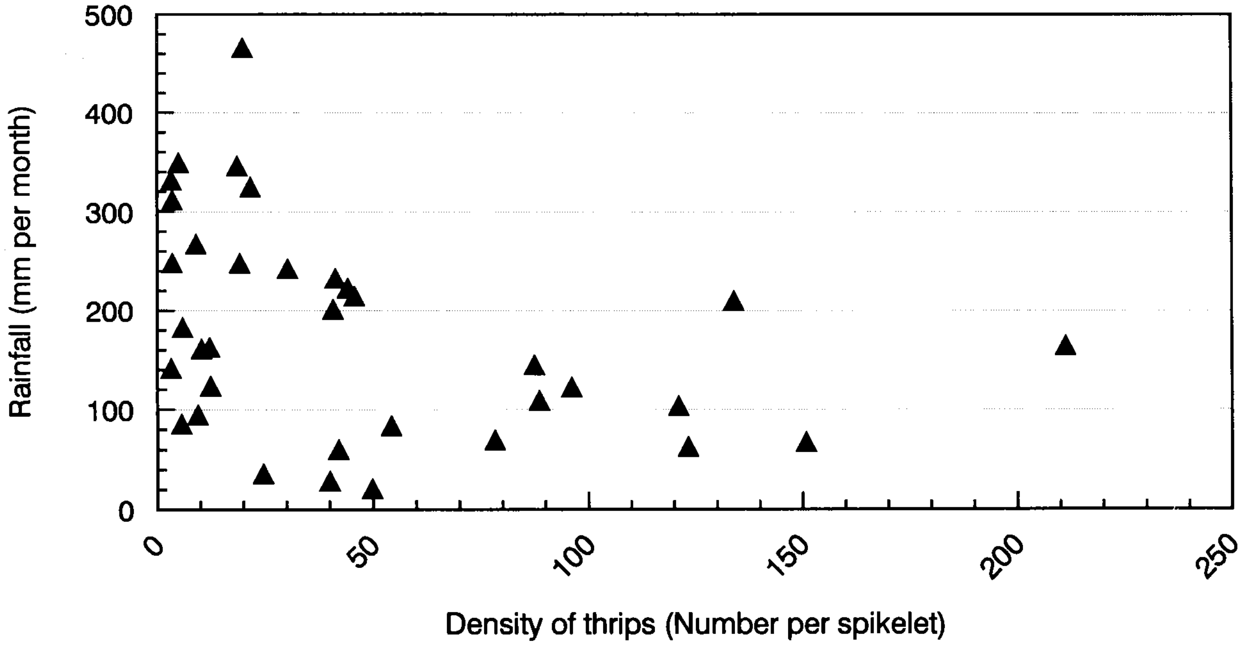


Figure 4. Relationship between density of thrips and rainfall at UPM plantation in Serdang

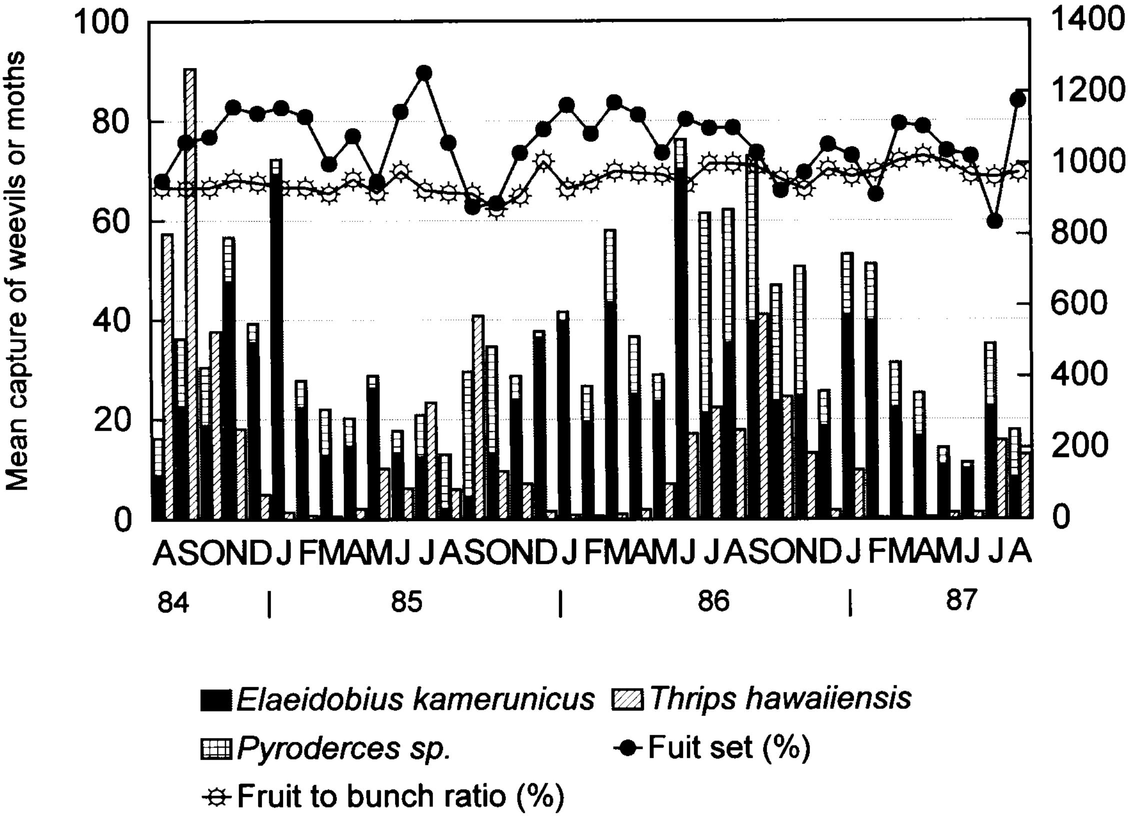


Figure 5. Activity of oil palm pollinators above anthesising female inflorescences at UPM plantation in Serdang

