Ann. Bot. **43**, 467–473, 1979

Comparisons of Earlier- and Later-formed Pods of Chickpeas (*Cicer arietinum* L.)

A. R. SHELDRAKE and N. P. SAXENA

International Crops Research Institute for the Semi-arid Tropics (ICRISAT), Hyderabad-500016, India

Accepted: 8 February 1978

ABSTRACT

In chickpeas (*Cicer arietinum* L.) flowering and pod development proceed acropetally. In plants grown under normal field conditions at Hyderabad, in peninsular India, and at Hissar in north India, at successively apical nodes of the branches there was a decline in pod number per node, weight per pod, seed number per pod and/or weight per seed. The percentage of nitrogen in the seeds was the same in earlier- and later-formed pods at Hyderabad; at Hissar the later-formed seeds contained a higher percentage. Earlier- and later-formed flowers contained similar numbers of ovules. The decline in seed number and/or weight per seed in the later-formed pods of 28 out of 29 cultivars indicated that pod-filling was limited by the supply of assimilates or other nutrients. By contrast, in one exceptionally small-seeded cultivar there was no decline in the number or weight of seeds in later-formed pods, indicating that yield was limited by 'sink' size.

Key words: *Cicer arietinum* L., chickpea, flowering, pod development, seed number, seed weight, nitrogen content.

INTRODUCTION

Chickpeas (*Cicer arietinum* L.) are annuals; during their reproductive phase, leaves and nodules senesce, growth and nutrient uptake slow down, and the plants finally die. The processes of senescence are accelerated by the development of pods, probably because of a competition for assimilates and other nutrients between reproductive and vegetative sinks (Sheldrake and Saxena, in press).

The growth of chickpeas is indeterminate; the main stems and branches continue to develop during the reproductive phase. In most cultivars a single flower is produced at each node. Under favourable environmental conditions, there is little flower or pod abortion; consequently pods are formed sequentially at most of the reproductive nodes, with the earlier-formed pods on the more basal (proximal) nodes of the main stem or branches, and the later-formed pods at the more apical (distal) nodes.

We compared earlier- and later-formed pods of a range of chickpea cultivars in order to find out how the development of the pods was influenced by the changes occurring in the plants during the reproductive phase.

MATERIALS AND METHODS

Observations were made on plants grown in the field at Hyderabad, in peninsular India, on a Vertisol (clayey, montmorillonitic, hyperthermic, Typic Pallustert) and at Hissar, in northern India, on an entisol (sandy, calcareous, Typic Camborthids). At both locations the soil was fertilized with single superphosphate (50 kg P_2O_5 ha^{-1}). No nitrogenous fertilizer was supplied; the roots were well nodulated with native *Rhizobia*. The chickpeas

0305-7364/79/030467+07 \$02.00/0

were sown in plots at the normal plant-to-plant spacing of 30 × 10 cm and were grown in the normal season, without irrigation. Cultivars were planted in randomized block designs with two replications in 1974–5 and 1975–6, and four replications in 1976–7, but observations were made on plants from only one replication unless otherwise indicated.

Hyderabad

In 1974–5, two early cultivars (Chafa and JG-62), two medium-duration (850-3/27 and L-550) and two late cultivars (T-3 and G-130) were compared. Cv. L-550 is a 'Kabuli' type; the other cultivars are 'desi' types. They were sown on 1 October. At the time of harvest (February–March, 1975), the main stems, primary, secondary and tertiary branches were separated from 20 plants per cultivar and the number of branches in each category recorded. From each class of branches, the pods at the most basal pod-bearing node (node 1) were pooled, as were the pods from the second and succeeding nodes. The oven-dry weight of the pods and the number and weight of seeds they contained were recorded. Some pods contained no seeds and hence in some cases the average number of seeds per pod was less than one.

In 1975–6, 23 cultivars with mean seed weights ranging from 42 to 289 mg were sown on 10 November. At the time of harvest, 25 well-developed primary branches were collected from each replicate plot and the pods were separated node-wise as described above. The dates on which 50 per cent of the plants of each cultivar had begun to flower were noted. The mean weight per seed was determined from subsamples of the bulk seed harvested from each cultivar.

