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INTERRELATIONS AMONG FEATURES OF FLORAL DEVELOPMENT AND ABORTIONS IN CHILLI (*CAPSICUM ANNUUM* CV C10)

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RINGKASAN

Pokok-pokok cili *Capsicum annuum* cv C10 telah ditanam di ladang selama enam bulan. Tunas-tunas bunga dari enam pokok yang dipilih secara rawak telah ditanda dan perkembangan bunganya diperhatikan. Cili mempunyai dua pusingan di dalam perkembangan bunga dan dua pusingan pemungutan hasil. Dalam pusingan pertama, tunas bunga yang terjadi pada awal minggu menghasilkan 85 peratus buah yang dipungut. Ini disebabkan di minggu-minggu yang berikutnya kadar keguguran tunas bunga adalah tinggi. Pungutan hasil pada pusingan kedua makin berkurangan kerana kadar keguguran tunas bunga yang tinggi. Pembentukan tunas-tunas bunga didapati tidak selaras dengan pertambahan bilangan buah-buah besar. Keguguran bunga dan buah-buah kecil adalah selaras dengan pertambahan bilangan buah-buah besar. Secara purata cili menghasilkan 1180 tunas bunga, 362 bunga, 229 buah kecil, 159 buah besar, 159 buah yang dipungut. Purata berat buah yang dipungut ialah 4.3 g.

INTRODUCTION

Capsicum annuum is a perennial but is often cultivated as an annual (PURSEGLOVE, 1968; DEANON, 1967). Fruit harvest normally begins two to three months after a month old seedlings were transplanted to the field and is usually carried out once or twice a week for two to three months (PURSEGLOVE, 1968; DEANON, 1967; TAN 1973; ANON, 1974). GREENSILL (1964). and OCHASE (1931) however noted that the harvest period could last several months to a year respectively.

PURSEGLOVE (1968) noted that flowers of *C. annuum* are predominantly self-pollinated with cross pollination occuring in 16% of the flowers. FREE (1975) found cross pollinating *C. annuum* and *C. frutescens* as well as bagging the flowers did not significantly affect fruit set, and suggested that yields would not be limited by factors associated with pollination as the crops are mainly auto self-pollinated. Dry conditions are reported to cause shedding of flowers and fruits (DEANON, 1967). Temperatures are also known to affect fruit set. Optimum fruit set in bell pepper occurs at 16 to 23°C and would be prevented by night temperatures below 16°C and day temperatures above 32°C (DEANON, 1967). COCHRAN (1936) noted that low relative humidity and high temperatures in *C. frutescens* led to abscission of buds, flowers and small fruits. High nitrogen fertilisation led to more flowers and fruit production in the first three months after transplanting; but though fruit set and production would still be higher, flower production would decrease in the next one an a half months (MAYNARD, LACHMAN, CHECK and VERNELL, 1962).

The mechanisms of how fruit set and yield are affected are however not well understood as detailed information on the floral development is lacking. This paper reports detailed studies on the development and abortions among the floral stages during cultivation of *Capsicum annuum* cv C10, a chilli grown commonly in Malaysia, in order to understand more of the mechanism of fruit set in this crop.

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MATERIALS AND METHODS

Seeds of the chilli plant, *Capsicum annuum* cv C10, were sown on soil in shallow boxes. Watering was carried out in the morning and in late afternoon. A dilute fertilizer solution, containing 6 g Nitrophoska blue special in a litre of water, was given twice a week at a rate of about 50 ml per 100 seeds or seedlings. Germination occurred in about five days and at two weeks after emergence seedlings were transfered one each to a small polybag of soil (7.5 cm diameter by 15 cm high) in preparation for transplanting to the field. A month after sowing the seedlings with their soils were then transplanted into holes 60 cm apart on beds 60 cm apart. On transplanting 14 g Nitrophoska blue special was given to each plant and subsequently at 3 weeks intervals. During the first month, watering was given once in the morning and late afternoon; watering was not given for the remaining period of cultivation where the plants were thus rainfed. Malathion and Manzate D were sprayed weekly from time of flowering to control pests and diseases. The chilli plants for this study were planted in six rows, each row with fifteen plants. Six plants were randomly selected, one plant per row, for investigation.