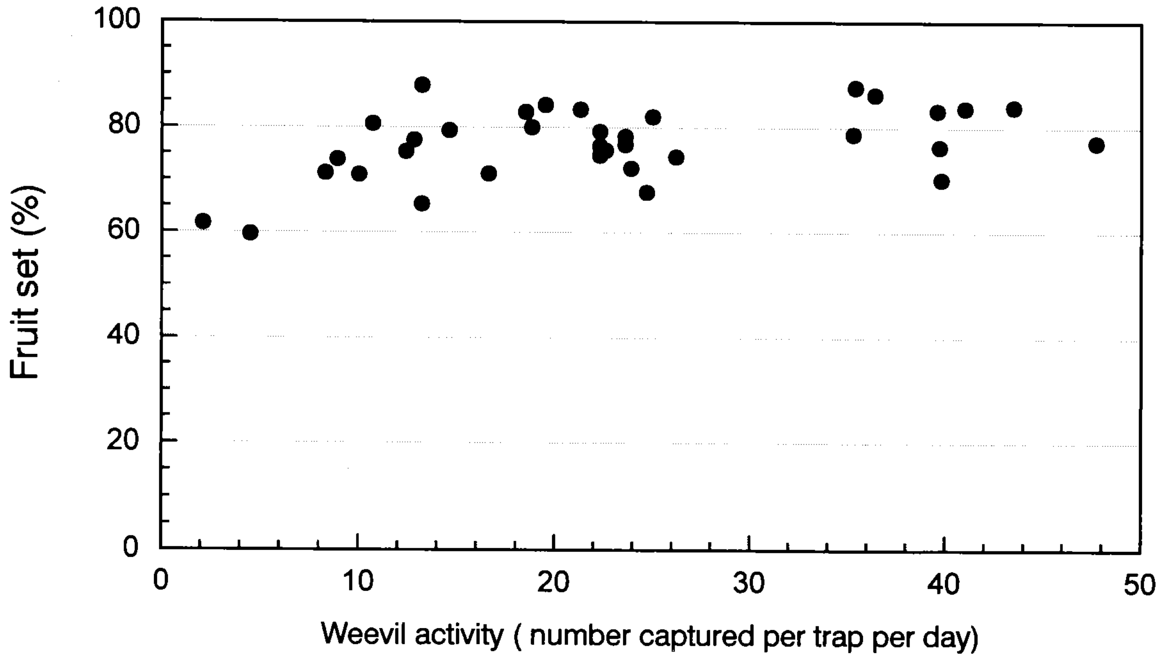


Figure 6. Relationship between weevil activity and fruit set at UPM plantation in Serdang

the ratio of fruit to bunch were always above 60 % even when the actual pollinator force was at its lowest. A significant correlation was found between actual pollinator force per female inflorescence and fruit set (df=44; r=-0.321; p<0.05) (*Figure 10*). No significant correlation was found between potential pollinator force per female inflorescence and fruit set (df=44; r=0.015; p>0.05).

In the case of thrips, the actual pollinator force averaged 7446 thrips per female inflorescence, with a minimum of 240 and a maximum of 26 770 per anthesising female inflorescence. No relationship could be found between thrips pollinator force and fruit set.

III. Effects on oil palm bunches

The fruit set levels were generally above 60% and a 20% increase in fruit set was accompanied by only a slight increase in fruit to bunch ratio, which varied from about 60% to 70% (*Figure 11*). There was a significant correlation between fruit set and fruit to bunch ratios (df=44; r=0.389; p<0.01) (*Figure 11*).

No significant correlation was found between the oil to bunch and kernel to bunch ratios (df=56; r=0.243; p>0.05), but significant correlations were found between oil to bunch ratio and three other bunch parameters: moisture content (df=56; r=-0.864; p<0.01), dry mesocarp to wet mesocarp ratio (df=56; r=0.884; p<0.01) and oil to wet mesocarp ratio (df=56; r=0.589; p<0.01) (*Figure 12a,b,c*).

There was a slight increase in oil to bunch ratio between 1983 to 1987 in the study area (*Figure 13*). However, between February and October 1985 a severe depression of about 7% in oil to bunch ratio occurred and this was accompanied by a similar depression in the oil to wet mesocarp and dry mesocarp to wet mesocarp ratios, but by an upsurge in moisture content. There was also some corresponding decline for kernel to bunch ratio but the trend was less obvious (*Figure 13a*).

The mean bunch weight showed an increasing trend over time, consistent with the effects of palm age: older palms produce fewer but bigger bunches, which results in an increase in mean bunch weight (N. Rajanaidu, personal communication). In contrast, although fluctuating, the trends for shell to fruit ratio, mean fruit weight and kernel to fruit ratio did not show any general increase or decrease over time (*Figure 13b*).

DISCUSSION

The presence of all three pollinators as observed in this study suggests that they were co-existing in the oil palm ecosystem in