In 1976–7 the same cultivars used in 1974–5 were sown on 12 October and harvested in February–March. The pods were separated node-wise from 25 primary branches of each cultivar and data recorded as described above. The seeds from the different node positions of cvs JG-62, L-550, 850-3/27 and G-130 were ground to powder and analysed for nitrogen by the micro-Kjeldahl method.

From cvs 850-3/27, F-502, L-550 and Rabat sown in October 1976, flowers were collected soon after the beginning and soon before the end of the period of flowering and kept in formalin–acetic acid–alcohol preservative fluid. Twenty-five flowers from each plot of each cultivar were dissected under a binocular microscope and the number of ovules per carpel recorded.

Hissar

In 1976–7 the same cultivars that were grown at Hyderabad were sown on 29 October and harvested on 19 April. Pods were separated node-wise from 25 primary branches of each cultivar; data were recorded and nitrogen was analysed as described above.

RESULTS AND DISCUSSION

Decline in components of yield on main stems and branches

In all six cultivars grown at Hyderabad in 1974–5, there was a decline from the basal to the apical nodes in pod number per node, weight per pod, seed number per pod and weight per seed. Representative results, for cvs 850-3/27 and G-130, are shown in Fig. 1. A similar pattern of decline was found in main stems and primary, secondary and tertiary branches, but the higher-order branches had fewer pod-bearing nodes, and generally the pods at their basal nodes weighed less than those at the basal nodes of primary branches, where flowering began sooner.

The same cultivars were grown at Hyderabad in 1976–7, and again the same pattern of decline in components of yield at the more apical nodes was observed. These cultivars were also grown at Hissar, in north India, where the winter season is cooler and longer

