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Response of spacing on yield and returns of CMS-based medium-duration pigeonpea (*Cajanus cajan*) hybrid

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ABSTRACT. The study was conducted during 2008-09 cropping season at ICRISAT, Patancheru, A.P., India, to determine the cost and economic benefits of seed production (AxR) of pigeonpea hybrid ICPH 2671. Two row ratios of 4:1 and 3:1 with seven planting distances were the treatments that served as the basis for analyzing economic returns. Production cost for each of the row spacing 75 cm and 150 cm was calculated. The current study revealed that productivity of hybrid ICPH 2671 differed significantly among planting distances, row spacings and row ratios. Planting distance at 75 cm x 30 cm in 4:1 row ratio gave the highest net returns (Rs. 224,614 ha^{-1}) and brought in the highest cost-benefit ratio (Rs. 6.32). Likewise, the cost of producing one kilogram of hybrid seeds at 75 cm x 30 cm spacing was estimated at Rs. 7.37.

Keywords : *Cajanus cajan, cost-benefit ratio, pigeonpea hybrid, planting distances, row ratios, row spacings, seed production.*

INTRODUCTION

Pigeonpea (*Cajanus cajan* (L.) Millspaugh), which is adapted in the arid and semi-arid tropics, is an important and valuable legume crop that ranks sixth in area and production in comparison to other grain legumes such as peas, beans, and chickpeas. Pigeonpea plays a key role in the nutrition of Indian populace because it is considered as one of the staple foods and is widely grown with a total area of over 3.5 million hectares, which accounts for 86% of the total area cultivated in Asia (Saxena, 2006). However, the country still experiences shortage of grain supply by about 1.5 - 2 million tons annually due to the low productivity estimated at 700 kg ha^{-1} (Saxena, 2009). The yield of pigeonpea is characteristically poor in the traditional farming systems and the low productivity of cultivars has necessitated in developing the pigeonpea hybrids.

Hybrids have transformed the productivity of various field and vegetable crops worldwide. The development of hybrid technology on pigeonpea was initiated with the discovery of two sources of genetic male-sterility (GMS) from germplasm to increase productivity of pigeonpea (Reddy *et al.,* 1978; Saxena *et al.,* 1983). However, to overcome the seed production problem associated with GMS, the cytoplasmic-nuclear male-sterility (CMS) system was developed. The CMS system is the most widely accepted means of producing commercial hybrids. The extensive testing of CMS-based hybrids has demonstrated that high levels of exploitable heterosis are present in pigeonpea. Pigeonpea hybrid for early, medium, and late maturity have increased production from 61% - 207% as compared to pure line cultivars. These hybrids have greater plant vigour with 43.9% and 42.8% higher shoot and higher root mass, respectively as compared to the pure line cultivars. In merit of higher root mass and greater root depth, this hybrid has greater ability than pure line cultivars to draw water from different depth of any soil profile with greater adaptability, which helps the plant overcome drought stresses. Pigeonpea hybrid also produced more number of primary, secondary and tertiary branches with wider canopy having greater plasticity without affecting the yield which translate to reduce seed rate by 40-50%, offsetting the higher seed cost which farmers may have to incur during purchasing of hybrid seeds. Furthermore, hybrid pigeonpea exhibits 60% superiority over pure line cultivars under disease sick conditions in which the hybrids have an extra degree of genotypic plasticity, which helps tolerate such stresses and produce higher yields (Saxena *et al.,* 1990; Saxena *et al.,* 1992 ; Saxena, 2006).

