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SECOND HARVEST YIELDS OF MEDIUM DURATION PIGEONPEAS (*CAJANUS CAJAN*) IN PENINSULAR INDIA

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ABSTRACT

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In Peninsular India medium duration pigeonpeas (*Cajanus cajan*) are normally sown soon after the onset of the monsoon, in June or July; they mature around December, when they are usually cut down and removed from the field. However, if they are harvested by ratooning or by picking the pods, the plants go on to produce a second flush of pods, which matures around March. In experiments conducted in four growing seasons at ICRISAT Center, second harvest yields were usually greater for non-ratooned than ratooned plants, and in experiments conducted on Vertisols they were greater for the plants ratooned high up in the plant than for those cut closer to the ground. Second harvest yields of non-ratooned plants without irrigation on Alfisols were on average 66% of the first harvest yields, but on Vertisols only 37%, in spite of the greater water-holding capacity of the latter. On Alfisols second harvest yields were approximately doubled by a single irrigation, but there was less response to irrigation on Vertisols. The poorer second harvest yields on Vertisols may have been due to the damaging effects of soil cracking on the root system of the plants. In non-ratooned plants from which the first and second flushes of pods were harvested together, yields were less than the total yield obtained from non-ratooned plants in two harvests, even though the yield loss, mainly due to pod shattering, was as little as 4% in one year. The taking of second harvests from pigeonpeas grown on Alfisols may have considerable potential as a method of obtaining additional yield for little extra cost.

INTRODUCTION

In Peninsular India, pigeonpeas are generally sown in June or July soon after the beginning of the monsoon. The most commonly used cultivars are of medium duration (5—6 months), and mature after the end of the monsoon. At that time they are usually cut down and threshed (Pathak, 1970; Sheldrake and Narayanan, 1979a). However, owing to their perennial nature (Sheldrake, 1979; Sheldrake and Narayanan, 1979b), plants left in the field produce a new flush of pods which mature by March or April, when a second

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TABLE 1

Details of experiments on second harvest yields of medium duration pigeonpeas carried out at ICRISAT Center

Year	Soil	Fertilizer	Treatments	Design	Sub-plot size (m)	Date (a) sowing (b) ratooning (c) irrigation
1976—77	Alfisol	50 kg P_2O_5 per ha; 22 kg $ZnSO_4$ per ha	Nonratooned, and ratooned at 60 cm	Split plot (cvs. in main plots) 3 reps.	8X9	(a) Jul 6 (b) Nov 18 (c) —
1976—77 (a)	Vertisol	50 kg P_2O_5 per ha; 22 kg $ZnSO_4$ per ha	Nonratooned, and ratooned at 90, 60, 30 or 10 cm	Split plot (cvs. in main plots) 3 reps.	8X9	(a) Jun 29 (b) Dec 28 (c) —
1976—77 (b)	Vertisol	50 kg P_2O_5 per ha; 22 kg $ZnSO_4$ per ha	Nonratooned, and ratooned at 60 cm	Split plot (cvs. in main plots) 3 reps.	8X9	(a) Jun 30 (b) Dec 6 (c) —
1977—78	Alfisol	20 kg P_2O_5 per ha; 25 kg $ZnSO_4$ per ha.	Nonratooned, and ratooned 60 cm	Split plot (irrigations in main plots) 5 reps.	8.5X4	(a) Jul 5 (b) Dec 21 (c) Dec 30
1977—78 (a)	Vertisol	20 kg P_2O_5 per ha; 25 kg $ZnSO_4$ per ha	Nonratooned, and ratooned at 90, 45 or 10 cm	Split plot (irrigation in main plots) 3 reps.	8.5X4	(a) Jul 7 (b) Jan 16 (c) Jan 6
1977—78 (b)	Vertisol	20 kg P_2O_5 per ha; 25 kg $ZnSO_4$ per ha.	Nonratooned, and ratooned at 60 cm	Split plot (irrigation in main plots) 3 reps.	8.5X4	(a) Jul 7 (b) Jan 16 (c) Jan 6
1978—79	Alfisol	125 kg P_2O_5 per ha; 25 kg $ZnSO_4$ per ha.	Nonratooned; and ratooned at 60 cm or single harvest in February	Split plot (irrigation in main plots) 6 reps.	10X5.3	(a) Jul 3 (b) Dec 6 (c) Dec 12
1978—79	Vertisol	100 kg diammonium phosphate per ha; 160 kg P_2O_5 per ha; 80 kg $ZnSO_4$ per ha.	Nonratooned; and ratooned at 90 or 45 cm, or single harvest in March	Split plot (irrigation in main plots) 4 reps.	11X4.5	(a) Jul 1 (b) Dec 12 (c) Dec 19
1980—81	Alfisol	nil	Nonratooned, and ratooned at 45 cm	Randomized block 4 reps.	9X4.5	(a) Jul 4 (b) Dec 2 (c) —

