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Assessment of ratoonability of short-duration pigeonpea genotypes

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SUMMARY

The extent of variation in ratoonability was examined in a range of recently bred short-duration pigeonpea [*Cajanus cajan* (L.) Millsp.] genotypes in 1989/90, 1990/91 and 1991/92 at the ICRISAT Asia Center, Andhra Pradesh, India. Traits with which this variation could be associated were assessed. Differences in the total ratoon yield of two flushes were significant among the genotypes in each season. In a few genotypes, ratoon yield constituted 50% of the total yield, which could be as high as 5·6 t/ha. Total ratoon yield was positively correlated with leaf area index in the last 2 years of experimentation. The relationship of total ratoon yield to main crop yield was significantly positive in 1991/92 only. The results suggest that there is a large variation in ratoonability among short-duration genotypes and that high leaf area retention at main crop maturity appears to contribute substantially to this variation.

INTRODUCTION

Pigeonpea [*Cajanus cajan* (L.) Millsp.] is a perennial plant, but it is usually grown as an annual crop. The possibility of exploiting the perennial nature of the plant to obtain substantial forage and seed yields from its ratoon growth has been indicated by Killinger (1968). The potential for ratooning pigeonpea has been subsequently demonstrated by several researchers (Akinola & Whiteman 1975; Sharma *et al.* 1978; Tayo 1985; Venkataratnam & Sheldrake 1985).

Interest in the commercial exploitation of the ratoonability of pigeonpea has been revived by the very high ratoon yield potential of a short-duration cultivar, ICPL 87 (Chauhan *et al.* 1987*a*). One of the advantages of using short-duration cultivars for ratooning is that the main crop matures soon after the rainy season, thereby permitting the utilization of residual moisture by the ratoon crop (Rao & Sachan 1988). Hence, additional short-duration cultivars similar to ICPL 87 are needed to suit specific production niches while meeting farmers' preferences for seed size, seed colour and other agronomic traits and also incorporating resistance to diseases and insect pests. The process of developing such cultivars with high ratoonability could be hastened if it could be determined whether any of the main crop traits or the main crop yield itself influences ratoon yield formation. Chauhan *et al.* (1987*a*) suggested that the superior ratoonability of ICPL 87 could be due to its high leaf area retention. The potential of leaf area as a selection criteria to identify genotypes with high ratoonability has not been examined. The objectives of the present study were, therefore, to assess recently bred, short-duration pigeonpea genotypes for ratoonability and to examine the relationship of ratoon yield with main crop yield and leaf area retention at main crop maturity.

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MATERIALS AND METHODS

The experiments were conducted at the ICRISAT Asia Center, Patancheru (18° N, 78° E, 540 m elevation) on Alfisols (Udic Rhodustalf) in 1989/90, 1990/91 and 1991/92. The available water-holding capacity of the soils is < 100 mm (Venkataratnam & Sheldrake 1985). Rainfall and temperatures recorded in a nearby meteorological observatory are given in Table 1.

Twelve genotypes (F_6 or later generations) in 1989/90, 15 in 1990/91 and 20 in 1991/92, which were undergoing advanced yield testing, were assessed for ratoonability (Table 2). The experiments in each season were laid out in randomized block designs with four replications. The sowing dates were 23 June 1989, 18 June 1990 and 22 June 1991. The net plot size in each season was 13 m² (3·6 × 3·6 m) with about 400

Table 1. *Mean monthly temperatures and rainfall and amount of irrigation applied to pigeonpea in 1989/90, 1990/91 and 1991/92 at ICRISAT, Patancheru, India*

	Mean temperature (°C)			Rainfall (mm)			
Month	1989/90	1990/91	1991/92	1989/90	1990/91	1991/92	Long-term mean
June	28·3	26·8	28·0	99	84	238	106
July	25·8	26·4	25·9	83	145	416	163
August	25·5	25·6	25·8	109	269	172	148
September	25·7	26·0	26·7	286	96	106	174
October	24·9	24·3	25·3	27	129	55	79
November	22·5	23·3	22·2	0	11	3	25
December	20·8	21·1	20·4	5	0	0	6
January	21·1	22·3	20·1	10	16	0	6
February	24·0	24·4	23·1	0	3	0	9
March	27·2	28·6	27·5	6	1	0	11
Total				625·4	754·3	989·6	
Irrigation (mm)				550·0	250·0	450·0	

plants plot^{-1}. Two seeds per hill were sown at 10 cm spacing within shallow furrows opened 30 cm apart on both sides of 60 cm ridges. Seedlings were thinned to one per hill at *c*. 25–30 days after sowing (DAS).