The backbone of any hybrid breeding technology is in its seed production system that will provide quality seeds at economically feasible costs. Both the hybrid technology and crop management practices are important factors in determining the production costs and its adoption. Some inferences about the cost of hybrid pigeonpea seed were generated using the data involving genetic male-sterility (GMS) based hybrids. Murugrajendran *et al.* (1990) estimated the cost of producing hybrid seeds in 1988 as Rs 6.25 kg^{-1} at Tamil Nadu Agricultural University (TNAU), Coimbatore; but there was a large variation in the production cost at Punjab Agricultural University (PAU), Ludhiana (Verma *et al.,* 1994). The seed production cost of male-sterile

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line of hybrid PPH 4 was estimated at Rs. 39.40 and Rs. 12.30 kg^{-1} in 1990 and 1991, respectively. In two studies conducted in 1992, the cost on hybrid seed was estimated to be Rs. 3.70 and Rs. 13.80 kg^{-1}. The vast differences observed in these experiments were attributed to the levels and effectiveness of crop management practices. Among the cost components of the genetic male-sterility based hybrids, roguing of fertile plants within female rows was found to be the most expensive and tedious activity. Production cost is an important parameter for seed producers and farmers to assess the viability of the enterprise; hence, this study was conducted using a CMS-based medium-duration hybrid ICPH 2671.

MATERIALS AND METHODS

The experiment was sown at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Patancheru on June 22, 2008. ICPH 2671, a medium duration pigeonpea hybrid, was selected for computing the economic benefits in this study. The treatments with two row ratios and seven planting distances were each laid-out in a randomized complete block design (RCBD) in two replications. A plot size of 0.75m x 5m and 1.5m x 5m per treatment were used in recording yield data. The parents of this hybrid were sown in a row ratio of 4 female rows (A-line) and 1 male row (R-line) and 3 female rows and 1 male row in an isolated location measuring 0.3 ha. Additional male-lines were planted around the borders (2 rows on the left and right corner and 2m length on the front and back side) of the field to ensure additional pollen for enhanced cross-pollination. The planting distance of male-lines in both row ratios was 75 cm x 30 cm.

The recommended fertilizer rate of 100 kg ha^{-1} of di-ammonium phosphate at 100 kg ha^{-1} was applied in row spacing of 75cm while 50% of the recommended rate was use in row spacing of 150cm. Other cultural practices were undertaken as and when required for ensuring a good crop growth. Roguing of off-type plants commenced two months after sowing and continued till the flowering stage at monthly intervals to prevent contamination due to cross-pollination. Recording of activities from sowing to threshing and various inputs applied was regularly done. The data were statistically analyzed by using the Statistical Analysis System (SAS) for testing the significant difference among various spacings when the F-test was significant at 5% level of significance for comparison.

RESULTS AND DISCUSSION

Yield

Effect of planting distances : Pigeonpea yield tends to be higher at closer spacings than wider spacings. This is shown by this study where planting distances for both row ratios were significantly different. The t-test revealed that hybrid seeds in planting distance of 75cm x 30cm in both 4:1 and 3:1 row ratios recorded significantly higher yields at 2,091.6 kg ha^{-1} (31.40 - 72.20% higher than the other treatments) and 1,341.5 kg ha^{-1} (3.46 - 56.60% higher than the other treatments), respectively (**Table 1**). This was found in conformity with the findings of Veerasway *et al.* (1972), Natarajan and Wiley (1980), and Sekhon *et al.* (1996) that closer spacings achieve higher grain productivity. Moreover, the yield obtained from the present study for planting distance of 75cm x 30cm in the row ratio of 4:1 was greater than the experiment conducted in 2005 (Saxena *et al.*, 2006).

Effect of row spacings : There was a significant difference on the productivity of pigeonpea among the two row spacings (75 cm and 150 cm) in 4:1 but not in 3:1 row ratio. However, for both row ratios combined, the effect of row spacing on the yield differed significantly between rows of 75cm and 150cm (Table 1). For 150cm row-to-row spacing with different plant-to-plant spacings, the yields of hybrids were low and comparable in both the row ratios. Yield tended to be higher at lower spacing between rows and at highest plant density, which is corollary with the findings of Abrams and Julia (1973) and confirmed the results of Wilsie (1935) where the spacings more widely resulted in a progressive decline in yield of pigeonpea.