harvest can be taken. The additional yield obtained in this way can be quite high, sometimes equalling the first harvest yield (Sharma et al., 1978; Wallis et al., 1981).

In view of the potential of this system for increasing the productivity of pigeonpea, we have investigated the second harvest yields which can be obtained after harvesting the first crop of pods either by ratooning or by picking the pods from the plants. We carried out experiments both on Alfisols and Vertisols, which differ considerably in their water-holding capacity.

MATERIALS AND METHODS

Experiments were carried out from 1976 to 1981 at ICRISAT Center, Patancheru (17'N, 78'E; 500 m elevation) 25 km north-west of Hyderabad, India. The trials were carried out on both Alfisol and Vertisol, in different fields each year. The Alfisols in these fields hold less than 100 mm of available water and the Vertisols about 250 mm.

In all cases, medium duration cultivars were sown by hand soon after the beginning of the monsoon season in rows of 75 cm apart, along the tops of ridges, with a plant-to-plant spacing of 30 cm. In 1976—77 cvs. No. 148 and AS-71-37 were used, and in the other years cv. BDN-1.

Nine experiments were carried out, the details of which are given in Table 1. Except in the Vertisol trial in 1978—79, no nitrogenous fertilizer was used. The roots of the plants nodulated naturally with native Rhizobia. The crops were protected against pest attack by sprays of endosulfan as and when necessary, and kept free of weeds by hand weeding.

The ratooning treatments were carried out by hand using either shears or small sickles. Irrigations (5 cm) were given through the furrows between the ridges.

TABLE 2

Meteorological data for the four planting seasons at ICRISAT Center

Year	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Total monthly rainfall (mm)											
1976—77	86	219	299	74	1	30	0	0	0	0	8
1977—78	67	184	194	40	59	28	2	17	26	4	56
1978—79	181	228	516	82	71	10	1	0	41	0	3
1980—81	141	127	306	153	6	1	2	16	0	77	3
Open pan evaporation (mm)											
1976—77	302	165	123	140	193	124	148	176	202	301	307
1977—78	278	177	131	166	153	136	144	149	170	321	321
1978—79	256	140	108	127	161	129	146	165	170	291	345
1980—81	255	181	124	134	186	167	162	155	226	288	336

The second harvests were taken in March—April, excluding the borders of the plots.

Data on monthly rainfall and evaporation for the growing seasons 1976—1981 are given in Table 2.

