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Influence of spacing and irrigation on the seed yield of a CMS line 'ICPA 2043' of hybrid pigeonpea

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ABSTRACT

The study was undertaken to develop a package of agronomic practices for large-scale nucleus seed production of a cytoplasmic-nuclear male-sterile (CMS) line 'ICPA 2043'. The experimental treatments included two planting ratios involving 4 male-sterile: 1 male-fertile and 3 male-sterile: 1 male-fertile lines, two irrigation frequencies (14 and 18 day intervals), and eight plant spacings. Spacing of 75 cm × 30 cm in the 3:1 row ratio with irrigation at 14 days interval during reproductive period produced the highest seed yield of 1871 kg/ha, which was 18.30% more than the best seed yield (1529 kg/ha) obtained in the 4:1 planting ratio with spacing of 75 cm × 30 cm and irrigation at every 14 days. The results further showed that for 4:1 and 3:1 planting ratios, the yield in 75 cm row spacing was 42.64 and 45.56% greater, respectively than the 150 cm with irrigation at every 14 days. Under low plant population density, plants were shorter and sturdier with semi-spreading branches and produced greater single plant yield, biomass, number of primary branches, and pods/plant due to better availability of light. These attributes, however, did not help in realizing high seed yield per unit of land area. In contrast, under high plant population density, individual plants were tall with erect branches, had relatively less biomass and seed yield per plant but produced significantly higher seed yield per ha.

Key words: Cytoplasmic-nuclear male-sterility, Pigeonpea, Planting ratio, Plant spacing, Seed production

Pigeonpea [*Cajanus cajan* (L.) Millspaugh] is recognized as an important pulse crop for subsistence agriculture in the tropics and sub-tropics due to its drought tolerance, high protein (20-22%) grains, quality fodder, and fuel wood. It is cultivated in 4.63 million ha (FAOSTAT 2008) in Asia, Africa, Latin America, and Caribbean islands. India is the largest producer and consumer of pigeonpea. It is one of the major staple foods providing proteins to complement a carbohydrate-rich vegetarian diet in India. According to DAC report (2011), India is cultivating 3.90 million ha of pigeonpea (about 77% of the total global area) with annual production of only 2.89 million tons due to low productivity at 741 kg/ha. However, the annual domestic consumption of this legume is around 3.4 million tons (Price *et al*. 2003). To meet the shortage, the country has to import about 1.5 – 2.8 million tons of pigeonpea annually from Myanmar and Africa (CRNindia.com 2008). The level of productivity of pigeonpea has remained unchanged for decades, which poses a challenge to researchers.

To improve the productivity of this crop, pigeonpea hybrid technology based on cytoplasmic-nuclear male-sterility (CMS) system was developed at ICRISAT (Saxena *et al*. 2005), which facilitated the large-scale economic seed production of hybrids and their female parents. The nucleus seed production of the female parental line of hybrids was undertaken to ensure the highest standards of genetic purity and uniformity (Saxena 2006).

For large-scale nucleus seed production of female parents of pigeonpea, cytoplasmic-nuclear male-sterile (A) and maintainer (B) lines should be planted at an isolation distance of about 500 m from other pigeonpea fields to avoid contamination due to natural out-crossing. However, the success of seed production depends on various physical and biological factors such as the number and type of pollinating insects (Bhatia *et al*. 1981). Some other agronomic practices are regarded as important for seed production. These include sowing seeds at a right time and in a right way; appropriate inter- and intra-row spacing; optimum soil moisture during crop growth, and efficient insect management.

Growth and development of pigeonpea varies from location to location due to variability in agro-climatic and soil-water related parameters. Even in the same location, variability in growth takes place due to different sowing dates, plant density, irrigation methods and frequency, nutrient and weed management, and other cultural and management practices (Ahlawat and Rana 2005). Plant density is an important factor in increasing crop production; however, narrow row spacings bring variation in microclimate like light intensity, evapo-transpiration and temperature of soil surface (Sinha *et al*. 1988). These production constraints stand as a challenge among stakeholders including farmers. This research was conducted to identify the best plant spacing and irrigation frequency for optimizing yield of nucleus seed of a CMS-line 'ICPA 2043' of pigeonpea.

MATERIALS AND METHODS

The male-sterile 'ICPA 2043' and its male-fertile maintainer line 'ICPB 2043' were sown in an isolated area of 0.4 ha in Alfisols at the International Crops Research Institute

for the Semi-Arid Tropics (ICRISAT), Patancheru on June 20, 2008. The parental lines were sown in two planting ratios that included 4 male-sterile (female) to 1 male-fertile (male) (4:1) and 3 male-sterile to 1 male-fertile (3:1). Within each planting ratio, there were two row-to-row spacings (75 cm and 150 cm), two irrigation frequencies (14 day and 18 day intervals after flower initiation till pod development) at field capacity of 50 mm/irrigation by flooding, and four plant-to-plant spacings (30 cm, 50 cm, 75 cm and 100 cm) of male-sterile plants. During the reproductive stage, three irrigations (at every 14 days interval) and two irrigation levels (at every 18 days interval) were applied. The maintainer line was sown at 30 cm intra-row spacings. The length of each row was 5 m. A basal dose of di-ammonium phosphate (18-46-00) @ 100 kg/ha was applied. Recommended agronomic practices were followed uniformly to produce a good crop for all the experimental units. Total rainfall of 868.4 mm was received during 2008-2009 cropping season with more rainfall in the months of July (114.3 mm), August (382.1 mm), September (184.4 mm) during its vegetative phase and October (85.4 mm) during its flower initiation phase. Irrigation was stopped when the pods are at physiological maturity. Data on plant height at 50% flowering (cm), diameter of main stem (cm), weight of dry biomass (kg), number of primary branches, pods/plant, seeds/pod, 100-seed mass (g), and seed yield (g/plant) were collected on 10 randomly selected competitive plants within each treatment. The total seed yield (kg/ha) was calculated on plot basis. To determine the best plant spacing in each row ratio and irrigation, analyses of variance for split-split plot design with two replications was used to determine the best treatments for optimizing seed yield of 'ICPA 2043'.