Effect of row ratio : The t-test showed that there was a significant difference on the yield among the two row ratios. The 4:1 ratio with 25% more male-sterile plants produced 70% more grain yield than that of 3:1 ratio (Table 1). This was found in conformity with the findings of Joshi *et al.* (1998) where 4:1 row ratio yielded the maximum seeds and is suitable female : male row proportion for hybrid seed production in pigeonpea.

Total cost of production : Prevailing market prices during the cropping period were used to determine the estimates on cost of inputs used in this research. The analysis includes land, labor and capital utilization costs. Two production cost were computed for this study. The gross expenditure for row spacing of 75 cm was Rs. 35,512 ha^{-1}; while it was Rs. 34,815 ha^{-1} for row spacing of 150 cm for both 4:1 and 3:1 row ratios. The cost of insecticide was the highest expenditure (Rs 10,000 ha^{-1}) and weeding entail the highest labor demanding operation while in GMS systems the most costly operation was the roguing of fertile plants (Niranjan *et al.*, 1998). The detailed information on hybrid seed production cost is summarized in **Table 2**.

Cost of hybrid seeds : In this study, the wider spacings produced less grain yield and had the lowest production cost. The planting distance of 75cm x 100cm revealed the highest

Table 1. Net income, seed production cost and cost-benefit ratio of hybrid ICPH 2671

Spacing (cm)	*Net yield (kg ha^{-1})* Hybrid (A-line) [a]	R-line [b]	*Total cost of* production* (Rs ha^{-1}) [c]	Gross income (Rs ha^{-1}) Hybrid** [d]	By-products*** [e]	Total f = [d+e]	Net income (Rs ha^{-1}) g = [f-c]	Cost-benefit ratio (Rs) i = [e-c]/[a]	Cost of hybrid seed (Rs kg^{-1}) h = [g/c]
Effect of planting distance in 4 female rows and 1 male row (4:1)									
75 x 30	2,091.6	1,383	35,512	209,200	50,926	260,126	224,613	6.32	7.37
75 x 50	1,120.9	1,383	35,512	112,100	52,793	164,893	129,380	3.64	15.42
75 x 75	965.2	1,383	35,512	96,500	50,994	147,494	111,981	3.15	16.04
75 x 100	898.5	1,383	35,512	89,900	51,578	141,478	105,965	2.98	17.88
150 x 30	1,435.2	1,052	34,815	143,500	40,484	183,984	149,169	4.28	3.95
150 x 50	791.8	1,052	34,815	79,200	39,548	118,748	83,933	2.41	5.98
150 x 75	602.4	1,052	34,815	60,200	39,050	99,250	64,435	1.85	7.03
R_2	0.97								
CV (%)	11.25								
Mean	1129.36								
MSE	16132.91								
P(<0.05)	0.0003								
LSD	310.8								
Effect of row spacing (75cm and 150cm) in 4:1									
y_{75}	1269.05								
y_{150}	943.13								
MSE	16132.91								
P(<0.05)	0.0032								
Effect of planting distance in 3 female rows and 1 male row (3:1)									
75 x 30	1,341.5	1,271	35,512	134,200	48,125	182,325	146,812	4.13	9.40
75 x 50	1,126.0	1,271	35,512	112,600	46,661	159,261	123,748	3.48	9.90
75 x 75	730.6	1,271	35,512	73,100	47,489	120,589	85,076	2.40	16.39
75 x 100	583.3	1,271	35,512	58,300	46,960	105,260	69,747	1.96	19.63
150 x 30	1,295.1	959	34,815	129,500	39,701	169,201	134,386	3.86	3.77
150 x 50	772.4	959	34,815	77,200	35,616	112,816	78,001	2.24	1.04
150 x 75	582.7	959	34,815	58,300	35,530	93,830	59,015	1.69	1.23
R_2	0.92								
CV (%)	15.01								
Mean	918.79								
MSE	19031.21								
P(<0.05)	0.0042								
LSD	337.56								
Effect of row spacing (75cm and 150cm) in 3:1									
y_{75}	945.35								
y_{150}	883.40								
MSE	19031.21								
P(<0.05)	0.44								
Effect of row spacing (75cm and 150cm) for both row ratio									
Y_{75}	1107.20								
Y_{150}	913.26								
MSE	16624.52								
P(<0.05)	0.0017								
Effect of row ratio (4:1 and 3:1)									
Y 4:1	2049.22								
Y 3:1	914.37								
MSE	16624.52								
P(<0.05)	0.0008								

