Ann. appl. Biol. (1979), **91**, 383–390
Printed in Great Britain

The effects of flower removal on the seed yield of pigeonpeas (*Cajanus cajan*)

BY A. R. SHELDRAKE, A. NARAYANAN* AND N. VENKATARATNAM
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) 1-11-256, Begumpet, Hyderabad-500 016, A.P. INDIA

(*Accepted 9 June 1978*)

SUMMARY

In field experiments carried out at Hyderabad, India with early and medium-duration cultivars of *Cajanus cajan* sown at the normal time, in July, removal of all flowers and young pods for up to 5 wk had little or no effect on final yield. The flowering period of the deflowered plants was extended and their senescence delayed. The plants compensated for the loss of earlier-formed flowers by setting pods from later-formed flowers; there was relatively little effect of the deflowering treatments on the number of seeds per pod or weight per seed. The plants were also able to compensate for the repeated removal of all flowers and young pods from alternate nodes by setting more pods at the other nodes.

The removal of flowers from pigeonpeas grown as a winter crop resulted in yield reductions roughly proportional to the length of the deflowering period, probably because maturation of these plants was delayed and occurred under increasingly unfavourable conditions as the weather became hotter.

INTRODUCTION

Pigeonpeas (*Cajanus cajan* (L.) Millsp.) generally flower profusely, but only a small minority of the flowers give rise to mature pods; most of the flowers are shed (Howard, Howard & Khan, 1919; Datta & Deb, 1970). The flowering period usually lasts for a month or more. Most pigeonpea cultivars are indeterminate; in these cultivars flowering proceeds acropetally on the racemes and also on the branches as new racemes develop (Mahta & Dave, 1931). In morphologically determinate cultivars, which produce inflorescences at the apices of the main stem and branches, the racemes continue to develop indeterminately, and flowering within the racemes proceeds acropetally as in the indeterminate cultivars; there is also a continued production of new inflorescences from axillary shoots (Reddy & Rao, 1974). Under favourable conditions, the earlier-formed flowers set more pods than the later-formed flowers. Consequently most of the pods develop on the more proximal nodes of the racemes and, in indeterminate cultivars, at the more proximal nodes of the branches (Sheldrake & Narayanan, unpublished data). Most of the flowers produced at the distal nodes of racemes abscind.

In the field, pod-set may be reduced by unfavourable climatic conditions, such as wet or cloudy days (Mahta & Dave, 1931) and many flowers and developing pods are damaged by insect pests (Pathak, 1970; Davies & Lateef, 1977). In the experiments described in this paper we have simulated this by removing flowers and young pods from the plants for different periods of time after the onset of flowering in order to obtain some idea of the plants' ability to compensate for such damage by setting pods from later-formed flowers.

* Present address: Department of Agricultural Botany, Andhra Pradesh Agricultural University, Rajendranagar, Hyderabad-500 030, A.P., India.

MATERIALS AND METHODS

All experiments were carried out in the field at the ICRISAT Centre at Patancheru (17° 32′N, 78° 16′E) near Hyderabad, India. The soils were fertilised with single superphosphate (50 kg/ha P_2O_5) but no nitrogen was supplied; the roots were well-nodulated with native *Rhizobia*. In all experiments, the plants were protected against insect pests by sprays of endosulfan.

Experiments were done with pigeonpeas planted at the normal time in June or July, soon after the beginning of the monsoon, and with pigeonpeas planted in November as a winter crop. Extra-early, early, medium and late maturing cultivars were used; at Hyderabad, when the crop is planted in June or July, these cultivars mature in 4·5, 5·5, to 6·5 and 6·5 to 9 months respectively. When grown as a winter crop, early, medium and late cultivars of pigeonpea mature in 3·5, 4 and 4·5 months respectively, owing to photoperiodic effects (Narayanan & Sheldrake, unpublished data).