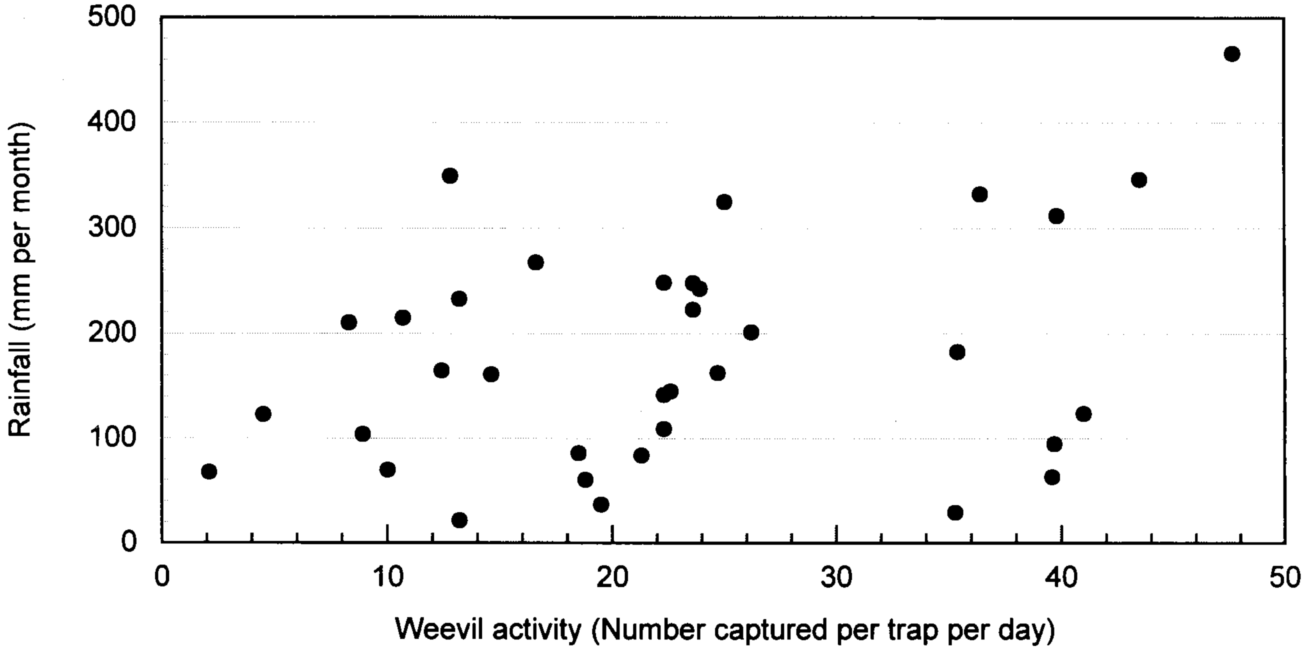


Figure 7. Relationship between weevil activity and rainfall at UPM plantation in Serdang

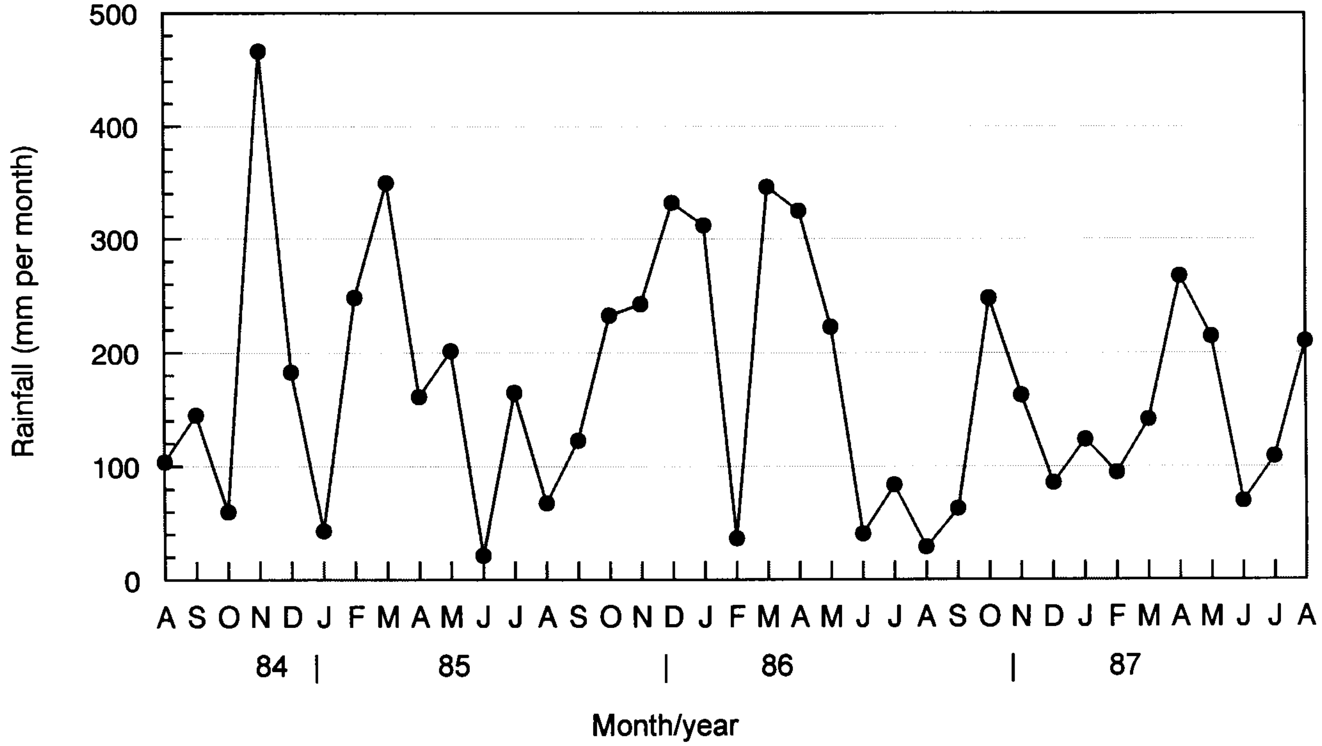


Figure 8. Variations in rainfall at UPM plantation in Serdang

spite of having to compete for a common food resource. Co-existence had possibly prevailed because of a difference in habitat requirements for pupation; *T. hawaiiensis* pupates in the soil but both *E. kamerunicus* and *Pyroderces* pupate in post- anthesis male spikelets (Jagoe, 1934; Syed, 1981). Another factor could be rainfall, in that *T. hawaiiensis* thrives better than *E. kamerunicus* during the dry months as was evident in this study during June, August and September 1985. During this period, the thrips complemented the reduced pollinating activities of the weevil. Another factor could be the difference in time of activity; thrips and weevils are active throughout the day (Syed, 1979) but the *Pyroderces* is active for only about two to three hours beginning half an hour after sunset. (Tan and Basri 1985).