Marketable fruits were harvested every two or three days for four and a half months. Each week all new flower buds were tagged. The development of each weekly batch of buds through various floral stages till fruit harvest were monitored weekly. This also allows an assessment of the stages at which each weekly batch of buds aborted. At each weekly interval, all the flower buds, flowers, small and large fruits on the plant, irrespective of the week of tagging, were also counted. The proportion of each stage that aborted could be determined by comparing the number of that stage at one week and the number of that same stage at the previous week. For the purpose of this paper, small fruit refers to fruit of length less than 6 cm while large fruit refers to fruit of length longer than 6 cm.

Least significant differences were calculated for changes in the number of stages and various aspects of their development. Correlations between various floral stages and their development were done by Spearman's Rank Correlation Method.

RESULTS

Development of the Typical Flower Bud

Flower buds were visible 3 weeks after transplanting of the chilli plants. New batches of flower buds appeared with the new branches developing along the edges of the plant canopy. The buds of each batch of flowering did not develop evenly and some bud development would overlap with those from earlier or later batches of flowering. The flowers lasted for a few days. The average weeks for buds to become flowers, small fruits, large fruits or harvestable fruits were respectively 1.6, 2.9, 5.1 and 9.0 weeks *(Figure 1)*. *Figure 1* shows that buds formed during the first seven weeks took a longer period to become flowers than buds that formed later. It also appeared that buds formed later during the first seven or eight weeks took longer time to become small or large fruits than buds that formed earlier during the first seven or eight weeks. After the first seven or eight weeks, the time for buds to become small or large fruits tended to shorten; though the time was still longer than that taken by buds formed early at the first three or four weeks of flowering. Time to reach harvestable stages rose from eight weeks for buds formed in the first few weeks to about 11 weeks for buds formed five to eight weeks later. This declined to less than seven weeks for buds formed in the last two weeks of study.

Harvesting of Fruits

The first harvest was about six weeks after flowering began *(Figure 2.i)*.