Table 1. *Summary of field experiments*

Season	Normal season 1975			Winter 1975–76			Normal season 1976		
Sowing date	July 4	June 26		11 Nov. 1975			July 1		
Harvest date	Nov. 1975	Jan. 1976		Mar.–April 1976			Nov. 1976–Jan. 1977		
Maturity and cultivar	Plant spacing cm	Plot m²	Soil type	Plant spacing cm	Plot m²	Soil type	Plant spacing cm	Plot m²	Soil type
Extra early									
Pant-A_2	50 × 30	30	Ustochrept						
Prabhat	50 × 30	30	Alfisol						
Early									
T-21	50 × 30	30	Alfisol	37·5 × 20	24	Chromustert vertisol	50 × 30	54	Pallustert vertisol
Pusa ageti	50 × 30	30	Alfisol	37·5 × 20	24	Chromustert vertisol	50 × 30	54	Pallustert vertisol
Medium									
ST-1	75 × 30	67·5	Chromustert vertisol	37·5 × 20	24	Chromustert vertisol			
HY-3C	75 × 30	67·5	Chromustert vertisol	37·5 × 20	24	Chromustert vertisol			
ICP-1				37·5 × 20	24	Chromustert vertisol	75 × 30	81	Pallustert vertisol
HY-3A							75 × 30	81	Pallustert vertisol
ICP-6997							75 × 30	81	Pallustert vertisol
Late									
ICP-7065				37·5 × 20	24	Chromustert vertisol			

A detailed summary of field experiments is given in Table 1.

Winter season 1975–76

At least 25 plants, in two adjacent rows, were used for each unreplicated treatment. The plants were harvested in March–April 1976. Probably because this crop was sown late, in November rather than October, the yield was poor (mean yield: 450 kg/ha).

Normal season 1976

Each replicate block consisted of two adjacent plots. Two adjacent rows (i.e. about 60 plants) were used for each treatment; rows adjacent to these were untreated. A separate experiment was carried out with each cultivar: the treatments were carried out in a randomised block design with four replications, except in the case of cvs T-21 and ICP-6997, for which there were three replications. The trials were harvested between November 1976 and January 1977 depending on the duration of the cultivars and the delay in maturity caused by the treatments.

Deflowering treatments

The flower removal treatments involved the removal by hand of all open flowers and young pods at weekly intervals. In 1975 the deflowering treatments were carried out for 1, 2, 3, 4, 5 and 6 wk with the medium cultivars, and for 1 to 4 and 1 to 5 wk with the extra-early and early cultivars respectively. In the 1975–76 winter crop, flowers were removed for 1 to 5 wk; and in 1976 for 1 to 3 wk in cv. T-21, 1 to 4 wk in cv. Pusa ageti and 2 to 5 wk in cvs ICP-1, ICP-6997 and HY-3A. After flowers had been removed for the appropriate period of time, the plants were not treated further and were left to produce pods. The treatments were started when 50% of the plants began to flower; in 1976 these dates were as follows: cv. T-21, 21 September; Pusa ageti, 25 September; ICP-1, 31 October; ICP-6997, 1 November; HY-3A, 13 November.

At harvest, the shoot dry weight, pod number, pod weight, seed number per pod and seed weight were recorded from all treated plants. Air dry weights were corrected to oven-dry weights on the basis of subsamples taken from every set of treated plants.

The pattern of pod set within racemes was recorded from 50 racemes collected from the basal parts of the branches of indeterminate cultivars, and from the terminal racemes of determinate cultivars. The number of pods and scars at each node position within the raceme was noted. The nodes were numbered from the most basal (proximal) node. The number of scars indicate the number of flowers, buds or young pods which were removed or which abscinded.

RESULTS

Senescence and maturation

In all experiments, the removal of flowers and young pods from the plants resulted in a protraction of the flowering period and a delay in the maturation of the plants roughly proportional to the length of the flower-removal period. The leaves on the plants from which flowers were removed remained green longer and the leaf area of these plants declined less rapidly than that of the controls. The stems contained large amounts of starch in the medullary rays and xylem parenchyma (revealed by staining with iodine when flowering began). In the control plants these starch reserves disappeared during the reproductive phase, but in plants from which flowers were removed, the stems contained large amounts of starch which began to disappear only after the flower removal treatments ceased. These observations indicate that the development of pods accelerated the senescence of the leaves and led to a mobilisation of starch reserves from the stems.