All the experimental plots received a basal application of diammonium phosphate (N:P in the ratio 18:20) at the recommended rate of 100 kg/ha. Plants were well nodulated with native *Rhizobium*, which is abundant in these soils. Weeds were controlled by a pre-emergence application of a tank mixture of fluchloralin at 0·75 kg active ingredient (a.i.)/ha and prometryn at 1·25 kg a.i./ha followed by three hand-weedings at monthly intervals after sowing. Four insecticides, endosulfan (2 l/ha), monocrotophos (1 l/ha), quinalphos (2 l/ha) and methomyl (2 l/ha) were used in rotation to control insect pest damage, especially that caused by *Helicoverpa armigera*, at 8–10 day intervals starting from the time of flowering of the main crop. To allow the maximum expression of ratoon yield potential, crops were irrigated 11 times in 1989/90, five times in 1990/91 and nine times in 1991/92 when the crop began to show acute paraheliotropic movement of leaves at noon. The approximate amounts of supplemental irrigation given to the crop during this period are also shown in Table 1.

At maturity of the main crop, five plants were sampled from each plot to estimate leaf area index (LAI) in 1989/90 and 1990/91. In 1991/92, LAI was measured non-destructively using a Plant Canopy Analyzer (Model LAI 2000, Licor Inc, USA).

The mature (brown-coloured) pods of the main and the first ratoon crops were harvested by picking the pods by hand as described by Chauhan *et al.* (1987*b*). The second ratoon crop was harvested by cutting the stems at the base. The first harvest was between 20 October and 24 November in 1989/90, between 4 October and 31 October in 1990/91, and between 9 October and 26 October in 1991/92, depending on time to maturity of the particular genotype. Likewise, the second harvest was done from 21 December to 22 January in 1989/90, from 8 December to 19 December in 1990/91 and from 22 January to 3 February in 1991/92. The third harvest was done on 14 March in 1989/90, on 28 February in 1990/91 and between 30 March and 6 April in 1991/92.

The data were analysed statistically using GENSTAT software. The relationship of total ratoon yield with the main crop yield, and final LAI of the main crop (which were expected *a priori* to influence ratoon yield and total yield) were determined.

RESULTS

Climatic variability

There was little variation in temperature across the seasons, but the total rainfall and its distribution varied considerably (Table 1). September of the 1989/90 season was very wet, with nearly three times as much rain as that received in the other seasons for this month. Similarly, very high rainfall was received in August of the 1990/91 season and July of the 1991/92 season. Within each growing season, mean temperatures declined in November and December. There was little rainfall after October in each season when the crops were irrigated.

Comparison of genotypes for main and ratoon crop yields

Grain yields of the main as well as ratoon crops varied significantly among the genotypes (Table 2). The total yield for the two ratoon crops was highest in ICPL 87102 and ICPL 86012 in 1989/90, ICPL 88027 in

Table 2. *Yield (t/ha) of main crop, first ratoon, second ratoon, total ratoon and total yield of short-duration pigeonpea genotypes in 1989/90, 1990/91 and 1991/92 in India*