In contrast, in Costa Rica and Honduras, when *E. kamerunicus* was introduced, it completely displaced another pollinator *E. subvittatus* (introduced earlier) within a few years (Chinchilla and Richardson, 1991).

The weevil population remained satisfactory throughout the period of this study, as evidenced by the level of the fruit to bunch ratio, which was always above 60%, the minimum considered adequate to indicate pollination (Hardon, 1973). The corresponding levels of fruit set were also above 60%, indicating that there was sufficient pollination activity to sustain the high level of fruit to bunch ratio. Because of the satisfactory activity of the weevil and the other pollinators, the minimum level of pollination (that is, in terms of fruit set) to effect a 60% fruit to bunch ratio could not be determined from this study. Some information can perhaps be deduced from other studies: Tan (1982) reported that in100 bunches which had undergone assisted (manual) pollination, the average fruit set and fruit to bunch ratio were 49% and 54% respectively. From another set of 160 bunches which were weevil-pollinated, the corresponding values were 67% and 62%. This set of data might suggest that a fruit set lower than 50% could affect the fruit to bunch ratio. Nevertheless, in another report (Hardon, 1973), a much lower level of fruit set (42.1%) produced a fruit to bunch ratio of 68%. It appears that more information is required to determine the minimum level of fruit set for adequate bunch development in terms of fruit to bunch ratio. It should also be stated that the level of fruit to bunch ratio obtained in the current study is comparable to that observed in a study of pollination in Cameroun, where it was about 65% (Syed, 1981).

To effect adequate fruit set, a sufficient weevil population needs to be present. Syed and Salleh (1987) suggested a critical threshold of 700 weevils per female inflorescence for this, but in the current study, a level as low as 347 weevils per inflorescence brought about a satisfactory fruit set of 82%. This suggests that the critical threshold could be lower than the value suggested by Syed and Salleh (1987). The present study could not establish the threshold because instances of low fruit set were not encountered.

The positive correlation observed between weevil density and the number of anthesising female inflorescences but not with the number of male inflorescences suggests that the female inflorescences have a greater influence on the activity of the weevils than the males. Thus, the higher the number of female inflorescences, the higher the density of weevils on male inflorescences, which suggests that the chance of weevils finding female inflorescences would be reduced. The effect may also be associated with a greater tendency of the weevils to return to male flowers to collect more pollen but subsequently being unable to locate all anthesising female inflorescences. This explanation appears to be in agreement with the negative correlation between actual pollinator force per female inflorescence and fruit set, found in this study. It seems that the higher the pollinator force per female infloresecence, the greater the chance of weevils not being able to locate female inflorescences because of confusion and competition, resulting in slightly reduced fruit set. This can be substantiated by *Figure 10*, from which it can be seen that pollinator forces of 22 410 weevils and 347 weevils per female inflorescence resulted in fruit set of 65.2% (sex ratio of inflorescence 1:3) and 81.9% (sex ratio 3:1) respectively. A similar phenomenon has been reported by Syed and Salleh (1987) and Dhileepan (1992, 1994). Dhileepan (1992) reported that the pollination