Effects of flower removal treatments on the pattern of pod-setting

Experiments carried out in the normal season of 1975 showed that in control plants, most of the pods were set from the earlier-formed flowers at the more basal nodes of the racemes. If these flowers were removed, pod-set occurred from flowers at more apical nodes. Protracted flower removal resulted in a production of more flowering nodes per raceme. Data for cv. ST-1 are shown in Fig. 1. A similar pattern was found in all cultivars, both determinate and indeterminate.

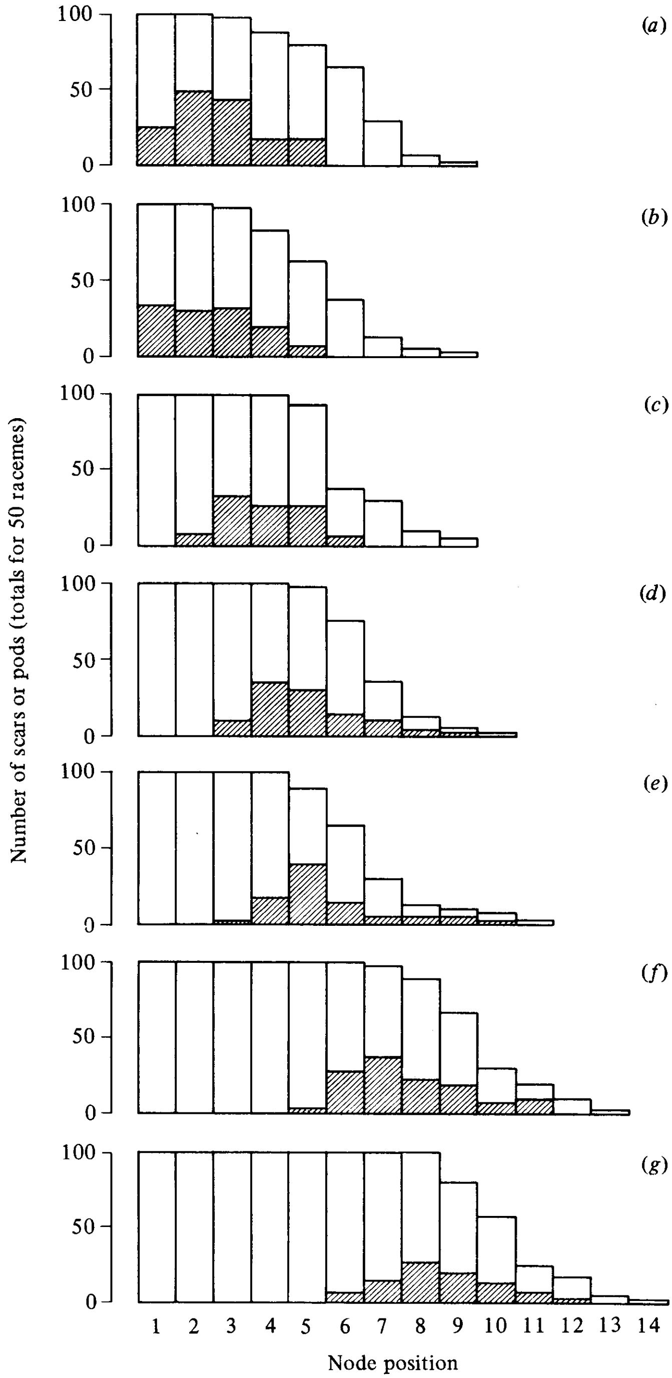

Fig. 1. Effect of flower removal for different periods of time on the pattern of pod set on racemes of pigeonpeas cv. ST-1 grown in the normal season, 1975. The nodes within the raceme are numbered from the most basal (proximal) node. Each node gives rise to two flowers. Other cvs grown at the same period (Table 1) have shown a similar pattern of pod set on racemes. □, scars; ▨, pods. Deflowering period (wk): (*a*) 0 (control), (*b*) 1, (*c*) 2, (*d*) 3, (*e*) 4, (*f*) 5 and (*g*) 6.