RESULTS AND DISCUSSION

Second harvest yields on Alfisols

On Alfisol, unirrigated plants from which the first harvest had been taken

TABLE 3

First harvest grain yields of pigeonpeas grown on Alfisols or Vertisol in different years and second harvest yields of non-ratooned and ratooned plants, with or without a single irrigation soon after the first harvest. On Alfisols, from 1976—79 plants were ratooned at 60 cm above ground levels and in 1980—81 at 45 cm, but on Vertisols at 90 cm, except in experiment b in 1976—77 and 1977—78, when they were ratooned at 60 cm

Year	Cultivar	First harvest yield (kg/ha)	Non-irrigated (NI) or irrigated (I)	Second harvest yield (kg/ha)			
				Non-ratooned	Ratooned	SE	
						Ratooning effects	Irrigation effects
Alfisol							
1976—77	No. 148	1207	NI	822	449	± 18.5	—
	AS-71-37	1262	NI	1167	555		
1977—78	BDN-1	1669	NI	704	262	± 100.9	± 123.5
			I	1538	403		
1978—79	BDN-1	1153	NI	531	438	± 36.8	± 27.1
			I	1093	663		
1980—81	BDN-1	760	NI	785	303	± 78.9	—
Vertisol							
1976—77 (a)	No. 148	749	NI	135	99	± 20.2	—
	AS-71-37	790	NI	191	85		
1976—77 (b)	No. 148	702	NI	263	154	± 38.8	—
	AS-71-37	676	NI	414	292		
1977—78 (a)	BDN-1	1841	NI	337	682	± 74.9	± 55.7
			I	286	675		
1977—78 (b)	BDN-1	1640	NI	660	613	± 72.8	± 104.9
			I	551	291		
1978—79	BDN-1	1686	NI	152	165	± 12.6	± 34.6
			I	372	353		

by pod-picking gave a mean second harvest yield of 802 kg/ha (Table 3). The mean first yield was 1210 kg/ha.

In 1977—78 and 1978—79, a single irrigation given soon after the first harvest in December approximately doubled the yields of the non-ratooned plants, from 704 to 1538 kg/ha and from 531 to 1093 kg/ha, respectively (Table 3). This large response to irrigation is not surprising in view of the low water-holding capacity of the Alfisol and the very low rainfall from November onwards (Table 2).

The mean second harvest yield of unirrigated ratooned plants was 421 kg/ha, compared with 802 kg/ha on non-ratooned plants from which the pods had been picked by hand at the time of first harvest. In each experiment a similar pattern was apparent, both with and without irrigation (Table 3).

The non-ratooned plants produced a new flush of flowers soon after the first harvest, but in the ratooned plants flowering mostly occurred on new shoots which took time to develop; hence the second flush of pods was delayed. In unirrigated plants in the 1977—78 experiments, for example, the second flush on the non-ratooned plants matured by 2 March but on the ratooned plants only by 4 April. With irrigation, the pattern was similar, although the dates of maturity were slightly later, on 7 March and 8 April, respectively.

Thus one probable reason for the lower yields of the ratooned plants is that the delay in the development of the second flush of pods exposed the plants to greater water stress. In this period there was almost no rainfall, and the plants were relying on extracting residual moisture from the soil while the temperatures and the evaporative demand of the atmosphere were rising (Table 2).

A second reason for the lower yield of ratooned than non-ratooned plants is that more of them died after the first harvest (Table 4). The main cause of death was fusarium wilt disease. Susceptibility of plants to this disease is increased by ratooning and defoliation, probably because the reduced supply

TABLE 4

Percentage mortality of non-ratooned and ratooned pigeonpeas grown on Alfisols

Year	Cultivar	Irrigated (I) or nonirrigated (NI)	Non-ratooned	Ratooning height (cm)		SE
				60	45	
1976—77	No. 148	NI	10	39	ND[a]	± 8.9
	AS-71-37	NI	7	33	ND	± 10.4
1977—78	BDN-1	NI	2	34	ND	± 8.2
	BDN-1	I	1	17	ND	± 4.3
1978—79	BDN-1	NI	1	12	ND	± 2.1
		I	1	1	ND	± 0.8
1980—81	BDN-1	NI	3	ND	16	± 3.0

[a] ND = not determined.

of assimilates to the roots reduces their ability to resist the entry and/or development of the fungal pathogen (Sheldrake et al., 1978). Cultivars differ in their susceptibility to this disease, and this is a major reason for differences among cultivars in the ability of plants to survive ratooning (Sharma et al., 1978).