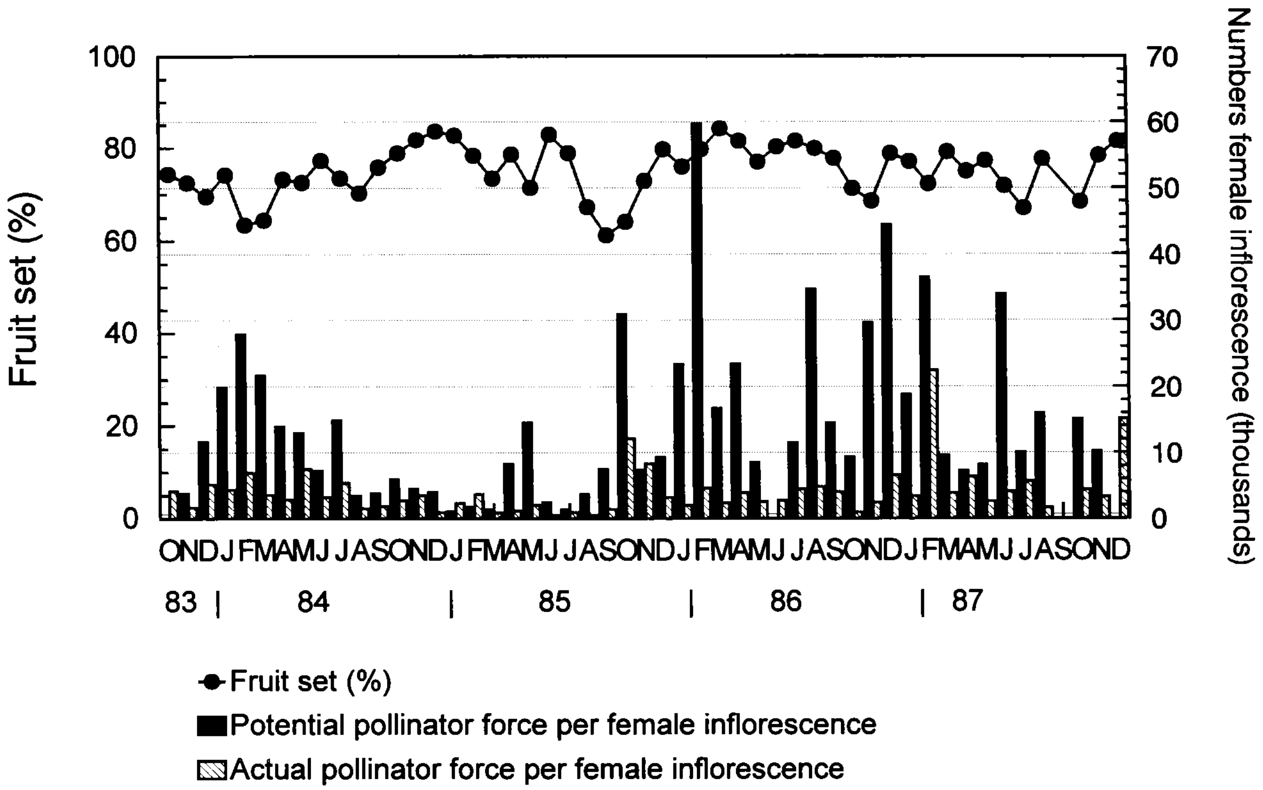


Figure 9. Relationship between pollinators force and fruit set at UPM plantation in Serdang

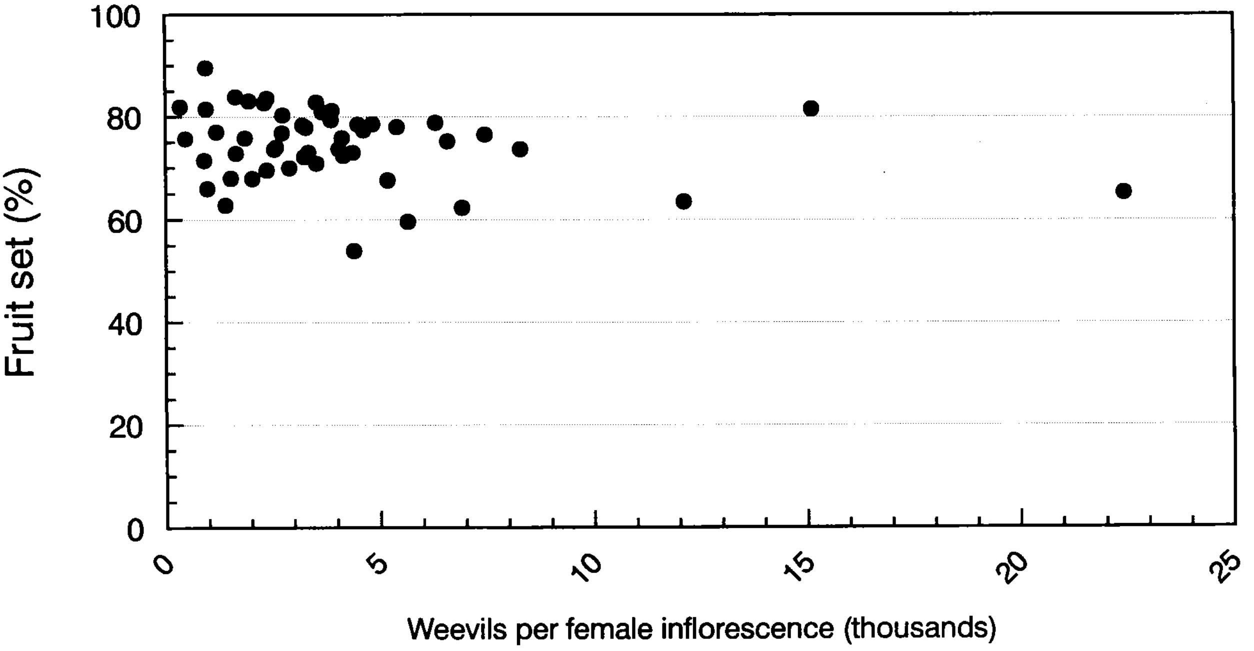


Figure 10. Relationship between fruit set and weevil population at UPM plantation in Serdang

efficiency of the weevil was greater when the weevil population per spikelet was very low (18.7 weevils/spikelet) resulting in good fruit set (84.9%). He added that in contrast, higher weevil population (99.2 weevils/spikelet) resulted in reduced pollinating efficiency (72.9%, fruit set), presumably associated with intra-specific competition for the pollen resource.

Donough *et al.* (1996) believed that 20 000 to 80 000 weevils per hectare would be required to effect a fruit set of 55 per cent. Our minimum value was much lower (4711 weevils per hectare), yet the fruit set was more than 60 per cent. Dhileepan (1994) reported results similar to ours, in which about 7000 weevils per hectare resulted in 60% fruit set. As mentioned earlier, a very high pollinator force could reduce fruit set. Thus, the minimum level of pollinator force suggested by Donough *et al.* (1996) was probably on the high side. It should also be noted that Syed and Salleh (1987) were not in favour of the population per hectare as a criterion for measuring pollination efficiency because in two out of three examples of very low fruit set, their population per hectare was quite high.

The negative correlation between density of thrips and density of male inflorescences suggests that the population of thrips gets dispersed easily as more male inflorescences become available. However, no significant relationship could be found between thrips and fruit set, suggesting that their activities are masked by those of the weevils because of the dominance of the latter. Nevertheless, the contribution of the thrips to complement the pollinating activities of the weevil, particularly during periods of low rainfall, should be recognized (*Figure 5*). Between June and September 1985, the average pan-trap captures (per trap per day) were 32.2 adult weevils and 267.4 thrips. Taking into account the sex-ratio of the weevil and the capacity of each pollinator to carry pollen grains (*i.e.* 235 and 56 pollen grains by male and female *E. kamerunicus* respectively, and 4.8 pollen grains by *T. hawaiiensis* (Syed 1980)), the average transfers of pollen grains by the weevils and the thrips would have been 911.7 and 1282.6 grains respectively. In another instance, in August 1984, the average captures were 8.9 weevils and 1266.8 thrips, which translates into 874 and 6081 pollen grains respectively. These figures illustrate that during the dry season, *T. hawaiiensis* could perform much better pollinating activity than *E. kamerunicus*. Another favourable characteristic of the thrips is that they enter deep into and stay within