	1989/90					1990/91					1991/92				
Genotypes	Main crop	First ratoon	Second ratoon	Total ratoon	Total	Main crop	First ratoon	Second ratoon	Total ratoon	Total	Main crop	First ratoon	Second ratoon	Total ratoon	Total
ICPL 87	3·27	0·28	0·81	1·09	4·36	2·05	0·36	1·24	1·60	3·65	2·96	1·90	0·66	2·56	5·52
ICPL 83015	—	—	—	—	—	2·00	0·24	0·41	0·65	2·65	2·56	0·66	0·17	0·82	3·39
ICPL 83024	2·77	0·13	0·54	0·67	3·44	2·06	0·43	1·14	1·57	3·64	—	—	—	—	—
ICPL 84031	—	—	—	—	—	2·05	0·23	1·15	1·38	3·43	—	—	—	—	—
ICPL 84052	—	—	—	—	—	—	—	—	—	—	2·34	2·01	0·76	2·77	5·11
ICPL 85010	—	—	—	—	—	—	—	—	—	—	1·84	0·69	0·20	0·90	2·74
ICPL 85012	2·26	0·86	0·96	1·82	4·08	—	—	—	—	—	—	—	—	—	—
ICPL 85015	—	—	—	—	—	1·81	0·58	1·01	1·59	3·40	2·54	1·81	0·64	2·45	4·99
ICPL 85030	—	—	—	—	—	1·96	0·13	0·85	0·98	2·94	—	—	—	—	—
ICPL 85102	—	—	—	—	—	2·20	0·57	0·82	1·39	3·60	—	—	—	—	—
ICPL 86005	3·03	0·42	0·56	0·98	4·01	—	—	—	—	—	2·53	1·83	0·51	2·34	4·86
ICPL 86007	2·06	0·84	0·92	1·76	3·82	—	—	—	—	—	—	—	—	—	—
ICPL 86012	2·83	1·28	0·71	1·99	4·82	2·26	0·42	1·13	1·55	3·81	2·71	1·70	0·40	2·10	4·81
ICPL 86013	—	—	—	—	—	2·21	0·43	1·03	1·47	3·67	—	—	—	—	—
ICPL 86015	—	—	—	—	—	—	—	—	—	—	1·97	1·60	0·52	2·13	4·10
ICPL 87101	2·94	0·50	0·74	1·24	4·18	—	—	—	—	—	2·61	2·20	0·49	2·69	5·30
ICPL 87102	2·55	1·02	1·04	2·06	4·61	2·15	0·64	0·83	1·48	3·62	—	—	—	—	—
ICPL 87104	2·76	1·13	0·54	1·67	4·43	2·44	0·38	1·22	1·60	4·04	2·75	1·46	0·32	1·78	4·53
ICPL 87105	2·30	0·43	0·84	1·27	3·57	—	—	—	—	—	2·71	2·11	0·56	2·67	5·38
ICPL 87108	2·70	0·29	0·36	0·65	3·35	—	—	—	—	—	—	—	—	—	—
ICPL 87111	—	—	—	—	—	—	—	—	—	—	2·22	0·99	0·21	1·20	3·42
ICPL 88001	—	—	—	—	—	—	—	—	—	—	2·76	1·53	0·70	2·23	4·98
ICPL 88007	—	—	—	—	—	—	—	—	—	—	1·92	0·50	0·11	0·60	2·53
ICPL 88009	—	—	—	—	—	1·87	0·34	1·26	1·60	3·47	—	—	—	—	—
ICPL 88017	—	—	—	—	—	1·98	0·58	0·76	1·34	3·33	—	—	—	—	—
ICPL 88023	—	—	—	—	—	2·53	0·56	1·24	1·80	4·33	2·83	1·95	0·51	2·46	5·29
ICPL 88026	1·84	0·34	0·81	1·15	2·99	—	—	—	—	—	—	—	—	—	—
ICPL 88027	—	—	—	—	—	2·04	0·62	1·29	1·91	3·95	2·91	1·74	0·64	2·38	5·29
ICPL 88032	—	—	—	—	—	—	—	—	—	—	2·08	1·22	0·66	1·88	3·96
ICPL 89024	—	—	—	—	—	—	—	—	—	—	1·67	0·33	0·07	0·40	2·07
ICPL 89030	—	—	—	—	—	—	—	—	—	—	2·84	2·09	0·69	2·78	5·63
UPAS 120	—	—	—	—	—	—	—	—	—	—	2·21	1·80	0·67	2·47	4·68
Mean	2·61	0·63	0·74	1·37	3·98	2·11	0·43	1·03	1·46	3·57	2·45	1·51	0·47	1·98	4·43
S.E.*	0·404	0·143	0·144	0·098	0·471	0·079	0·068	0·060	0·077	0·096	0·171	0·100	0·050	0·132	0·226
C.V. %	15·5	22·9	19·6	14·5	11·9	7·5	31·5	11·6	10·5	5·4	13·9	13·3	20·9	13·4	9·9

* D.F. for 1989/90 = 33, for 1990/91 = 42, for 1991/92 = 57.