Second harvest yields of non-ratooned plants on Vertisols

The second harvest yield of non-ratooned plants grown without irrigation on Vertisols ranged from 135—660 kg/ha and on Alfisols from 531—1167 kg/ha (Table 3). With irrigation the second harvest yields of non-ratooned plants on Vertisols did not exceed 551 kg/ha, and in the two experiments in 1977/78 irrigation even led to a slight reduction in yield compared with non-irrigated controls (Table 3). By contrast, on Alfisols irrigation led to an approximate doubling of the yield of non-ratooned plants, giving a yield as high as 1538 kg/ha (Table 3).

This striking difference between the second harvest yields on Vertisol and Alfisol was observed repeatedly (Table 3). On both soils different fields were used each year. Moreover, except in 1976—77, when growth was poor in the trial on a Vertisol (one reason for which seemed to be boron toxicity), the first harvest yields were higher on Vertisols than on Alfisols (Table 3); it was only in respect of second harvest yields that plants performed better on Alfisols.

This was the opposite of what we had expected. During the season in which the second flush is produced, the plants depend almost entirely on residual moisture within the soil. The water storage capacity of Vertisols is high (around 250 mm in our fields) while that of Alfisols, which are shallow and contain less clay, are relatively low, usually less than 100 mm (Reddy and Virmani, 1981).

We investigated whether the lower second harvest yields on Vertisols were due to nutrient or micronutrient deficiencies. In several separate experiments, we failed to obtain any significant response to spraying the plants with phosphate (in the form of potassium polyphosphate), micronutrient mixtures or zinc sulphate. The analysis of leaf tissue did not suggest that the plants on Vertisols were suffering from nutrient deficiencies; nor were the nutrient or micronutrient levels in the surface or the deeper regions of the soil sufficiently low to make it likely that the plants would be deficient.

One possile explanation is that pigeonpeas growing on Vertisols are adversely affected by the large cracks which develop as the soil dries out after the end of the monsoon (Sheldrake and Venkataratnam, 1982). Such cracks do not appear in Alfisols. The cracks could damage the plants directly by stretching and rupturing roots, and indirectly through providing a larger surface area for evaporation from the soil.

The poor, and even negative, response to irrigation on Vertisol may also be related to soil cracking. By the time the irrigation was given, in December

or January (Table 1), deep cracks had already developed. After irrigation the soil swelled again, and the cracks closed up. It is possible that the swelling of the soil caused further damage by stretching the roots. This negative effect would no doubt have been offset to some extent by the beneficial effect of a greater availability of water in the soil, but it may well explain why the large increases due to irrigation obtained on Alfisols, were not obtained on Vertisols.

Effects of ratooning on Vertisols

By contrast with the results on Alfisols, where ratooned plants gave considerably lower yields than non-ratooned plants, on Vertisols there was no such clear-cut pattern. In some experiments ratooned plants yielded less than non-ratooned plants, and in others more (Table 3). The variation in results from year to year may reflect both the different climatic conditions (Table 2) and the fact that different fields were used. In 1976—77, growth was generally poor in the particular field used for this experiment, and the plants showed toxicity symptoms, probably due to boron. In 1977—78, when second harvest yields were high, the plants were grown in a field next to a lake, with a high water table.

Plants ratooned at 45 or 30 cm yielded only between half and two-thirds as much as ones ratooned at 90 cm, and those cut back to 10 cm gave extremely low second harvest yields (Fig. 1).