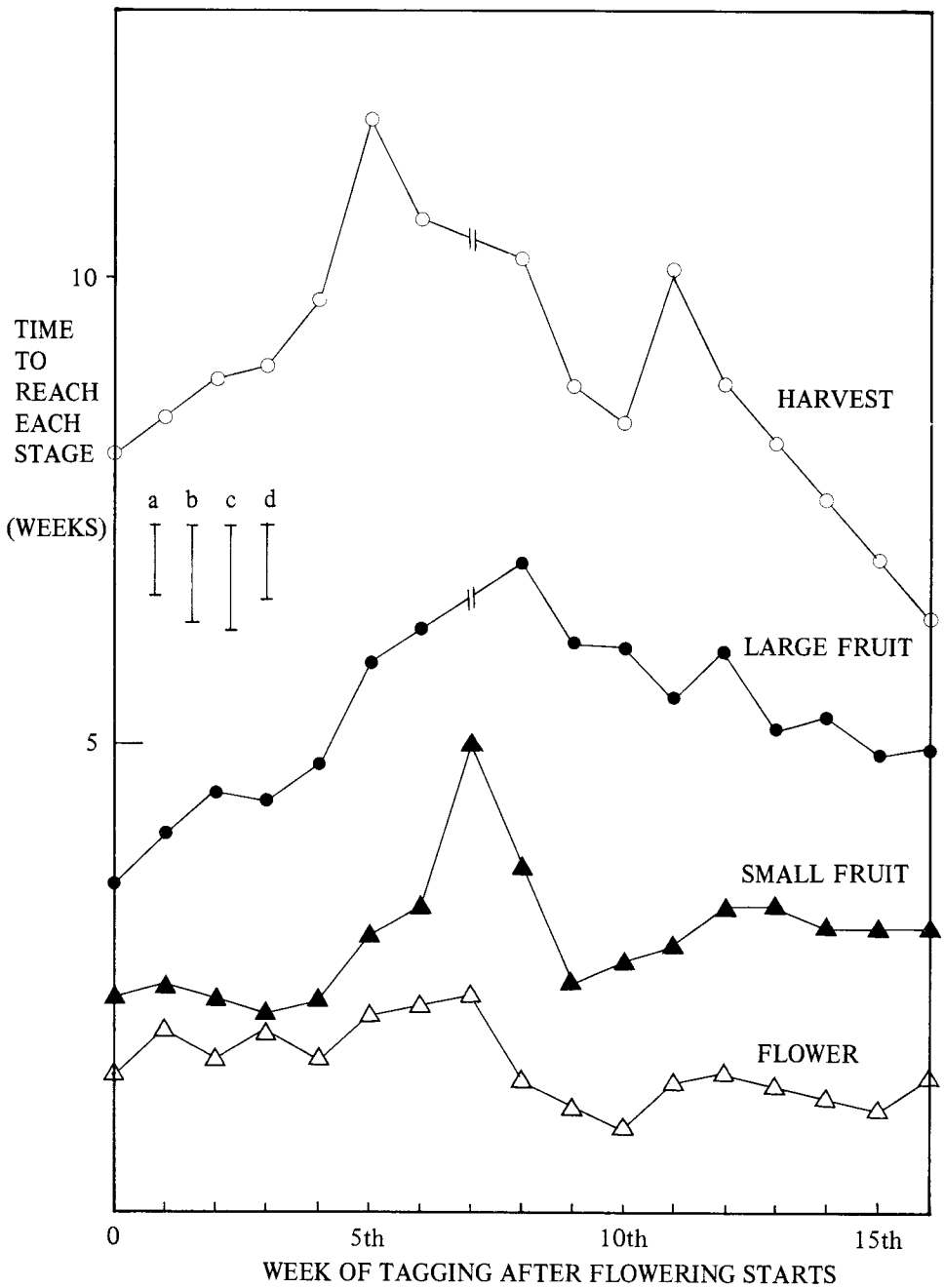

Figure 1: The number of weeks for weekly tagged floral buds to reach the various stages in Capsicum annuum cv C10.

(Vertical bars denoted by 'a', 'b', 'c' and 'd' refer respectively to l.s.d. for flower, small fruit, large fruit and harvest).

Accumulative number of fruits and yield in weight increased over the next eight weeks before reaching a plateau which lasted about six weeks, after which further increase in number and weight of fruits lasted 3 weeks. The fresh weight of fruit at the first cycle of harvest was about 475 g while in the next cycle was 184 g, about 39% that of the first cycle. Average fruit weight per fruit fell from 6.8 g at the start of harvest to about 4 g at the end of the first cycle and fluctuated around 3 g for the rest of the harvest.

Figure 2.ii shows the fruit harvested from each batch of flowering tagged weekly. Although the first cycle of fruit harvest lasted 8 weeks, the majority of fruits came from the initial 3 weeks of flowering, forming 85% of the first cycle of fruit harvest or 61% of the whole harvest. Few fruits formed from buds of the next 8 weeks of flowering but formed again from the next 6 weeks of flowering. Average fruit weight fell from 5.8 g for the fruits from the first week of flowering to 3.4 g at the end of the study. The changes in fruit yield appeared to be due more to changes in fruit number than fruit size.

Development of Floral Stages

The total number of flower buds on the plant increased after over five weeks of flowering, declined in the next six weeks, rose again over the next 3 weeks and declined after that *(Figure 3.1)*. Thus there were two cycles of flowering. Parallel cyclic changes were seen in the number of flowers as well as small and large fruits. The maximum number of flowers, small and large fruits occurred respectively after 1, 1 and 3 weeks when the bud number was maximum in the first cycle and after 4, 2 or 7 weeks when the bud number was maximum in the second cycle.

