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Growth and yield of determinate and indeterminate cowpeas in dryland agriculture

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SUMMARY

Cowpea is an important food legume crop of arid and semi-arid regions of the tropics. In such climates whether a determinate or indeterminate type of growth habit would be more useful is not clear. In the present study a determinate and indeterminate cultivar of cowpea were grown at two population densities under rainfed conditions for 2 years. Grain yield was higher in the indeterminate variety for both years. At higher density more dry matter was produced but it had no effect on grain yield. Nitrogen analysis showed that it moved from leaves to developing pods. However, a large amount of nitrogen was still left in vegetative parts in contrast to cereals. Pod development was completed in 19 days and the rate of dry-matter accumulation during the peak period of growth was as high as 120 mg/day per fruit. It was difficult for the plant to cope with this high demand for photosynthates. It is suggested that more pods can develop on a plant provided the growth rate of individual pods is slower and extended to a longer period.

INTRODUCTION

Food legumes are important crops in arid and semi-arid regions of India and other tropical regions (Sinha, 1977). Among the various food legumes, cowpeas occupy a significant place. In recent years efforts have been made to improve the productivity of various food legumes (Sinha, 1974). There are suggestions that determinate types may be more successful because the synchronous habit has proved more advantageous in wheat and rice. However, the fact is that food legumes are dryland crops and it is questionable whether determinate types would really have any advantage in such conditions. In this communication we report the behaviour of a determinate and an indeterminate cowpea at Delhi.

MATERIALS AND METHODS

Cowpea cvs C-152 and C-779, indeterminate and determinate types respectively, representative of their groups, were grown in 1977 and 1978, each at two levels of population density, (P_1) 12 and (P_2) 24 plants/m^2. In 1977 only yield data was recorded but in the next year detailed observations were made on growth, nitrogen accumulation, flowering and fruit and seed development. The plot size was 5 × 6 m and N, P and K were given at rates of 20, 60 and 30 kg/ha respectively at the time of sowing. There were three replicates for each of the treatments. Data on rainfall and temperature were recorded regularly during the crop season. Weekly samples of plants from the 2nd week after sowing were obtained. Leaf area was recorded by using model AA7 automatic area meter (Hayashi Denkoh Comp., Japan). Plant material was dried at 80 °C and weighed.

When the plants started flowering they were tagged in each replication and the number of flowers recorded by counting the number of flowers or flower bud scars and the number of fruits. The total number of inflorescences was also determined. Thus, the effective fruit setting percentage could be calculated. Fruit and seed development was determined after tagging inflorescences on the 2nd or 3rd days. Samples for fruit development were obtained at 2-day intervals. Nitrogen content was determined following the method of Novozamsky *et al.* (1974).

RESULTS

Vegetative characters

In the first 4 weeks after sowing accumulation of dry matter was slow and no differences among either the varieties or the density treatments could be observed (Fig. 1). However, branching started from the 2nd week and reached near maximum by the 5th week (Fig. 2). The determinate variety C-779