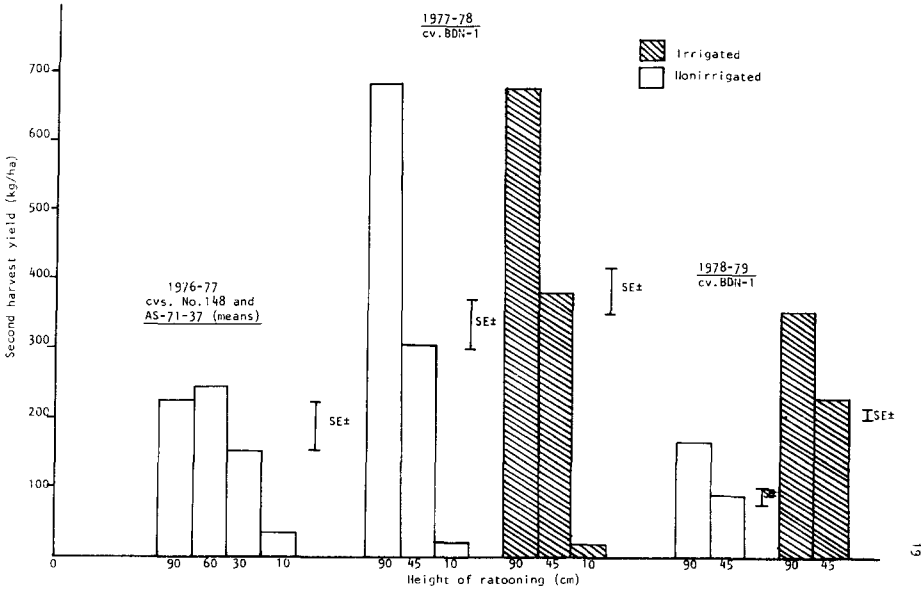

Fig. 1. Effect of height of ratooning on second harvest grain yield (kg/ha) of medium duration pigeonpeas grown on Vertisol.

The yield reductions due to ratooning closer to the ground were due in part to the greater mortality of the plants and in part to the greater delay in the development of the second flush of pods. The nearer to the ground the plants were cut, the more vegetative regrowth took place before flowering began on the new shoots, and the later the second flush of pods matured. As on Alfisols, such delays exposed the plants to increasing water stress.

An additional reason why the plants yielded the less the more severely they were ratooned may be that greater amounts of stem were removed, and the plants were therefore deprived of any reserves of nutrients and assimilates which may have been stored within the stems.

Whatever the relative importance of the different reasons for yield reductions, it is clear that the higher second harvest yields were obtained either from plants that were not ratooned at all, or from those ratooned furthest away from the ground. Similar results have been described by Suarez and Herreara (1971).

The harvest of both flushes of pods at the same time

The first flush of pods can simply be left on the plants at the time the first harvest is normally taken. The second flush then develops on the same plants, and both can then be harvested at the same time, around March. We compared the yield harvested in this way with the total yield obtained by taking first and second harvests separately from non-ratooned plants. In 1977—78, the yield with a single harvest was lower by 27% in the non-irrigated plants, and by 22% in the irrigated plants (Table 5). A major reason for this lower yield was the shattering of the pods from the first flush.

In 1978—79, the yield obtained from a single harvest was similar to that obtained by harvesting the first and second flushes separately (Table 5), and

TABLE 5

Total grain yield obtained from the first and second harvests from non-ratooned pigeonpeas (cv. BDN-1) compared with the yield in a single harvest at the time of maturity of the second flush of pods.

Year	Soil	Irrigated (I) or nonirrigated (NI)	Yield (kg/ha)			Percentage reduction in yield in single harvest
			First + second harvests	Single harvest only	SE	
1977—78	Vertisol	NI	2311	1679	± 160.5	27
	Vertisol	I	2200	1724		22
1978—79	Vertisol	NI	1759	1624	± 35.8	8
	Vertisol	I	2094	1732		17
1978—79	Alfisol	NI	1662	1554	± 52.7	7
	Alfisol	I	2321	2219		4

there was less shattering of the mature pods. One reason for the difference between this and the previous year may have been that there were showers in both January and February in 1978, but only in February in 1979 (Table 2) and the more repeated wetting and drying of the mature pods in 1978 may have caused more of them to shatter. In situations in which there is a low probability of rainfall between the times of maturity of the first and second flushes of pods, or where cultivars selected for relatively shatter-resistant pods are used, the yield losses by taking a single harvest might be small, and more than offset by the savings in time and expenditure by eliminating the first harvest.