Table 2. *Effect of flower removal for different periods of time on total dry weight of flowers removed, seed yield and components of yield and total shoot dry weight at the time of harvest of pigeonpeas cvs T-21, Pusa ageti ICP-1, ICP-6997 and HY-3A grown in the normal season, 1976*

Cultivar and variable	Deflowering period (wk) 0 (Control)	1	2	3	4	5	Continuous flower removal from alternate racemes	S.E. of treatment grand mean
Cv. T-21								
Dry wt of flowers/ plant, g	—	1·3	6·9	11·5	—	—	—	0·36
Yield/plant, g	14·3	14·3	13·5	14·0	—	—	14·3	1·31
Pods/plant	79·6	81·2	73·8	89·0	—	—	68·1	8·16
Seeds/pod	3·1	3·3	3·0	2·5	—	—	3·4	0·19
100-seed wt, g	5·8	5·5	6·3	6·4	—	—	6·2	0·23
Shoot dry wt/ plant, g	63·8	62·0	62·9	69·9	—	—	67·5	3·89
Cv. Pusa ageti								
Dry wt of flowers/ plant, g	—	1·1	4·0	8·3	11·1	—	—	0·56
Yield/plant, g	17·2	14·0	12·8	12·5	10·7	—	—	0·98
Pods/plant	102·6	103·7	72·1	75·8	75·7	—	—	8·69
Seeds/pod	2·2	2·0	2·6	2·5	1·9	—	—	0·15
100-seed wt, g	8·0	7·0	7·0	6·8	7·3	—	—	0·28
Shoot dry wt/ plant, g	62·2	53·4	52·8	51·9	53·5	—	—	3·98
Cv. ICP-1								
Dry wt of flowers/ plant, g	—	—	8·6	11·8	14·2	19·4	—	0·86
Yield/plant, g	28·4	—	30.0	29·2	31·1	30·2	23·5	1·74
Pods/plant	135·1	—	132·3	132·3	147·0	149·8	116·8	9·64
Seeds/pod	2·5	—	2·6	2·6	2·6	2·6	2·3	0·11
100-seed wt, g	8·3	—	8·6	8·6	8·1	7·8	8·9	0·30
Shoot dry wt/ plant, g	145·0	—	142·6	140·5	142·8	145·1	144·3	7·64
Cv. ICP-6997								
Dry wt of flowers/ plant, g	—	—	7·2	8·1	8·0	11·9	—	0·92
Yield/plant, g	21·2	—	27·9	28·0	25·5	25·4	—	2·02
Pods/plant	61·1	—	75·3	71·7	63·7	70·3	—	24·72
Seeds/pod	2·8	—	3·1	3·2	3·3	3·5	—	0·13
100-seed wt, g	12·4	—	12·1	12·1	11·6	10·4	—	0·34
Shoot dry wt/ plant, g	97·8	—	113·7	105·3	89·5	99·9	—	11·06
Cv. HY-3A								
Dry wt of flowers/ plant, g	—	—	2·9	4·3	5·7	6·5	—	0·43
Yield/plant, g	13·1	—	16·4	18·1	11·0	14·0	—	1·34
Pods/plant	23·9	—	33·5	35·8	30·0	44·5	—	2·92
Seeds/pod	3·4	—	3·2	3·1	2·6	2·6	—	0·11
100-seed wt, g	16·5	—	15·1	16·4	14·3	12·1	—	0·39
Shoot dry wt/ plant, g	71·2	—	85·7	90·6	70·1	91·2	—	4·42

Effects of flower removal on yield and components of yield

In replicated experiments carried out on plants sown in July 1976, all the indeterminate cultivars were able to compensate completely for the removal of all flowers and young pods; the treatments were carried out up to 3 wk in the case of cv. T-21 and up to 5 wk with cvs ICP-1, ICP-6997 and HY-3A (Table 2). There was in fact a small increase in yield in cvs ICP-6997 and HY-3A after deflowering for 3 wk. The treatments had no consistent effects on seed numbers per pod, but in the medium-duration cultivars the 100-seed weights declined after longer periods of deflowering. The total weights of flowers and young pods removed from the plants during the course of the treatments were considerable. There was no significant effect of the flower-removal treatments on shoot dry weight at harvest, except in cv. HY-3A where there was an increase. In fact in most cultivars, the flower removal treatments probably resulted in an increased production of total dry matter; this tendency is indicated by the sum of the shoot dry weight at harvest and the weights of flowers removed. However, precise estimates of total dry matter production should include data on roots, fallen leaves and fallen flowers and pods. Such increases could be most simply explained in terms of the longer growing period of the deflowered plants. Deflowering of the determinate cultivar, Pusa ageti, resulted in a small but significant reduction in pod number and yield. This was not because its morphological habit imposed a limitation on its ability to continue flowering. This cultivar and cv. Prabhat, which is also determinate, compensated completely for flower removal in the 1975 experiments. Further work will be necessary to find out if repeatable differences can be detected between determinate and indeterminate cultivars in this respect.