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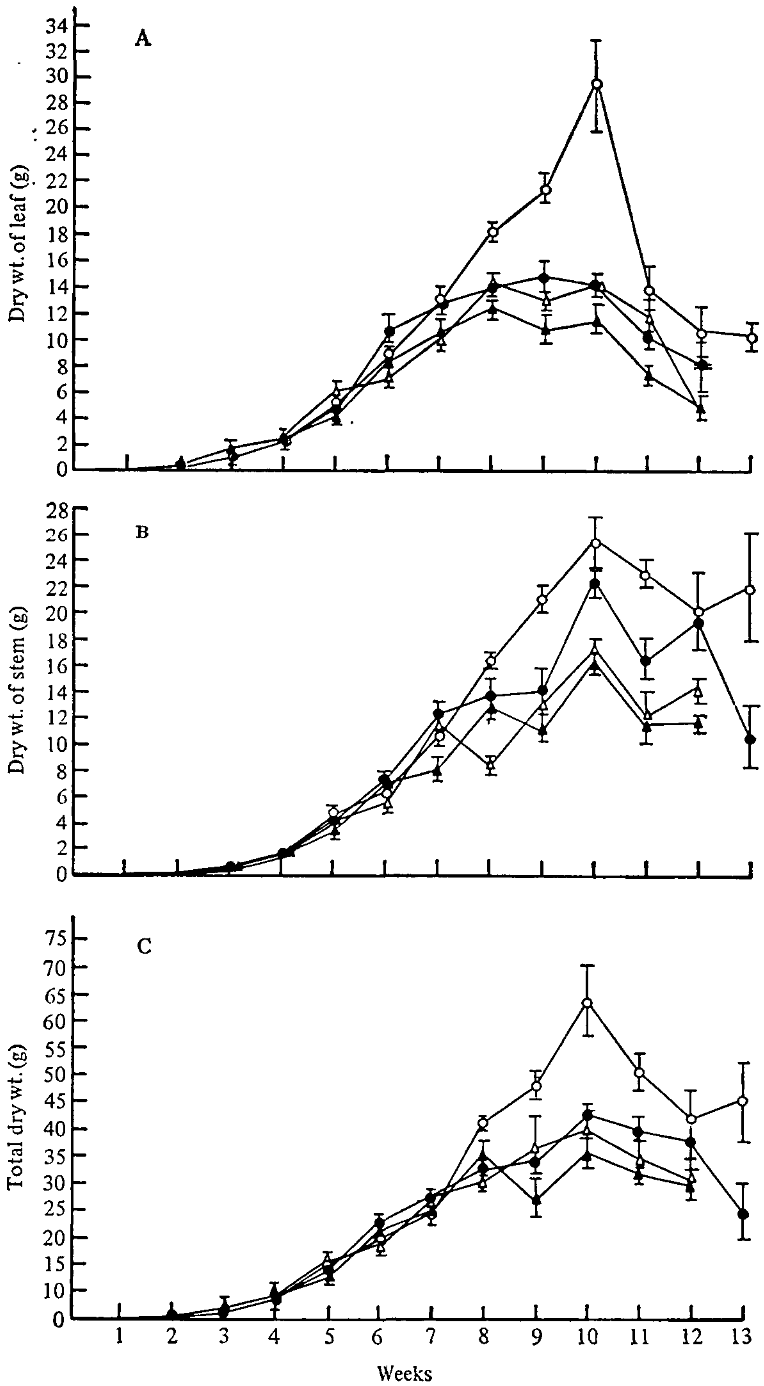

Fig. 1. Pattern of dry-matter accumulation in cowpea. A, leaf; B, stem and C, whole shoot. C-152, 12 plants/m^2 (○); C-152, 24 plants/m^2 (●); C-779, 12 plants/m^2 (△) and C-779, 24 plants/m^2 (▲); standard error (I).

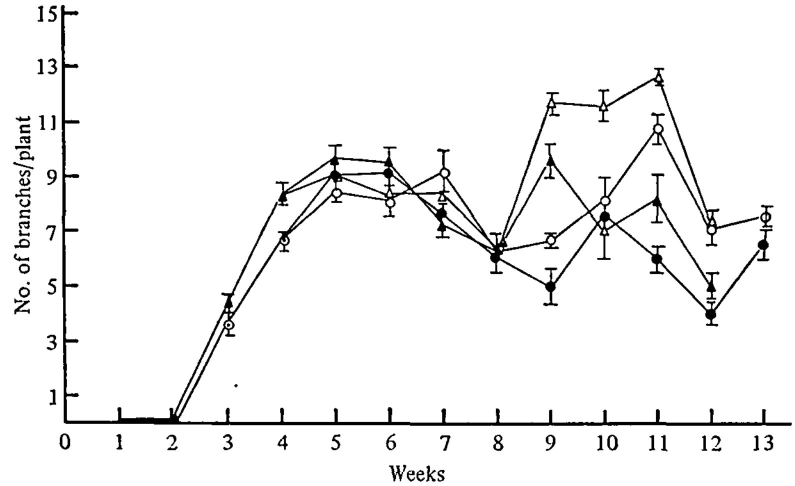

Fig. 2. Weekly change in numbers of branches in cowpea. C-152, 12 plants/m² (○); C-152, 24 plants/m² (●); C-779, 12 plants/m² (△) and C-779, 24 plants/m² (▲); standard error (I).