In the first cycle it was the 3rd weekly batch of flowering, which had the highest number of flower buds and flowers, though the highest number of small and large fruits were formed by the 2nd week of flowering *(Figures 3.ii* and *2.ii)*. In the second cycle, it was the 13th weekly batch of flowering which gave the highest number of buds, though the highest number of small and large fruits were formed by the 12th week. The first cycle had about 600 buds, 282 flowers, 168 small fruits and 100 large or harvestable fruits, while the second cycle had a similar number of buds (about 580) but much less other floral stages (80 flowers, 61 small fruits and 59 large or harvestable fruits). The fruit set, if expressed in terms of number of buds, would be 16.7% in the first cycle, 10.2% in the second cycle, averaging 13.5%. Fruit set, if expressed in terms of the number of flowers, would be 35.5% for the first cycle, 73.8% for the second cycle, averaging 43.9%.

Abortion

Abortion of buds increased with time of cultivation *(Figure 4.i)*, rising from 5% at the start of flowering to 100% by the end of cultivation. Abortion of flowers and small fruits however fluctuated and showed no relationship with the time of cultivation.

Buds abortion was low in the first 4 weekly batches of flowering and then became high in the later batches where the abortion fluctuated between 80 to 95% *(Figure 4.ii)*. Total abortion, which was slightly higher, showed a similar trend as buds abortion. Abortions among flowers and small fruits, if expressed among themselves, fluctuated throughout cultivation.

Overall Production and Abortion

During the 27 weeks of field cultivation, the chilli plant produced on an average about 1180 buds, 362 flowers, 229 small fruits and 159 large or harvestable fruits. The overall abortions, expressed on buds basis were 66.3% for buds, 12.8% for flowers and 6.2% for small fruits, totalling 85.3%, giving an overall fruit set of 14.7%. Average fruit weight was 4.3 g.

Based on *Figures 3.i* an *4.i,* correlations were made between the floral changes