Effect of continuous flower removal from alternate nodes

The effect of the removal of all flowers and young pods from alternate nodes of the main stem and branches at weekly intervals throughout the reproductive phase was investigated with cvs T-21 and ICP-1 planted in July, 1976. In the former cultivar there was no effect on yield; in the

Table 3. *Effect of flower removal for different periods of time on seed yield and components of yield of early, medium and a late cultivar of pigeonpeas grown in the winter season 1975–76*

	Deflowering period (wk)					
	0	1	2	3	4	5
Early cultivars						
(Cvs T-21 and Pusa ageti)						
Yield/plant, g	2·1	1·4	0·9	1·0	0·7	0·4
Pod number/plant	15·3	13·2	11·1	9·9	7·8	5·3
Seeds/pod	2·6	2·5	2·2	2·1	1·8	1·4
100-seed wt, g	5·2	4·2	3·7	4·6	5·0	4·9
Medium cultivars						
(Cvs ST-1, ICP-1 and HY-3C)						
Yield/plant, g	3·4	3·7	1·7	1·2	1·0	0·6
Pod number/plant	19·1	23·5	13·8	10·9	9·5	6·6
Seeds/pod	2·8	2·4	2·1	2·0	1·8	1·5
100-seed wt, g	6·8	7·1	5·3	5·9	4·5	6·0
Late cultivar						
(Cv ICP-7065)						
Yield/plant, g	6·3	4·2	3·3	2·6	1·3	1·5
Pod number/plant	63·0	50·5	42·1	31·3	17·1	21·8
Seeds/pod	2·1	2·0	1·7	1·9	1·6	1·5
100-seed wt, g	4·7	4·2	4·5	4·4	4·8	4·8

latter there was a reduction of only 17% (Table 2). Neither 100-seed weight nor seed number per pod were affected significantly. These results show that the prevention of pod-set at 50% of the flowering nodes resulted in a compensatory setting of pods at the remaining nodes.

Effects of flower removal from pigeonpeas grown as a winter crop

Pigeonpeas are normally planted at the beginning of the monsoon season, in June or July. They can also be grown as an unirrigated winter crop, planted in October or November, in which case they mature in February or March, when the hot, dry summer season begins (Narayanan & Sheldrake, unpublished data). Flowers were removed for up to 5 wk from plants of two early, three medium and one late cultivar grown in the winter season of 1975–76. In all cultivars, deflowering resulted in reductions in yield, roughly proportional to the length of the period of flower removal. The mean yields for cultivars within the three duration groups are shown in Table 3. The reduced yields were associated with reduced numbers of pods per plant and reduced numbers of seeds per pod.

DISCUSSION

An apparently excessive production of flowers occurs in many species, including a number of legume crops (Sinha, 1977). As in pigeonpeas, removal of earlier-formed flowers results in a setting of pods from later-formed flowers which would otherwise have abscinded, in yellow lupins (van Steveninck, 1957) cowpeas (Ojehomon, 1970) and soybeans (Tayo, 1977). Under certain conditions, cowpeas have been shown to compensate completely for the removal of flowers and young pods for up to 9 days (Ojehomon, 1970) and soybeans for up to 2 wk (Tayo, 1977). In our experiments, the pigeonpeas grown in the normal season were able to compensate more or less completely for the loss of all flowers and young pods for up to 5 wk after flowering began (Table 2).