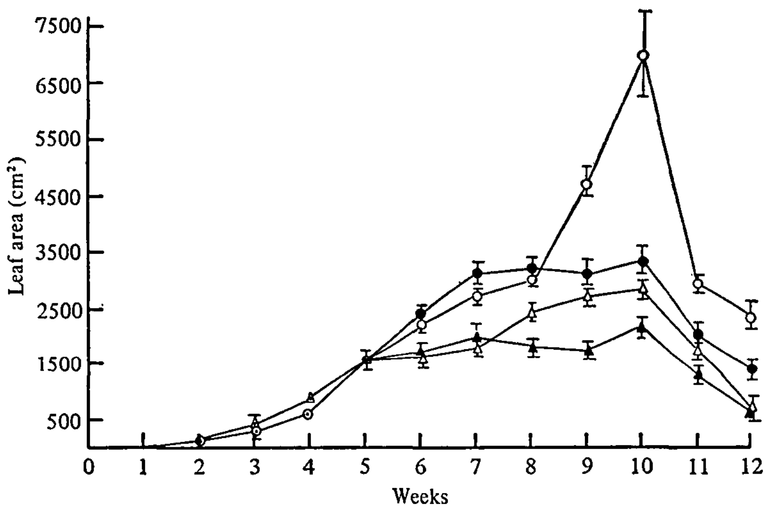

Fig. 3. Weekly change in leaf area per plant in cowpea. C-152, 12 plants/m² (○); C-152, 24 plants/m² (●); C-779, 12 plants/m² (△) and C-779, 24 plants/m² (▲); standard error (I).

had more branches but there were no treatment differences. There were no differences in the number of branches among the varieties or the treatments until the 5th week but there was a decrease in the number of branches from the 5th to 8th week indicating failure of some of the branches to survive and grow. From the 8th week onward the number of branches increased in the low density treatment in both varieties. During this period the determinate variety C-779 maintained more branches. On the other hand it is seen from Fig. 1 that the indeterminate variety C-152 had more dry matter in leaves, stem and total plant beyond the 8th week. Thus it is clear that in the determinate variety the size of branches was smaller. In both the varieties, the plants at the low population density had a greater leaf area (Fig. 3), dry weight of stem and total plant weight. This difference was relatively greater in the indeterminate variety than in the determinate variety. This would suggest that the indeterminate variety had the greater capacity of compensation if larger space was available.

Both net assimilation rate (NAR) and relative growth rate (RGR) were determined at weekly intervals. Interestingly, NAR appeared to have a rhythmic pattern (Fig. 4). However, in both the varieties the peak for NAR appeared at the pre-flowering or flowering stage and subsequently declined. In C-779 the NAR peak was very high just prior to flowering. A continuous decrease in NAR could be indicative of the fact that there was sufficient leaf area on plants but there were many leaves which had reduced assimilatory activity. Although the differences due to density effect were insignificant, in C-152 the higher density treatment maintained higher NAR than the low density treat-