Legend : * For details refer to Table 2 ; **Sale of hybrid seeds @ Rs 100 kg^{-1}
***Sale of by-products includes: R-line seeds (@ 35 kg^{-1}), undersize seeds (@ Rs 3 kg^{-1}), and bulk dry stems (@ Rs 400 ha^{-1})
Y/y - mean yield

Table 2. Gross seed production expenditure of hybrid ICPH 2671 in two row spacing

Particulars	Person days	Row spacing (Rs ha^{-1}) 75 cm	150 cm
Land rental		7,500	7,500
Field operations		6,250	6,250
Farm inputs			
Fertilizer		1,150	575
Insecticide		10,000	10,000
Irrigation		1,000	1,000
Labor costs			
Fertilizer application	2.5	250	250
Sowing	12.5	1,250	1,250
Weeding	25	2,500	2,500
Spraying	10	1,000	1,000
Roguing	15	1,500	1,500
Harvesting	15	1,500	1,500
Seed cleaning	11	1,250	1,250
Seed costs			
A-line		(2 5 kg ha^{-1}) 250	(1.25 kg ha^{-1}) 125
R-line		(1.5 kg ha^{-1}) 112	(1.15 kg ha^{-1}) 115
Total gross expenditure		**35,512**	**34,815**

Note . Field operations: land preparation, interculture, weeding, threshing
Labor cost : Rs 100 day^{-1}; Machine rental cost: Rs 350 hr^{-1}
Cost of seeds : A-line @ Rs 100 kg^{-1} and R-line @ Rs 75 kg^{-1}

production cost both in 4:1 and 3:1 row combinations at Rs 17.88 kg^{-1} and Rs 19.63 kg^{-1}, respectively while planting distances of 150cm x 30cm in 4:1 ratio and 150cm x 50cm in 3:1 ratio registered the lowest cost of hybrid seeds at Rs 3.95 kg^{-1} and Rs 1.04 kg^{-1}, respectively (Table 1). However, having the least cost in producing one kilogram of hybrid seeds is not the only indicator that measures its feasibility, and the other factors such as net income and cost-benefit ratio also be considered that would contribute to the viability of this enterprise. Noting that in the plant spacing of 75 cm x 30 cm and the row ratio of 4:1, the cost of producing one kilogram of hybrid seed was acceptable @ Rs 7.37 due to substantial amount of yield it produced (Table 1) as against the other treatments (**Fig. 1**). The present cost of Rs 7.37 kg^{-1} is 30.27% lower than the cost estimated during 2007-2008 season for 4:2 row ratio (Saxena, 2009); 74.09% lesser than the findings of Ravikesavan *et al.* (1995) for 4:1 row ratio; and 77.32% lower than the results of Pandey *et al.* (1998) for 4:1 and 6:1 row ratio.

Net Returns : Net returns were calculated by subtracting the total farm expenditure from the gross income. The basis for estimating the net returns is by using the net yield derived from the estimated yield at harvest. Gross income is derived from the value of net yield (Hybrid) and by-products (R-line, undersized seeds and dry stem). Undersized seeds are those

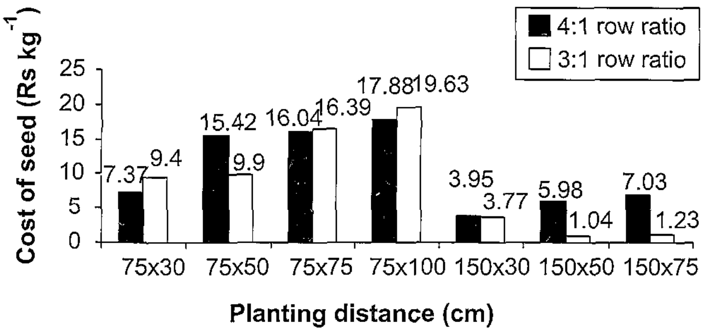

Fig.1. Costs of one kilogram of hybrid seed of ICPH 2671 at different planting distances in 4:1 and 3:1 row ratios.

that are unfilled, broken during threshing, husk and infected by pests, which can still be of use as animal feeds. The present investigation showed that a planting distance of 75cm x 30cm with 4:1 row ratio gave the highest net income of Rs 224,614 ha^{-1} (Table 1).