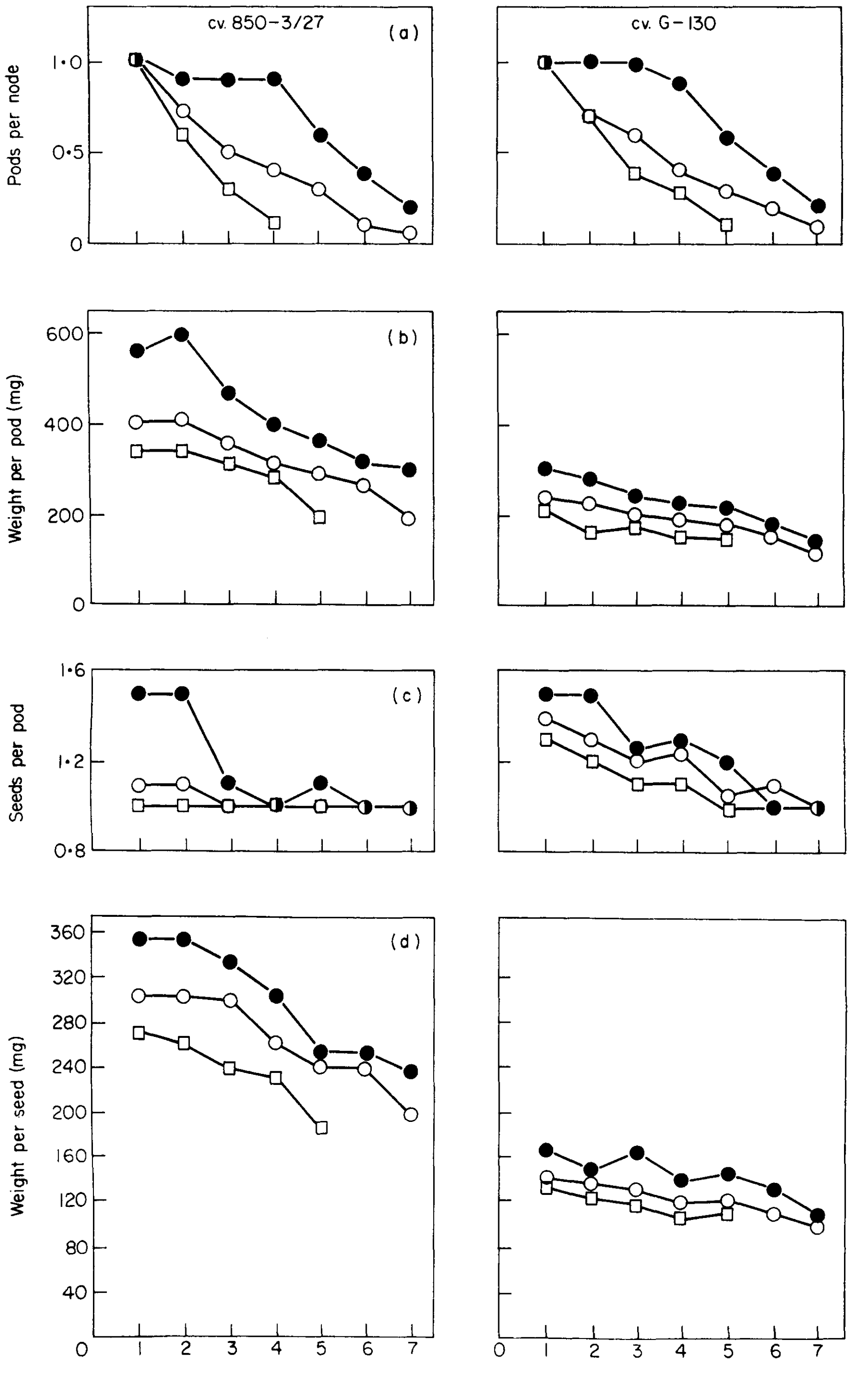

FIG. 1. Mean pod number per node (a), weight per pod (b), seeds per pod (c) and weight per seed (d) at successive pod-bearing nodes on main stems (■), primary branches (○) and secondary branches (□) of cvs 850-3/27 and G-130 grown at Hyderabad in 1974–5.