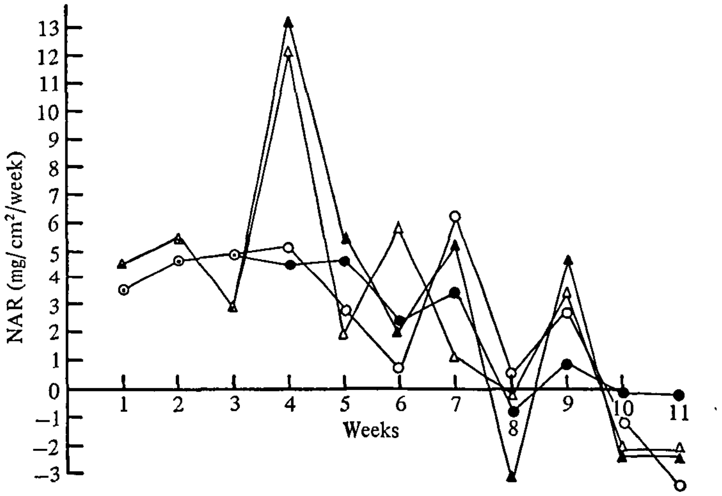

Fig. 4. Weekly change in net assimilation rate (NAR) in cowpea. C-152, 12 plants/m^2 (○); C-152, 24 plants/m^2 (●); C-779, 12 plants/m^2 (△) and C-779, 24 plants/m^2 (▲).

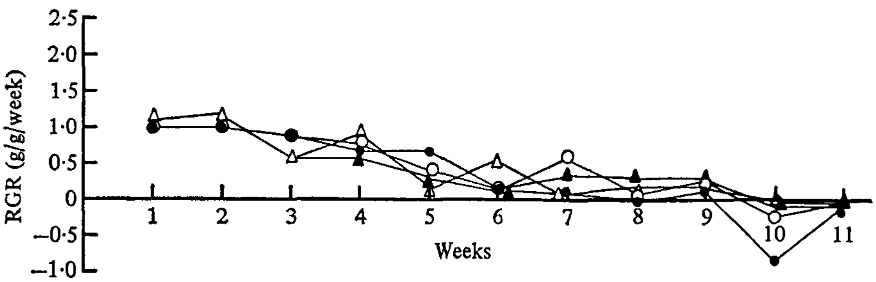

Fig. 5. Relative growth rate (RGR) in cowpea at weekly intervals. C-152, 12 plants/m^2 (○); C-152, 24 plants/m^2 (●); C-779, 12 plants/m^2 (△) and C-779, 24 plants/m^2 (▲).

Table 1. *Yield and yield components of determinate and indeterminate cowpea*

		No. of pods formed/plant	% pod setting	100-seed weight	Grain yield (t/ha) 1977	1978	Average
C-152	P_1 (indeterminate)	22·5	31·4	8·23	1·28	1·73	1·51
C-152	P_2	26·5	42·3	8·44	1·54	1·73	1·63
C-779	P_1 (determinate)	24·5	40·1	8·80	0·45	1·56	1·01
C-779	P_2	37·0	42·6	8·37	0·49	1·46	0·97
L.S.D.	(P = 0·05)	1·97	—	0·19	—	—	0·23

P_1 = 12 plants/m^2. P_2 = 24 plants/m^2.

ment after flowering. The relative growth rate (RGR) was highest in the earliest stages and it gradually declined until it became negative in the 10th week (Fig. 5). Thus, as expected, there was an increase in organs and parts such as stem and senescent leaves which did not contribute to assimilatory ability of plants.

Reproductive characteristics

There were three flowering flushes in the indeterminate variety whereas in the determinate variety only two flushes were distinct. The number of flowers per plant in each flush were 79, 80 and 70 respectively in varieties C-152, 80 and 62 in C-779.