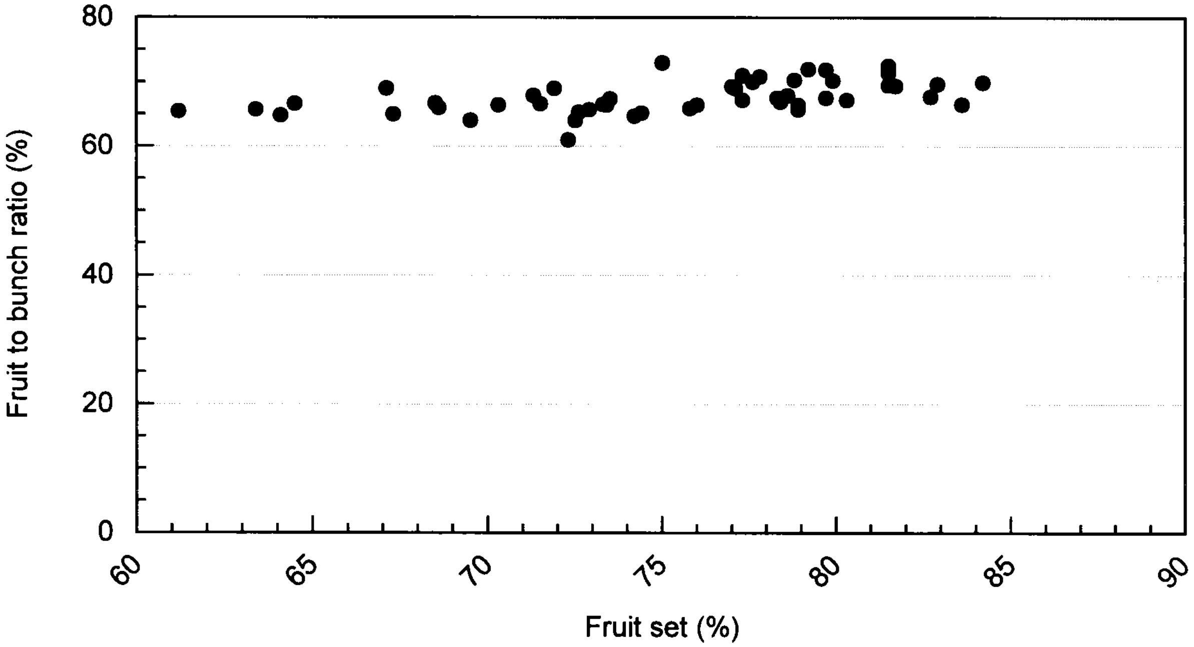
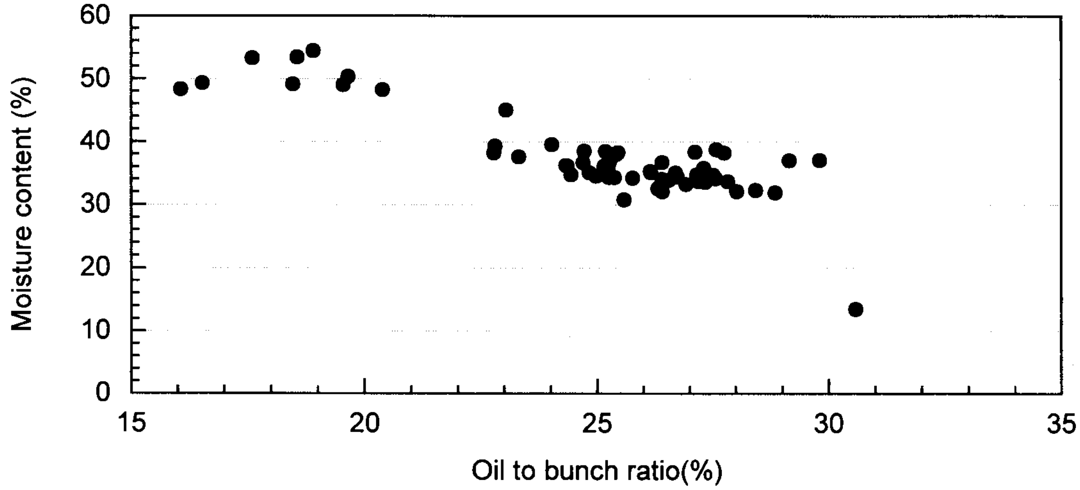
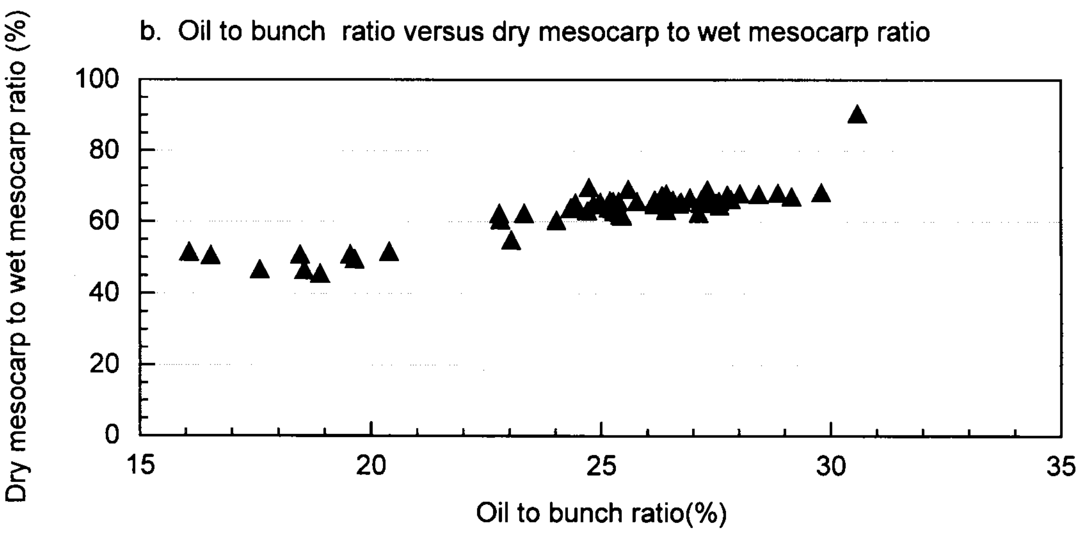