Experiments involving removal of all flowers for a given period simulate a very heavy pest attack, followed by a period in which there is minimal damage to the plants. In farmers' fields such a reduction in the intensity of pest attack may occur naturally or it may be brought about by insecticides. It seems clear that effective compensation would not be possible if a heavy pest attack continued indefinitely. The ability to recover from the type of damage which delays the onset of pod-setting and pod-development also depends on the environmental conditions. In our experiments, the pigeonpeas grown in the normal season matured in the relatively cool winter months; by contrast, pigeonpeas planted in November matured when the weather became hotter and drier at the beginning of the summer. Flower removal for the latter plants led to severe yield reductions (Table 3), probably because pod setting and pod development took place under increasingly unfavourable conditions.

The removal of flowers and young pods from different parts of the plant, or the removal of parts of developing pods, may give a better approximation to the type of pest damage normally encountered in the field than the removal of all or none of the flowers and young pods. In our experiments, the plants were able to compensate for local disturbances brought about by the continuous removal of flowers from alternate nodes by setting approximately twice the normal numbers of pods at the remaining nodes. Comparable results have been obtained with soybeans (Hicks & Pendleton, 1969). We are currently investigating the effects on pod set and yield of cutting off part of each developing pod, in an attempt to simulate the type of damage commonly caused by a pod borer such as *Heliothis armigera* Hub. and the pod fly, *Melanagromyza obtusa* Mall. (Davies & Lateef, 1977). In cowpeas, such treatments have been shown to result in a compensatory setting of additional pods (Anon., 1974).

The fact that damaging or removing earlier-formed flowers or pods results in the setting of pods from later-formed flowers which would otherwise have fallen infructuously indicates that developing pods promote the abscission of subsequently formed flowers and young pods. This influence of developing pods can be most simply explained in terms of a competition for photo-assimilates or for other nutrients (Sheldrake, unpublished data).

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) receives support from a variety of donors, Governments, foundations etc. including IBRD, IDRC, UNDP, USAID etc. The responsibility for all aspects of this publication rests with the ICRISAT.

REFERENCES

ANON. (1974). Cowpea Physiology. In *Report of the International Institute of Tropical Agriculture, Ibadan*, pp. 117–120.

DATTA, P. C. & DEB, A. (1970). Floral biology of *Cajanus cajan* (Linn.) Millsp. var. Bicolor D.C. (Papilionaceae). *Bulletin of the Botanical Society of Bengal* **24**, 135–145.

DAVIES, J. C. & LATEEF, S. (1977). The current pest situation in grain legumes in India. In *Proceedings of the International Grain Legume Conference (1976)* (in press). Ibadan: International Institute of Tropical Agriculture.

HICKS, D. R. & PENDLETON, J. W. (1969). Effect of floral bud removal on performance of soybeans. *Crop Science* **9**, 435–437.

HOWARD, A., HOWARD, G. L. C. & KHAN, A. R. (1919). Studies in the pollination of Indian Crops. *Memoirs of the Department of Agriculture in India (Botanical Series)* **10**, 201–207.

MAHTA, D. N. & DAVE, B. B. (1931). Studies in *Cajanus indicus*. *Memoirs of the Department of Agriculture in India (Botanical Series)* **19**, 1–25.

OJEHOMON, O. O. (1970). Effect of continuous removal of open flowers on the seed yield of two varieties of cowpea, *Vigna unguiculata* (L.) Walp. *Journal of Agricultural Science, Cambridge* **74**, 375–381.

PATHAK, G. N. (1970). Red gram. In *Pulse Crops of India*, pp. 14–53. Ed. P. Kachroo. New Delhi: Indian Council of Agricultural Research.

REDDY, R. P. & RAO, N. G. P. (1974). Inheritance and relation with some yield components of plant and flowering habit in *Cajanus*. *Indian Journal of Genetics and Plant Breeding* **34**, 94–99.

SINHA, S. K. (1977). Food legumes: distribution, adaptability and yield. FAO Plant Production and Protection Paper no. 3. Rome: Food and Agricultural Organization of the United Nations.

TAYO, T. O. (1977). Effect of flower or pod removal on the performance of soybeans (*Glycine max* L.). *Journal of Agricultural Science, Cambridge* **89**, 229–234.

VAN STEVENINCK, R. F. M. (1957). Factors affecting the abscission of reproductive organs in yellow lupins (*Lupinus luteus* L.). I. The effects of different patterns of flower removal. *Journal of Experimental Botany* **9**, 373–381.