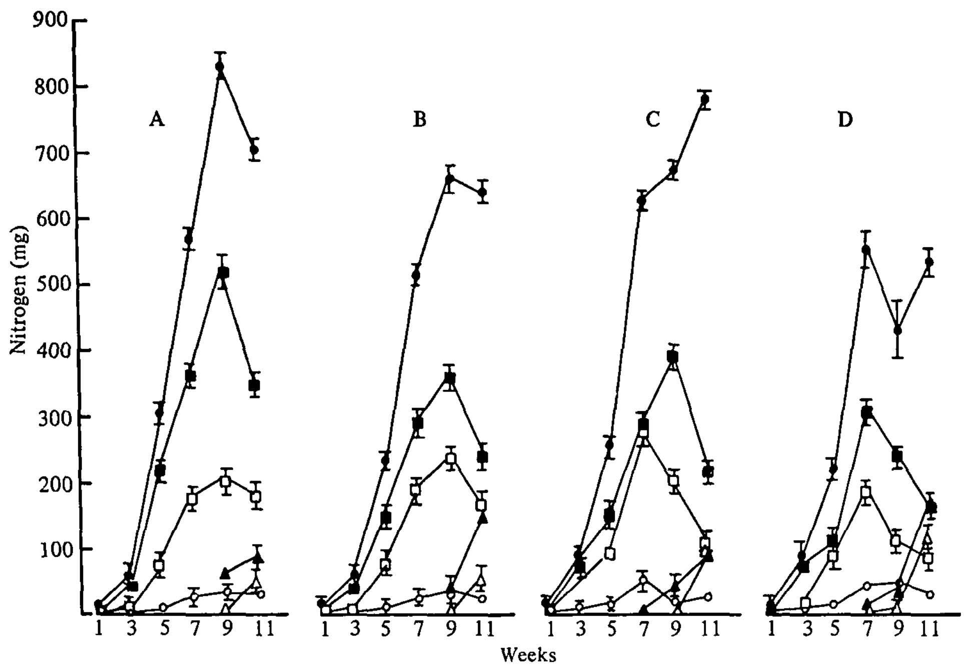

Fig. 6. Change in nitrogen accumulation with age in cowpea. A, C-152, 12 plants/m²; B, C-152, 24 plants/m²; C, C-779, 12 plants/m²; D, C-779, 24 plants/m². Total (○), leaf (■), stem (□), root (○), pod cover (△) and seed (▲); standard error (I).

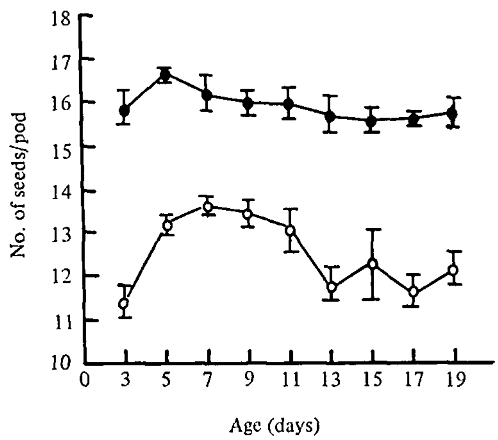

Fig. 7. Change in number of seeds/pod with age in cowpea C-152 (○) and C-779 (●); standard error (I).

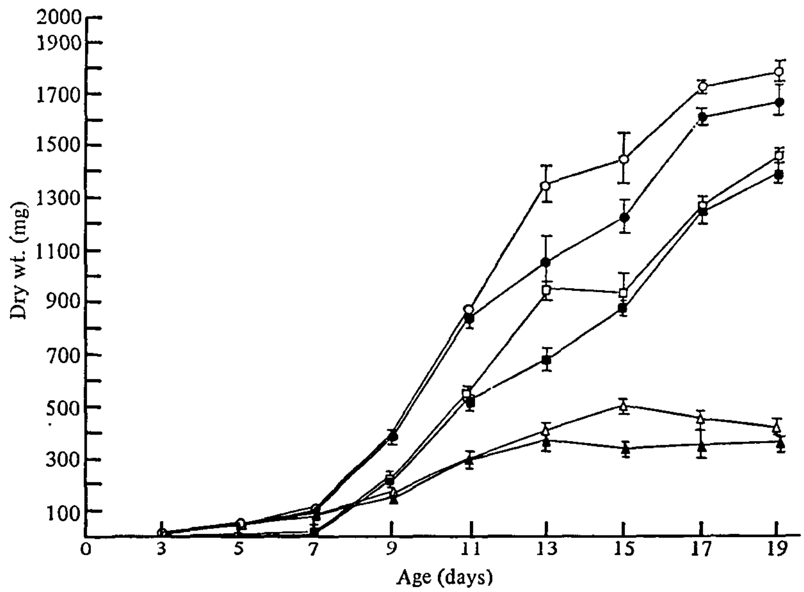

Fig. 8. Dry weight changes with age in whole pod (○), pod cover (△) and seed (□) of cowpea. C-152 (shaded) and C-779 (open); standard error (I).