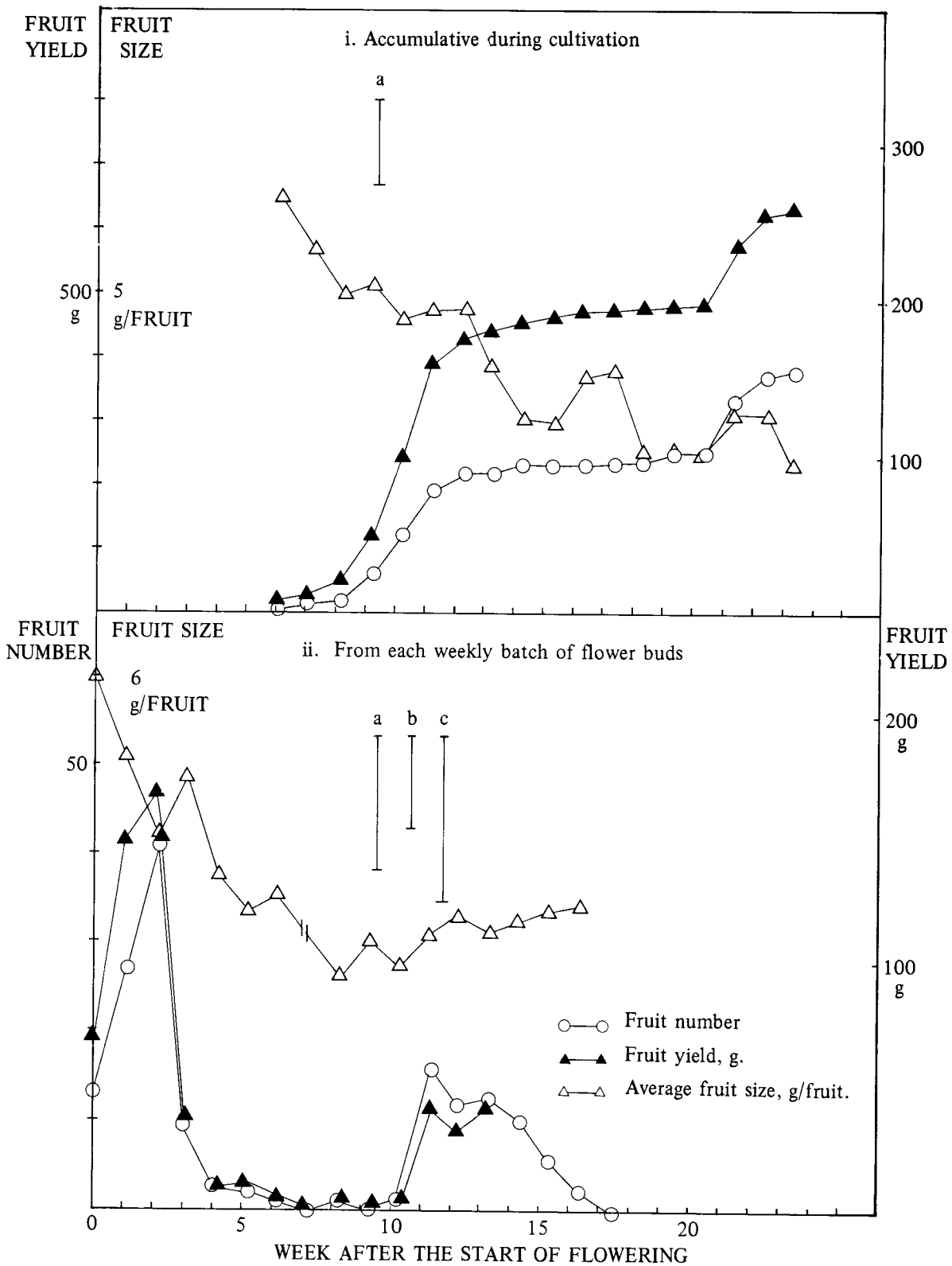

Figure 2: Fruit harvest per plant of Capsicum annuum cv C10.

(Vertical bars denoted by 'a', 'b', and 'c' refers respectively to l.s.d. in fruit size, fruit number and fruit yield).