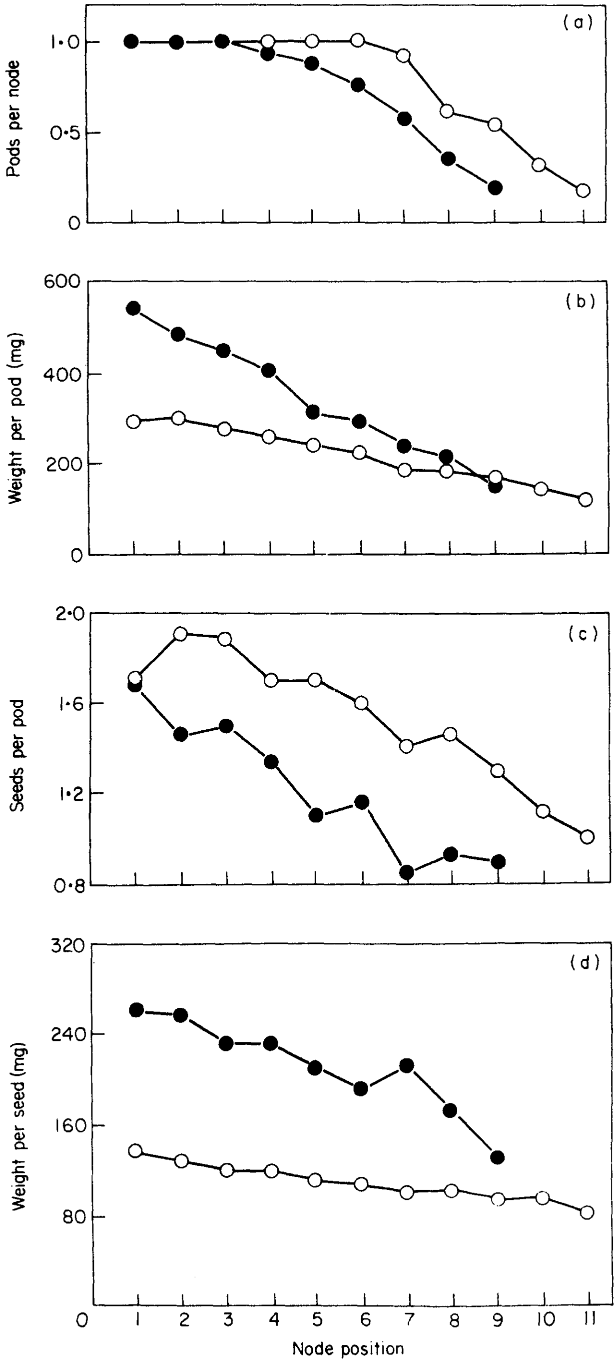

FIG. 2. Mean pod number per node (a), weight per pod (b), seeds per pod (c) and weight per seed (d) at successive pod-bearing nodes on primary branches of cvs 850-3/27 (●) and G-130 (○) grown at Hissar in 1976–7.

than at Hyderabad. At Hissar there were more pod-bearing nodes per branch and the average yield, 3447 kg ha^{-1}, was nearly three times that at Hyderabad (1240 kg ha^{-1}). In all cultivars, the weight per pod, seed number per pod and weight per seed declined at the more apical nodes. Data for cvs 850-3/27 and G-130 are shown in Fig. 2.

Nitrogen content of earlier- and later-formed seeds

The seeds from different node positions on the primary branches of four cultivars grown at Hyderabad and Hissar in 1976–7 were analysed for nitrogen. There was little or no difference in the percentage of nitrogen in the earlier- and later-formed seeds at Hyderabad, but at Hissar in all four cultivars the percentage of nitrogen increased in the seeds at the more apical node (Table 1). These data indicate that the development of the later-formed seeds was not limited by the supply of nitrogen, at least at Hissar.

The numbers of ovules in earlier- and later-formed flowers

We compared the number of ovules per carpel in earlier- and later-formed flowers of two 'desi' (850-3/27 and F-502) and two 'kabuli' cultivars (L-550 and Rabat) grown at Hyderabad in 1976–7. In none was there a significant decline; indeed in cv. 850-3/27 there was a tendency for the later-formed flowers to contain more ovules (Table 2).

TABLE 1. *Percentage of nitrogen in seeds at different node positions of four cultivars grown at Hyderabad and Hissar in* 1976–7

Node position	Hyderabad				Hissar			
	JG-62	850-3/27	L-550	G-130	JG-62	850-3/27	L-550	G-130
1	2·93	3·10	3·10	3·33	2·89	3·31	3·27	3·26
2	3·04	3·02	3·19	3·31	2·97	3·18	3·31	3·06
3	2·85	3·03	3·26	3·28	2·87	3·09	3·25	3·13
4	2·96	2·97	3·26	3·21	3·12	3·08	3·16	3·04
5	2·98	2·92	—	3·26	3·54	3·23	3·15	3·01
6	3·03	2·94	—	3·36	3·15	3·32	3·23	3·17
7	2·99	2·96	—	—	3·35	3·53	3·41	3·24
8	—	—	—	—	3·39	3·76	3·45	3·40
9	—	—	—	—	3·32	3·79	3·73	3·66

TABLE 2. *Number of ovules per carpel* ($\pm$*s.e.*) *in early- and late-formed flowers of four cultivars grown at Hyderabad in* 1976–7

Cultivar	Early flowers	Late flowers
850-3/27	$2{\cdot}09 \pm 0{\cdot}088$	$2{\cdot}51 \pm 0{\cdot}158$
F-502	$2{\cdot}04 \pm 0{\cdot}118$	$2{\cdot}08 \pm 0{\cdot}178$
L-550	$2{\cdot}01 \pm 0{\cdot}029$	$2{\cdot}04 \pm 0{\cdot}048$
Rabat	$2{\cdot}24 \pm 0{\cdot}224$	$2{\cdot}12 \pm 0{\cdot}180$

In two cultivars, 850-3/27 and L-550, grown at Hyderabad in 1975–6, earlier- and later-formed flowers were tagged; the developing pods were sampled at weekly intervals. The number of developing seeds per pod declined from just over two to about one during the second week; the decline was greater in the later-formed pods.

These results indicate that the smaller number of seeds in later-formed pods resulted from the abortion of more developing seeds, and not because the later-formed flowers had fewer ovules.