In the indeterminate variety fruit setting percentage increased with the increasing density whereas there was almost no effect of population density on fruit setting in the determinate variety (Table 1). This was due to a decrease in the number of flowers per inflorescence. Although the number of pods per plant increased at higher density, the 100-seed weight remained unaffected in C-152 and was slightly reduced at higher density in C-779 (Table 1).

In both the years, irrespective of the rainfall pattern, the indeterminate variety gave higher yield (Table 1).

Accumulation and distribution of nitrogen

Accumulation and partitioning of nitrogen are important in pulse crops. In both the varieties the total nitrogen per plant was greater in the P_1 treatment (Fig. 6). On an area basis more nitrogen was assimilated in P_2. In C-152 there was a decrease in total nitrogen after the 9th week but in the determinate type there was no significant decrease. An important feature of nitrogen distribution was that the leaf nitrogen decreased when fruit development occurred. In the determinate variety the decrease in nitrogen occurred in both leaves and stem. This appeared to suggest that after the 7th week there was no substantial assimilation of nitrogen. Apparently nitrogen from leaves and stem was mobilized for the development of pods. The mobilization from the stem was greater in the determinate variety.

A maximum of 153·8 kg N/ha was accumulated in the P_2 treatment in C-152. At the same density the determinate variety accumulated 140 kg N/ha. However, at low population density the accumulation of nitrogen was less. Considering the fact that the period of nitrogen accumulation lasted only 5 weeks, it is estimated that nitrogen was assimilated at a rate of 4·5 kg N/ha per day.

Fruit and seed development

Fruit development in cowpea being fast, it took only 19 days from anthesis to fruit maturation. In C-152 the number of seeds per pod was determined by the 7th day and it did not change thereafter (Fig. 7). On the other hand, in C-779 the number of developed seeds per pod decreased slightly. This is interesting because such material could be utilized for compensatory studies in relation to various adverse effects such as water deficit.

Dry-matter accumulation in the fruit wall increased progressively from anthesis to the 15th and 13th days in C-779 and C-152 respectively (Fig. 8). For the first 7 days the accumulation of dry matter in pod wall was more than in the seeds. But the seed development had a sharp peak between the 7th and 17th days after anthesis. During this period about 1·2 g dry matter was accumulated by the seeds per pod.

In C-152, nitrogen accumulation continued up to the 11th day in both fruit wall and seeds (Fig. 9). Thereafter, seeds continued to accumulate nitrogen but there was a gradual loss of nitrogen from the

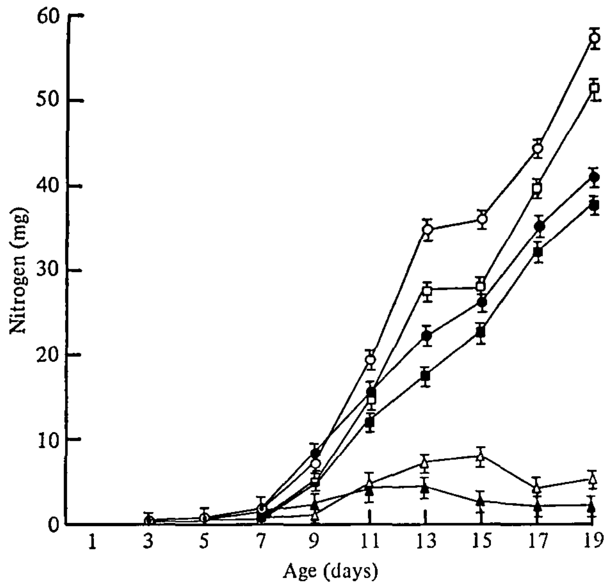

Fig. 9. Change in nitrogen accumulation in whole pod (○), pod cover (△) and seed (□) of cowpea. C-152 (shaded) and C-779 (open); standard error (I).