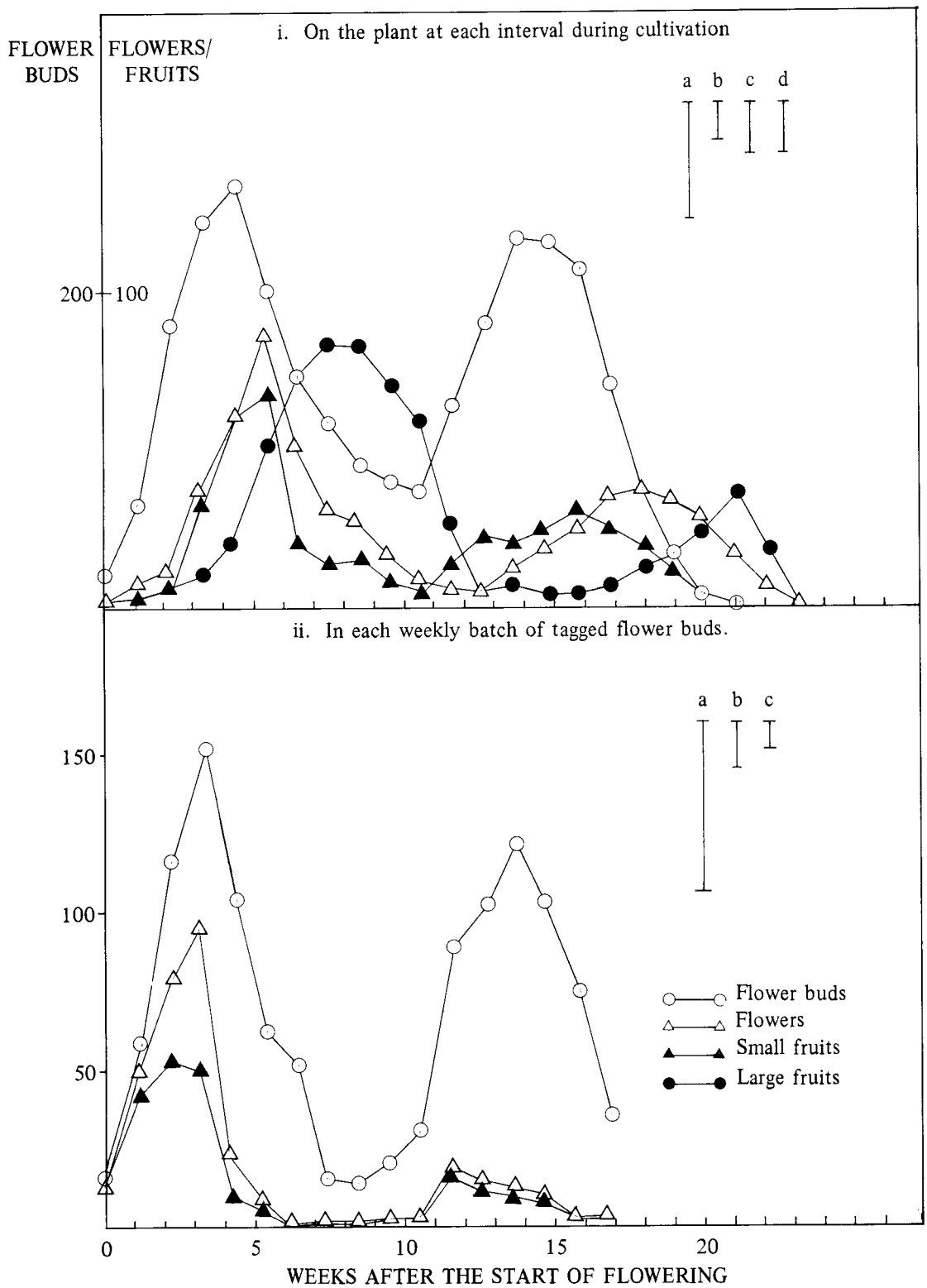

Figure 3: Changes in number of floral stages of Capsicum annuum cv C10.

(Vertical bars denoted by 'a', 'b', 'c' and 'd' refers respectively to l.s.d. in number of flowers, small and large fruits).