Comparisons among cultivars

In 22 out of 23 cultivars grown at Hyderabad in 1975–6 there was the usual decline in weight per pod, seed number per pod and/or weight per seed at successively apical nodes. In the larger-seeded cultivars, the decline in weight per pod was largely owing to a decline in seed weight; in the smaller-seeded cultivars, which tended to have more seeds per pod, seed number declined more than seed weight (Table 3). The negative correlation between apical:basal ratio of weight per seed and mean weight per seed ($r = -0{\cdot}60$) was significant at $P = 0{\cdot}01$. There was no significant relationship between the number of days of flowering and the apical:basal ratio of weight per pod ($r = -0{\cdot}19$).

TABLE 3. *Mean weight per seed and days to flowering of 23 chickpea cultivars, differing in maturity group and seed size, grown in 1975–6, and weight per pod, seed number per pod, and weight per seed at the two most apical pod-bearing nodes expressed as fractions of the values at the two most basal pod-bearing nodes*

Cultivar (ICC-number)	Mean weight per seed (mg)	Days to flowering	Apical:basal fraction		
			Weight per pod	Weight per seed	Seeds per pod
4972	289	67	0·67	0·62	0·93
1837	274	58	0·52	0·61	1·00
892	258	69	0·46	0·68	0·69
4999	254	49	0·62	0·66	0·98
1008	233	65	0·64	0·54	0·90
2281	233	63	0·50	1·03	0·53
5689	223	49	0·50	0·43	1·02
1236	215	49	0·39	0·63	0·69
346	173	69	0·51	0·87	0·64
371	168	69	0·47	0·64	0·73
1859	150	49	0·60	0·65	0·94
1860	146	58	0·77	0·79	0·94
431	145	53	0·54	0·90	0·64
4092	136	53	0·59	1·14	0·57
1861	135	53	0·58	0·76	0·61
336	126	65	0·55	0·86	0·63
1460	126	58	0·59	0·78	0·78
145	114	53	0·79	0·90	0·70
3031	111	49	0·65	1·08	0·58
178	109	44	0·54	0·87	0·57
138	92	53	0·36	0·68	0·52
4074	88	58	0·69	0·99	0·59
6013	42	49	1·11	1·04	1·03

The declines in the number of seeds and/or weight per seed in later-formed pods of all cultivars except ICC-6013 (Figs 1 and 2; Table 3) indicate that pod-filling was limited by the availability of assimilates or other nutrients. Nitrogen seems unlikely to have been limiting, at least at Hissar (Table 2).

The assimilate supply declines during the reproductive phase because of the declining leaf area as the plants senesce and the demand from developing pods (Sheldrake and Saxena, in press). If yield were limited by sink size, rather than by the supply of nutrients, the later-formed pods would be as well-filled as the earlier-formed pods; this was indeed the case in the exceptionally small-seeded cv. ICC-6013.

A general pattern of decline in the size of later-formed pods is found in other herbaceous legumes (Sinha, 1977). By contrast, in pigeonpeas there is no such decline; yield is limited by the numbers of pods set, rather than the ability of the plants to fill the pods (Sheldrake and Narayanan, 1979).

ACKNOWLEDGEMENTS

We thank Mr L. Krishnamurthy for technical assistance and Mr S. R. U. Rahman for the nitrogen analysis.

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 ICRISAT.

LITERATURE CITED

SHELDRAKE, A. R. and NARAYANAN, A., 1979. Comparisons of earlier- and later-formed pods of pigeonpeas (*Cajanus cajan* (L.) Millsp.). *Ann. Bot.* **43**, 459–466.

—— and SAXENA, N. P., 1979. The growth and development of chickpeas under progressive moisture stress. In *Stress Physiology in Crop Plants*, ed. H. Mussell and R. C. Staples. Wiley-Interscience, New York (in press).

SINHA, S. K., 1977. *Food Legumes: Distribution, Adaptability and Biology of Yield.* FAO Plant Production and Protection Paper 3. Food and Agriculture Organization of the United Nations, Rome.