Figure 11. Relationship between fruit set and fruit to bunch ratio at UPM plantation in Serdang

a. Oil to bunch ratio versus moisture content



b. Oil to bunch ratio versus dry mesocarp to wet mesocarp ratio



c. Oil to bunch ratio versus oil to wet mesocarp ratio

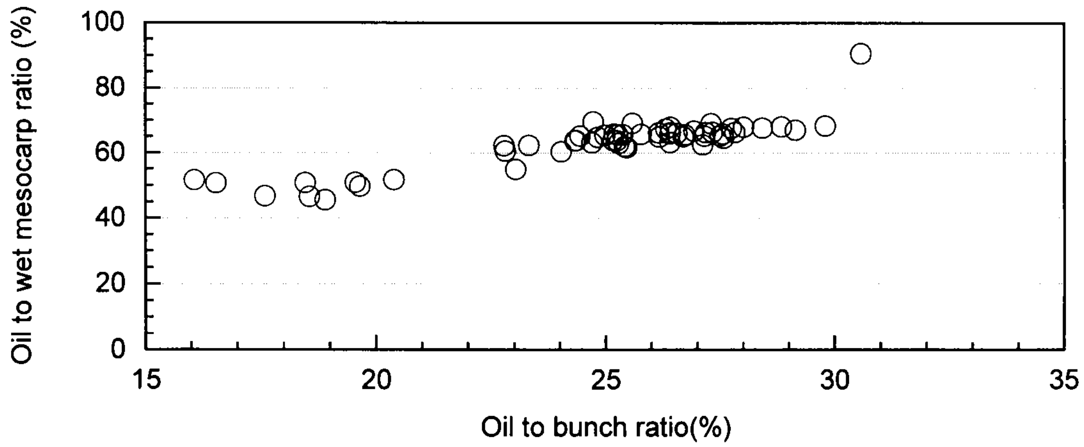
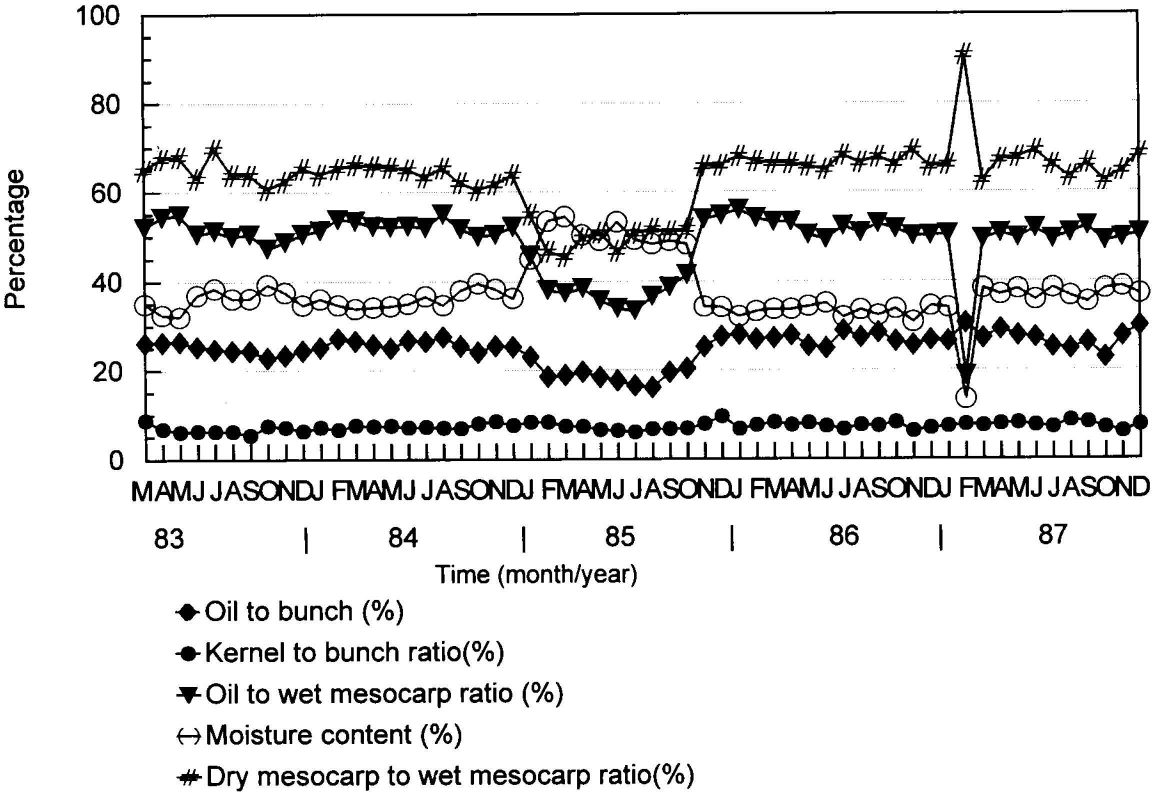


Figure 12. The relationship between oil to bunch ratio and three bunch parameters at a plantation in Serdang

a. Oil to bunch , kernel to bunch ratio, oil to wet mesocarp ratio, moisture content and dry mesocarp to wet mesocarp ratio.