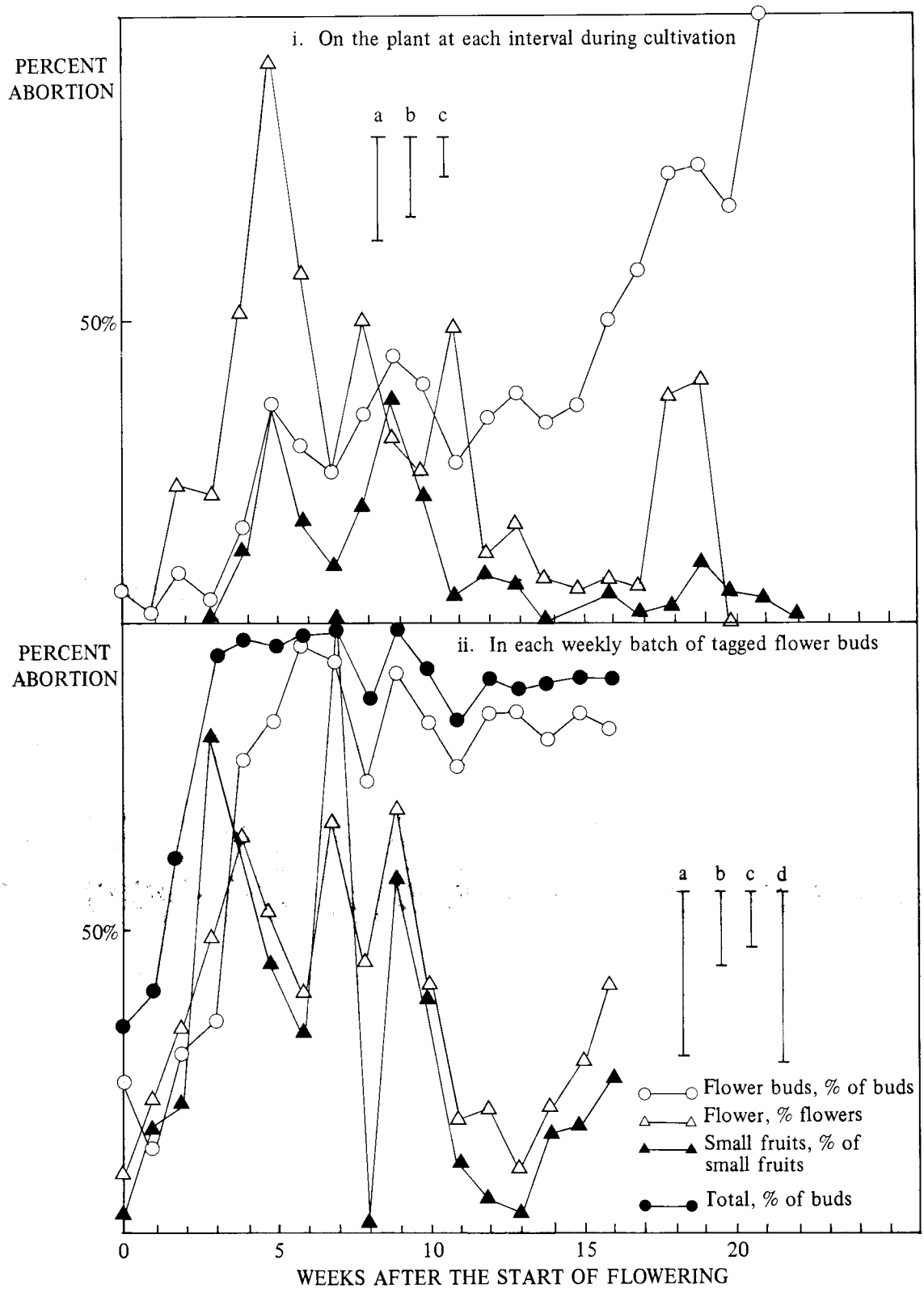

Figure 4: Percentage abortions of floral stages of Capsicum annuum cv C10.

(Vertical bars denoted by 'a', 'b', 'c' and 'd' refers respectively to l.s.d. in abortion of flower buds, flowers, small fruits and total).

on the plant and time of cultivation and the results are shown in *Table 1*. There were significant positive correlations between buds and flowers and also between flowers and small fruits. The formation of new buds each week were positively correlated to buds and flowers but was negatively correlated to that of large fruits. Presence of buds was also negatively correlated to the presence of large fruits. Abortion of flowers were positively correlated to the presence of small and large fruits. Small fruits abortion was positively correlated to large fruits but negatively to the presence of buds as well as formation of new buds.

As already mentioned, abortion of buds on the plant increased with time of cultivation. Time of cultivation was not found to be associated with other floral stages and their development.

DISCUSSIONS

Harvestable fruits in *Capsicum annuum* cv C10 could be collected for about 8 to 11 weeks before reaching a plateau where few fruits could be harvested for 6 weeks. This may be the reason why a 2 to 3 months harvest period is usually recommended (PURSEGLOVE, 1968;

TABLE 1: CORRELATIONS BETWEEN VARIOUS FLORAL STAGES AND DEVELOPMENT ON THE PLANT OF *CAPSICUM ANNUUM CV C10*[1]

	Stages on the plant during cultivation			Formation of new buds per week	Time[2]	Abortion on the plant of:		
	Flower	Small fruit	Large fruit			Bud	Flower	Small fruit
stages on the plant during cultivation								
Bud	0.80[a]	0.34	−0.66[a]	0.77[a]	−0.11	0.13	0.14	−0.61[a]
Flower		0.50[a]	−0.30	0.56[a]	−0.11	0.18	0.30	−0.39
Small fruit			0.37	−0.21	−0.32	0.14	0.65[a]	0.31
Large fruit				−0.84[a]	0.20	−0.05	0.47[a]	0.80[a]
Formation of new buds per week					−0.04	0.00	−0.15	−0.73[a]
Time						0.71[a]	−0.21	0.02
Abortion on plant of:								
Bud							0.22	0.33
Flower								0.44

[1] Correlation analysis by Spearman Rank Correlation Method 'a' denotes correlation coefficients significant at 0.05.
[2] Time of cultivation.