Cost-Benefit Ratio : The principle behind in estimating the cost-benefit ratio of seed production for ICPH 2671 is to determine the investment incurred for every rupee invested during the cropping season. Planting distance of 75cm x 30cm in 4:1 and 3:1 row ratio gave the highest cost-benefit ratio of Rs 6.32 and Rs 4.13, respectively (**Fig. 2**). Comparing both ratios, 4:1 gave the highest cost-benefit ratio due to additional row of female lines that provided an increase in yield of hybrid seeds. In this study, the potential of producing seeds for hybrid ICPH 2671 adapting 75cm x 30cm in 4:1 ratio plant spacing is a very lucrative enterprise as shown by the high cost-benefit ratio.

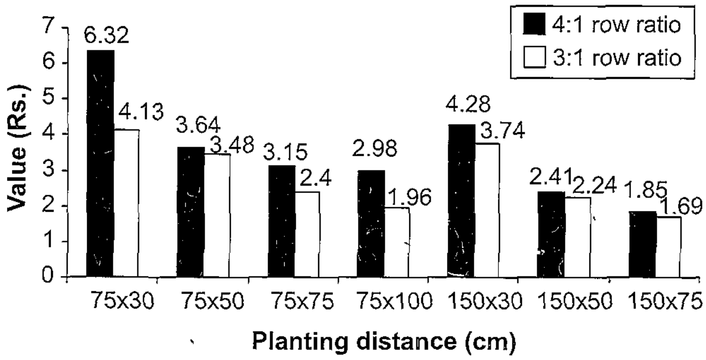

Fig. 2. Cost-benefit ratio of hybrid seed of ICPH 2671 at different planting distances in 4:1 and 3:1 row ratios

CONCLUSIONS

With respect to economic efficiency, closer spacing at 75cm x 30cm in row ratio 4:1 provided the highest net returns with the highest cost-benefit ratio of Rs 6.32. In addition, the cost of producing hybrid seeds kg^{-1} of ICPH 2671 was estimated at Rs 7.37 kg^{-1}, which is affordable by seed producers. In this study, it was found that the wider the spacing, yield tends to be lower which in turn means a lower production cost for producing hybrid seeds kg^{-1}. Hence, planting distance of 75cm x 30cm with 4:1 row ratio can be considered as possible plant spacing in producing seeds of hybrid ICPH 2671 as shown by the high cost-benefit ratio. It is further concluded that increase in yield coupled with acceptable production cost will result in an optimal cost of producing hybrid seeds thus a higher cost-benefit ratio.

For this study, it can be deduced that growing medium-duration hybrid pigeonpea instead of cultivars would provide more advantages to farmers not only on the biomass (hybrid pigeonpea have greater plant vigour than pure line cultivars) but also importantly on the economic benefits that the farmers can obtain with the same cultural management and time. The seeds required in producing the hybrid are very less @ 4 kg ha^{-1} as compared with farmers practiced of 10-12 kg ha^{-1} in producing cultivar seeds. The cost of planting materials for both types is almost the same @ Rs 175-250 kg^{-1}, therefore the total seed cost will not be a critical factor in introducing the hybrid technology. Yield derived from hybrid ICPH 2671 was recorded at 28.5-41.6% superior over the cultivar Maruti (Saxena, 2009). Hence, the increase in yield with an increase in price from Rs 100 kg^{-1} to Rs 150 kg^{-1}will relate to an increase in income to seed producers.

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