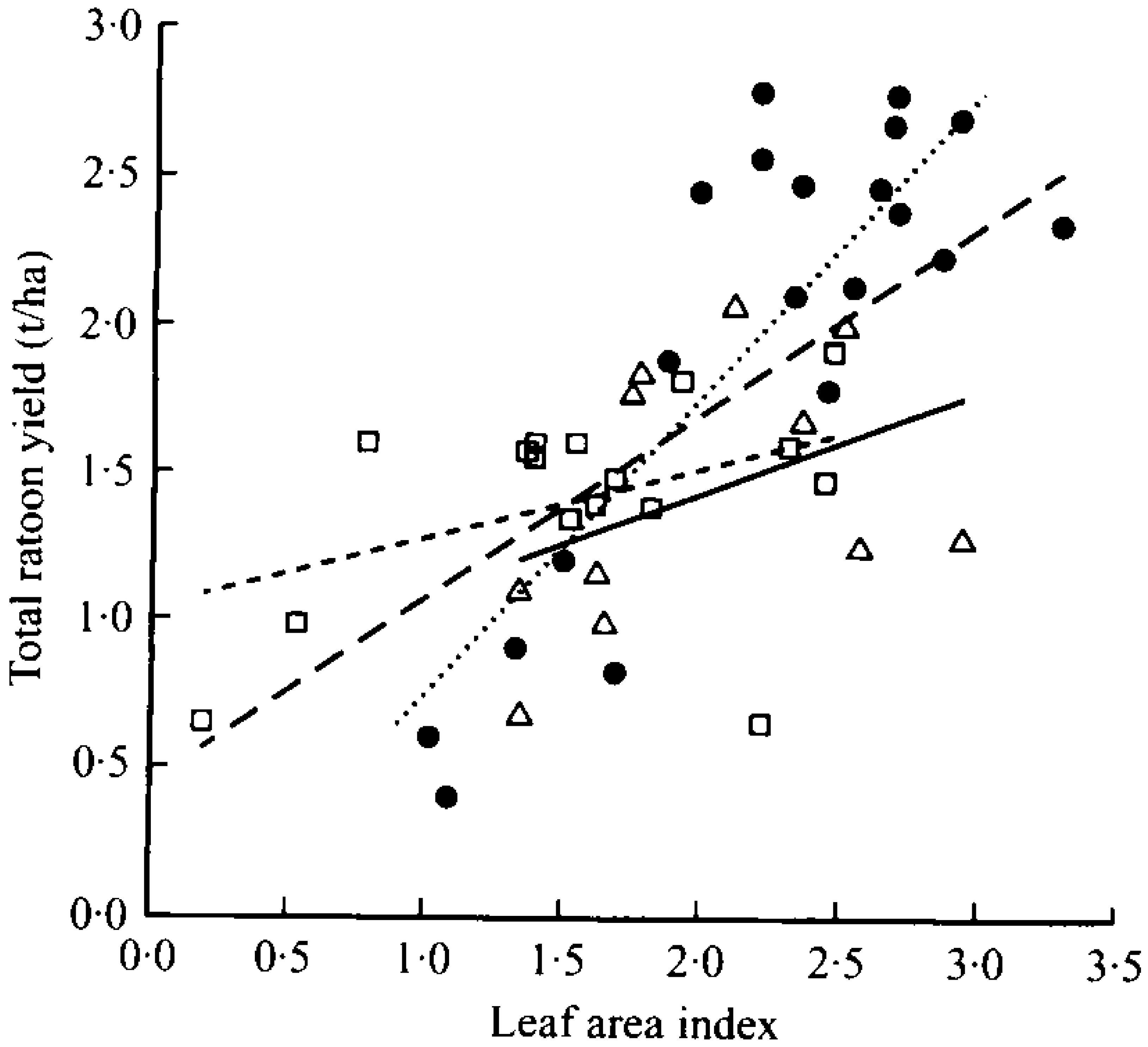

Fig. 1. Relationship between total ratoon yield of two flushes and leaf area index at maturity of the main crop in 1989/90 (△), 1990/91 (□) and 1991/92 (●). Fitted regressions for 1989/90 (–), 1990/91 (– – –), 1991/92 (-----) and the pooled data (– – –) are:
1989/90 $Y = 0.79\ (\pm 0.489) + 0.285\ (\pm 0.287)\ L;\ r^2 = 0.09$
1990/91 $Y = 0.94\ (\pm 0.220) + 0.343\ (\pm 0.089)\ L;\ r^2 = 0.50$
1991/92 $Y = -0.27\ (\pm 0.272) + 1.016\ (\pm 0.159)\ L;\ r^2 = 0.72$
Pooled data $Y = -0.44\ (\pm 0.216) + 0.630\ (\pm 0.105)\ L;$
$r^2 = 0.45$