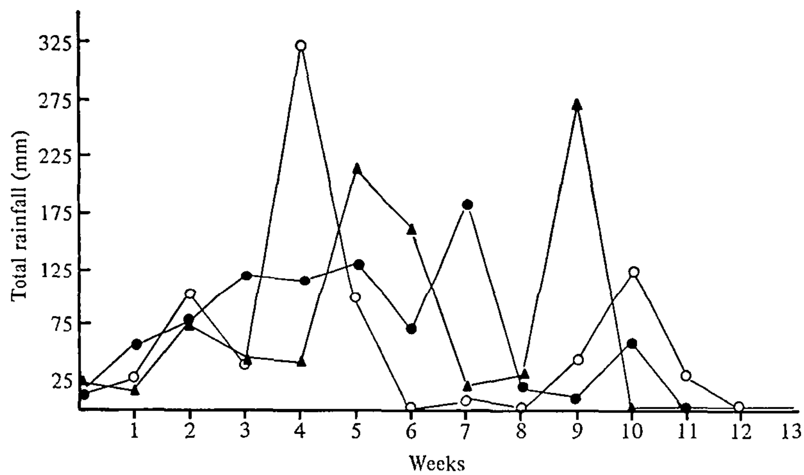

Fig. 10. Seasonal variation in rainfall at New Delhi, 1976 (●), 1977 (○) and 1978 (▲).

fruit wall from the 13th day onward. The results suggest that a small part of nitrogen accumulated in seeds was obtained from pod wall. However, there was a continuous increase in nitrogen content of seeds from 7 days after anthesis till maturity.

DISCUSSION

Cowpeas are grown largely as a rainfed or dryland crop. The suitability of varieties for such conditions has been a point of discussion. The present study showed that the indeterminate variety C-152 gave higher yield than the determinate variety C-779, irrespective of the rainfall pattern (Fig. 10). These two varieties do not differ significantly in pod size and seed weight which constitute important yield components.

The number of plants per hectare has a profound effect on the yield of cowpeas. Erskine & Khan (1976) and Ojehomon & Bamiduro (1971) obtained higher yield with increasing plant density up to 10–12 plants/m^2. In our studies no difference in yield was observed between 12 and 24 plants/m^2. Of the two varieties C-152 produced more dry matter. However, one distinctive feature of growth analysis was that the variety C-779 had a sharp NAR peak before flowering. This variety has relatively low leaf area and does not form a thick canopy so as to make lower leaves photosynthetically ineffective.

The data on nitrogen showed that there was mobilization of nitrogen from leaves to the developing pods but despite this a considerable amount of nitrogen was still left in the vegetative parts. This was much more than is left behind in cereals such as wheat. One possibility is that there is not enough availability of carbohydrates at this stage to make effective use of nitrogen present in the plant.

In our studies it was noticed that there were flushes of flowering and fruit setting. The fruit development took only 19 days to reach maturity. The rate of accumulation of dry matter in grains per pod reached 120 mg/day during the peak period of fruit development. This is a very high rate of seed development compared with any cereals (Evans, 1975) and would require the support of a high rate of photosynthesis. However, it has been reported by Sinha (1974, 1977) that in cowpeas, mung bean and chick peas there is a decline in photosynthesis rate following early fruit development which is associated with decreased RuDP carboxylase activity. Apparently then the assimilation of carbon dioxide becomes a limiting factor as has been observed in soya bean also (Hardy & Havelka, 1975). Therefore, if the development of more pods is desired, it may be useful to have slow development of pod so that it does not become a strong stress on the photosynthesis apparatus. This may also help in better utilization of dry matter for fruit development. Thus from the present study we reach the following conclusions: (1) The indeterminate types are better than determinate types under dryland conditions. (2) A simultaneous development of vegetative phase and fruit development may be more advantageous for utilizing dry matter and assimilated nitrogen. (3) In conjunction with this a longer duration of pod development may be more useful.

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