b. Bunch weight, fruit weight, shell to fruit ratio, and kernel to fruit ratio

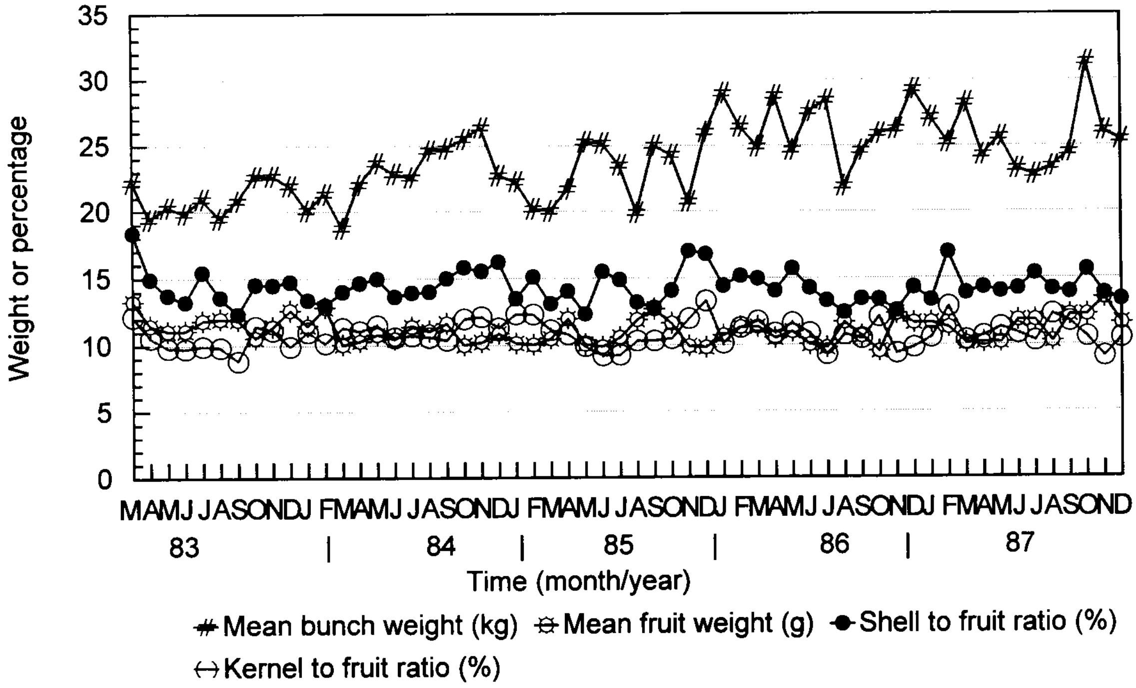


Figure 13. The variations of bunch parameters at UPM plantation in Serdang

anthesising a female inflorescence, while it is still receptive (Syed, 1980). Thus, thrips are not only capable of transporting pollen grains, but also capable of spreading them within each inflorescence (Syed, 1980).

The positive correlation between weevil activity and rainfall (*Figure 7*) indicates that the weevil thrives much better in wet than in dry conditions. The activities of the weevils were not suppressed at rainfall levels between 200 and 300 mm/month. There were six instances when the rainfall was more than 300 mm/month; in four of these higher weevil activity was recorded; in the other two activity was moderate, and in none was it low. Further, in November 1984, in spite of the high rainfall (466.3 mm/month), there were high levels of activity of both weevils (trap capture 47.7 weevils per trap) and thrips (trap capture 252.7 thrips per trap). This supports our earlier result (Basri *et al.*, 1987) and also those of Dhileepan (1994) who reported that weevil population was very high during the wet season in India (up to 400 mm/month).

The greater contribution of the weevil to oil palm pollination is exemplified by the significant relationship between weevil activity and fruit set (*Figure 7*) and the lack of such a relationship with the other pollinators. Nevertheless, it was not possible to determine the threshold activity level because of the consistently high fruit set. A similar relationship between weevil activity and fruit set has been reported by Donough *et al.* (1996).

Rajanaidu and Jalani (1994) reported that after the introduction of the weevil into Malaysia, an observed decline in oil to bunch ratio was associated mainly with an increase in kernel to bunch ratio resulting from better pollination. In contrast, the depression in oil to bunch ratio in 1985 reported in this study was not accompanied by a corresponding increase in kernel to bunch ratio. Instead it was associated with a marked increase in moisture content, probably at the expense of oil synthesis as suggested by Henson (1994). Nevertheless, the reason for the severe depression of oil to bunch ratio in 1985 is not known. One theoretical possibility would be high rainfall, because an excessively wet period would lower the oil to bunch ratio by increasing the water content or water retention of bunches (Henson, 1994; Ho, 1994). However, the total rainfall in 1985 was relatively low (1877.7mm), so it was not a likely factor. Another factor could be stress experienced by the palms resulting from sustained high production for three successive years after the introduction of the weevil in late 1981. More assimilates would be required to produce one gram of oil than one gram of non-oil dry matter. In terms of glucose, the assimilates required are 3.33 and 1.37 grams respectively (Henson, 1994). Possibly then, palms stressed by earlier high production made less oil, thus giving a lower oil to bunch ratio. One further factor could be related to potassium chloride fertilizer which has been shown to reduce oil to bunch ratio in coastal soil areas (Foster *et al.*, 1986; Wood, 1978): the chloride ion promotes water uptake, giving rise to a lower oil to wet mesocarp ratio (Breure, 1977; 1982).

As is evident in *Figure 5*, the *Pyroderces* moths also visited the anthesising female flower regularly. However as already mentioned, they are active for only about two or three hours beginning half an hour from sunset (Tan and Basri, 1985), so their contribution to oil palm pollination is probably small. Tan and Basri (1985) showed that the activity of *Pyroderces* resulted in a fruit set of 31% as compared with 62% attributable to the weevil.

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