1990/91, and ICPL 89030 and ICPL 84052 in 1991/92. The lowest total ratoon yield was for ICPL 89024 in 1991/92. Among the three genotypes, ICPL 87, ICPL 86012 and ICPL 87104, which were tested in all three seasons, no genotype was consistently superior for ratoon yield. Although ICPL 87 produced the highest main crop yield in the 1989/90 and 1991/92 seasons, other genotypes gave higher ratoon yields than ICPL 87 in all three seasons, although the difference was significant only in the first two seasons. The highest total yield of the main and ratoon crops was 5·6 t/ha obtained from ICPL 89030 in 1991/92.

The total crop (main + total ratoon) yield had significant positive correlations with total ratoon yield in all three seasons ($r = 0.68$ in 1989/90, 0·89 in 1990/91 and 0·96 in 1991/92) whereas its relationship with the main crop yield was significant in the second ($r = 0.71$) and the third ($r = 0.85$) seasons only. Total ratoon yield was significantly related ($r = 0.67$) to main crop yield in the third season only.

Relationship of ratoon yield with leaf area index at main crop maturity

Leaf area index at maturity of the main crop had a significant positive linear relationship with total ratoon yield in the second ($r = 0.73$, $P < 0.01$) and the third seasons ($r = 0.83$, $P < 0.01$) only (Fig. 1). In the first season, the correlation between main crop yield and leaf area was $r = 0.30$, which was not significant. The relationship was significantly positive ($r = 0.67$, $P < 0.01$) with the total ratoon yield across the data pooled for the three seasons, with the regression accounting for 45% of the total variance.

DISCUSSION

Ratooning is an accepted agronomic practice in several field crops such as rice (Krishnamurthy 1988) and sugarcane (Hunsigi 1989). Although the feasibility of ratooning in pigeonpea has been demonstrated for quite some time (Killinger 1968), commercial interest in augmenting its low yield potential has so far been very limited. This is probably because the long duration and photoperiod sensitivity of the traditional cultivars means that a major part of the available growing season is taken to produce the main crop itself. Sharma *et al.* (1978) reported that by the time the main crop of long-duration (> 250 days to maturity) cultivars could be harvested, the photoperiod had become non-conducive to flowering, and thus regrowth was only vegetative. In contrast, short-duration (< 150 days) cultivars produced a ratoon crop of grain which was equal to the main crop although total yield was only *c.* 1 t/ha (Sharma *et al.* 1978).

In recent years, considerable improvements in short-duration genotypes and their agronomy have been made and high main (> 2·0 t/ha) and ratoon crop (> 1·5 t/ha) yields have been harvested from some genotypes (Chauhan *et al.* 1987*a*). In some genotypes in the present study, the main crop yield exceeded 2·5 t/ha and the total ratoon crop yield exceeded 2·7 t/ha in 1991/92. In ICPL 89030, the total yield of > 5·6 t/ha was divided equally between main yield and ratoon yield. Thus, the results of the present study and those of others (Chauhan *et al.* 1987*a*; Rao & Sachan 1988; Ahmed & Carangal 1989) have confirmed the high ratoon yield potential of short-duration pigeonpea cultivars. In the earlier studies, among the limited number of genotypes tested, ICPL 87 was found to be the best genotype for ratooning (Chauhan *et al.* 1987*b*; Ahmed & Carangal 1989). The results of the present study suggest that several other genotypes may give a higher ratoon yield than ICPL 87. However, no genotype was consistently superior among those tested in the present study. For example, ICPL 87 produced a low ratoon yield in 1989 but reasonably good ratoon yields in the other two seasons. The relative contributions of the first and second flush to total ratoon yield in the three genotypes which were common to all three seasons varied considerably. This implies that this character is greatly influenced by environmental conditions.

In each season, the correlation of total yield with total ratoon yield was greater than that with the main crop yield. Therefore, to maximize the total yield in a multiple harvest system, it appears to be important to understand plant or environmental factors that affect ratoon yield besides those affecting the main crop yield. Since ratoon yield was not related to main crop yield in the first two seasons, and was positively related in the third season, such factors are likely to affect ratoon yield independently of main crop yield or to have similar effects on both.