CONCLUSIONS

The most surprising aspect of our results is that second harvest yields of medium duration pigeonpeas were generally better on Alfisols than Vertisols. Although experiments were carried out only at one location, they suggest that the agronomic potential for obtaining additional yields by taking a second harvest on Vertisols is limited, but on Alfisols may be considerable, especially if there is a posiibility of giving an irrigation to the crop after the first harvest.

Higher yields are obtained on Alfisols if the first harvest is taken by pod-picking, rather than ratooning; but pod-picking is more time-consuming and expensive. If the plants are ratooned, then the results of the experiments on Vertisol (Fig. 1) suggest that it would be best to ratoon them as high as possible. In circumstances where the mature first flush of pods is not likely to be eaten by animals or stolen, and where the probability of rainfall is low, it may be economically advantageous to eliminate the first harvest altogether and harvest both first and second flushes of pods together.

Most medium duration pigeonpeas in peninsular India are intercropped with other crop species (Willey et al., 1981), and if the pigeonpea population is low it may not be economically worthwhile to take a second harvest from the plants. However, in developing and improving cropping systems involving pigeonpea, it may well be possible to devise systems which enable the second harvest potential to be exploited at little extra cost.

REFERENCES

Pathak, G.N., 1970. Red gram. In: Pulse Crops of India. Indian Council of Agricultural Research, New Delhi.

Reddy, S.J. and Virmani, S.M., 1981. Pigeonpea and its climatic environment. In: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), Proceedings of the International Workshop on Pigeonpeas. 15—19 December 1980, Patancheru, India, Vol. 1, pp. 259—290.

Sharma, D., Saxena, K.B. and Green, J.M., 1978. Potential of ratooning in pigeonpea. Field Crops Res., 1: 165—172.

Sheldrake, A.R., 1979. A hydrodynamical model of pod-set in pigeonpea (*Cajanus cajan*). Indian J. Plant Physiol., 22: 137—143.

Sheldrake, A.R. and Narayanan, A., 1979a. Growth, development and nutrient uptake in pigeonpeas (*Cajanus cajan*). J. Agric. Sci. (Cambridge), 92: 513—526.

Sheldrake, A.R. and Narayanan, A., 1979b. Pigeonpea (*Cajanus cajan*) as winter crop in peninsular India. Exp. Agric., 15: 91—95.

Sheldrake, A.R. and Venkataratnam, N., 1982. Does soil cracking reduce pigeonpea yields? Int. Pigeonpea Newsl., 2: 34—35.

Sheldrake, A.R., Narayanan, A. and Kannaiyan, J., 1978. Some effects of the physiological state of pigeonpeas on the incidence of the wilt disease. Trop. Grain Legume Bull., 11—12: 24—25.

Suarez, J.J. and Herreara, D., 1971. Response of pigeonpea (*Cajanus cajan* Millsp.) at different populations submitted to different heights of cutting. Rev. Cubana Cienc. Agric., 5: 71—75.

Wallis, E.S., Byth, D.E. and Whiteman, P.C., 1981. Mechanized dry seed production of pigeonpea. In: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), Proceedings of the International Workshop on Pigeonpeas, 15—19 December 1980, Patancheru, India, Vol. 1, pp. 51—60.

Willey, R.W., Rao, M.R. and Natarajan, M., 1981. Traditional cropping systems with pigeonpea and their improvement. In: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), Proceedings of the International Workshop on Pigeonpeas. 15—19 December 1980, Patancheru, India, Vol. 1, pp. 11—25.