DEANON, 1967; TAN, 1973; ANON, 1974). But as the results indicate, another round of fruit harvest could be collected for 3 weeks after the 6 week-plateau. This second round of harvest was about 39% that of the first. GREENSILL (1964) also reported two rounds of harvest are possible in sweet pepper, where 10 to 12 weeks after planting produced a first harvest of large fruits and then 6 to 8 weeks later a second round of smaller fruits.

The two rounds of fruit harvests were due to two cycles of flowering and floral development. It is not known here whether there would be further cycles; though this is likely as harvest periods of several months to a year had been noted (GREENSILL, 1964; OCHASE, 1931).

Initially bud number on the plant increase. But as the number of large fruits increased the bud number started to decline. Only when large fruits started to decline did bud number increased again. When for the second time large fruits started to increase bud number declined again. Bud number was not inversely related to the number of flowers or small fruits. The presence of large fruits was also associated with reduced formation of new buds, as well as increased abortions of flowers and small fruits. These changes appear to indicate that the presence of large fruits had adverse influences on the development of the earlier floral stages. Naturally when large fruits started to decline development of the earlier floral stages would pick up again. But as the floral stages mature, large fruits would increase again and formation of new buds would also down while abortions of flowers and small fruits would increase. This inverse relationship between the large fruits and development of the earlier floral stages, especially that of the buds, appear to be the basis of the cyclic changes in floral stages and eventual harvests. Inverse relationships between large fruit development and flower buds/flowers development had been found in other crops by other workers (DAVIS, 1957; SEN 1962; LEOPOLD and KRIEDEMANN, 1975; SINNOTT, 1960) who had explained this inverse relationship on the basis of sink competition for plant reserves. The sink competition concept postulates that developing large fruits use large amounts of plant reserves such as photosynthetates and even endogenous hormones and would temporarily deplete the plant reserves. The depletion thus limits supply of plant reserves for other development such as those for bud formation, maintenance of flowers and small fruits. Such a sink competition appears to be the basis of the inverse relationship between large fruit development and flowering in chilli.

It was noted that though the first cycle of harvest came from about 8 weeks of flowering, the first 3 weeks of buds formation actually yielded the majority of the harvested fruits (85% of the first cycle, or 61% of both cycles). This was because in the later weeks of flowering there was high bud abortions. The high bud abortions also persisted in the flowering of the second cycle. Thus although bud formation in the second cycle was similar to that of the first cycle, the high bud abortion led to lower fruit harvest in the second cycle. Fruits of the second cycle were also smaller than those of the first cycle. The increase of bud abortions as well as the reduction in fruit size with time may indicate some form of buildup in inhibitory influences as the plant grew older. The experiment had shown that only 14.7% of the buds set into fruits for the two cycles (16.7% for the first cycle and 10.2% for the second cycle). As only a small proportion of buds set into harvestable fruits there is great potential for improvement of chilli yields if bud abortions could be controlled, especially during the later part of the cultivation.

The results thus indicate that the changes in floral development and fruit harvests could be accounted for by at least two types of relationship. One is that there is an inverse relationship between large fruit development and flowering, possibly due to sink competition, which would

account for the cyclical changes in floral development and fruit harvests. The other is that there appears to be some build up in inhibitory influences as the plant grew older and this led to high bud abortions as well as reduction in fruit size in later periods of cultivation.

SUMMARY

Capsicum annuum cv C10 was cultivated in the field for six months. New flower buds of six randomly selected plants were tagged weekly and their floral development noted. The chilli plant showed two cyclical changes in floral development which led to two rounds of fruit harvests during cultivation. In the first cycle, buds formed in earlier weeks yielded 85 percent of the first fruit harvest. This was due to that in later weeks of the first cycle there was high abortions of buds. There was much less fruit harvest in the second round due to much higher bud abortions in the second cycle than in the first cycle. The formation of new flower buds was inversely related to the number of large fruits. Higher abortions of flowers and small fruits were also positively correlated to number of large fruits. The chilli plant produced during the six months cultivation an average of 1180 flower buds, 362 flowers, 229 small fruits, 159 large or harvestable fruits, the harvested fruit averaging 4.3 g.

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