Identification of traits associated with high ratoon yield can assist in the screening of cultivars with high ratoonability potential. In rice, delayed senescence of leaves produced during the main crop was found to be a good criterion for assessing ratoonability (Vergara *et al.* 1988). In pigeonpea, leaf area retained at maturity may serve as a source of assimilates for ratoon growth. In the present study, the use of different genotypes and seasons resulted in a range of leaf area indices at the time of maturity of the main crop. There was a positive linear relationship between the total ratoon yield and LAI measured at the maturity of the main crop which was significant in the second and third seasons (Fig. 1). In the first season, when the relationship of LAI with total ratoon yield was poor, the maturity of some genotypes (e.g. ICPL 87, ICPL 87101, ICPL 87105 and ICPL 87108) was delayed by about a month (data not shown) and their second flush was produced in a relatively cooler period. For these genotypes, perhaps the effectiveness of their high LAI may have been reduced by the prevailing low temperatures. For this reason, although there appeared to be considerable variation for this trait, it appears that it could significantly influence ratooning ability only when the genotypes mature in a relatively warm period. Furthermore, leaf area index accounted for less than half of the total variance in ratoon yield. Ratoon yield, therefore, may be influenced by other factors. Identification of these traits would be important for improving and stabilizing ratoon yield.

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REFERENCES

AHMED, N. U. & CARANGAL, V. R. (1989). Cultivar differences in growth and yield of main and ratoon crops of short-duration postrainy season pigeonpea in a low-land rice based system. *International Pigeonpea Newsletter* **10**, 18–20.

AKINOLA, J. O. & WHITEMAN, P. C. (1975). Agronomic studies on pigeon pea (*Cajanus cajan* (L.) Millsp.). I. Field responses to sowing time. *Australian Journal of Agricultural Research* **26**, 43–56.

CHAUHAN, Y. S., VENKATARATNAM, N. & SHELDRAKE, A. R. (1987*a*). Factors affecting growth and yield of short-duration pigeonpea and its potential for multiple harvests. *Journal of Agricultural Science, Cambridge* **109**, 519–529.

CHAUHAN, Y. S., SHELDRAKE, A. R. & VENKATARATNAM, N. (1987*b*). Effect of harvest methods on the second flush yield of short-duration pigeonpea (*Cajanus cajan*). *Journal of Agricultural Science, Cambridge* **109**, 591–593.

HUNSIGI, G. (1989). Ratooning in sugarcane. *Outlook on Agriculture* **18**, 175–184.

KILLINGER, G. B. (1968). Pigeonpea (*Cajanus cajan* (L.) Druce) – a useful crop for Florida. *Proceedings of the Soil and Crop Science Society of Florida* **28**, 162–167.

KRISHNAMURTHY, K. (1988). Rice ratooning as an alternative to double cropping in tropical Asia. In *Rice Ratooning: Proceedings of an International Workshop on Rice Ratooning, 21–25 April 1986, Bangalore, India*, pp. 3–15. Manila, Philippines: IRRI.

RAO, M. R. & SACHAN, R. C. (1988). Potential of short-duration pigeonpea for a multiple-harvest system. *International Pigeonpea Newsletter* **7**, 14–17.

SHARMA, D., SAXENA, K. B. & GREEN, J. M. (1978). Potential of ratooning in pigeonpea. *Field Crops Research* **1**, 165–172.

TAYO, T. O. (1985). Assessment of the effects of ratooning pigeon pea (*Cajanus cajan* (L.) Millsp.) in the lowland tropics. *Journal of Agricultural Science, Cambridge* **104**, 589–593.

VENKATARATNAM, N. & SHELDRAKE, A. R. (1985). Second harvest yields of medium duration pigeonpeas (*Cajanus cajan*) in peninsular India. *Field Crops Research* **10**, 323–332.

VERGARA, B. S., LOPEZ, F. S. S. & CHAUHAN, J. S. (1988). Morphology and physiology of ratoon rice. In *Rice Ratooning: Proceedings of an International Workshop on Rice Ratooning, 21–25 April 1986, Bangalore, India*, pp. 31–40. Manila, Philippines: IRRI.