RESULTS AND DISCUSSION

Row ratio effect: The yield contributing traits of 'ICPA 2043' such as plant height, stem diameter, seeds/pod, and 100-seed mass were significantly (P<0.05) different between the two row ratios (Table 1). In the 4:1 row ratio, the t-test revealed that weight of dry biomass, number of primary branches, and number of pods was greater as compared to 3:1 row ratio. However, these traits did not help the plants influence the production of more seed yield. The study showed that among the yield contributing characters of pigeonpea, the 100-seed mass in the 3:1 row ratio has relatively influenced the seed yield (10.08 g/plant), which confirms to the findings of Makhan and Gupta (1984) where higher seed yields were positively associated with seed weight of pigeonpea. The present study further revealed that the 3:1 row ratio gave marginally higher (10.75%) but non-significant seed yield as compared to the 4:1 row ratio. These results refuted the findings of Saxena (2006), and Mula *et al.* (2010) where 4:1 was identified as the optimum row ratio of male:female parent lines for producing higher seed yield of hybrid pigeonpea.

Irrigation effect: The results showed that yield traits such as plant height and stem diameter were significantly (P<0.05) influenced by the different irrigation levels in both row ratios, whereas the 100-seed mass and dry biomass were significant for irrigation treatment in 4:1 ratio while seeds/pod was significantly affected by the different irrigation treatments in 3:1 ratio (Table 2). However, in both the row ratios, the number of primary branches, number of pods, and seed yield between the two irrigation frequencies were similar.

The t-test showed that irrigation at every 14 days for both row ratios of 4:1 (790 kg/ha) and 3:1 (909 kg/ha) produced the high seed yield. These results correspond to the findings of Mula *et al.* (2010) where irrigation at every 14 days in row ratio 4:1 resulted in higher seed yield by as much as 14.74%. According to Chauhan (1990), the application of three irrigations doubled seed yields of pigeonpea in Alfisols. The results are also in conformity to the findings of Rao *et al.* (1983) where application of one or two protective irrigations during the critical growth stages of pigeonpea (flowering and pod formation) produced higher yields. This concludes that the productivity of pigeonpea is enhanced through irrigation (Chauhan *et al.* 1987, Mula *et al.* 2010).

Row spacing effect: In the 4:1 row ratio, the agronomic characters of 'ICPA 2043' with irrigation at every 18 days were significantly (P<0.05) different between the row spacing of 75 cm and 150 cm on the stem diameter, dry biomass, pods/plant, seeds/pod, and 100-seed weight. While in irrigation at every 14 days, the two row spacings were significantly different for stem diameter, dry biomass, pods/plant, and seed yield/plant however, seed yield of the different row spacings with two irrigation levels was not significant; but the total effect of both the row spacings and irrigation levels on seed yield was significantly affected (Table 3). In the 3:1 row ratio with irrigation at every 18 days, stem diameter, dry biomass, number of branches, pods/plant, 100-seed weight, and seed yield/plant were significantly (P<0.05) different between the two row spacings. In irrigation at every 14 days, there were significant differences for stem diameter, weight of dry biomass, pods/plant, and seed yield. However, both the row

Table 1. Effect of row ratio on the various agronomic and yield and yield traits of 'ICPA 2043'

Row ratio	Plant height at 50% flowering (cm)	Stem diameter (cm)	Biomass (kg)	Branches (no.)	Pods/ plant (no.)	Seeds/ pod (no.)	100- seed weight (g)	Yield	
								Per plant (g)	Per ha (kg)
4:1	205.78	2.90	1.45	18.88	729.43	3.69	9.72	89.87	778
3:1	213.01	2.61	1.28	16.48	673.83	3.63	10.08	104.12	861
P(<0.05)	0.0004	0.02	0.27	0.086	0.44	0.01	0.04	0.17	0.34

Table 2. Effect of irrigation on various agronomic and yield traits of 'ICPA 2043' under 4:1 and 3:1 row ratio

Irrigation	Plant height at 50% flowering (cm)	Stem diameter (cm)	Biomass (kg)	Branches (no.)	Pods/ plant (no.)	Seeds/ pod (no.)	Weight of 100 seeds (g)	Yield	
								Per plant (g)	Per ha (kg)
Row ratio 4:1									
Every 18 days	202.61	3.00	1.30	18.53	697.44	3.686	10.16	92.96	765
Every 14 days	208.95	2.80	1.60	19.22	761.43	3.687	9.28	86.78	790
P (<0.05)	0.006	0.004	0.008	0.79	0.29	0.94	<.0001	0.61	0.79
Row ratio 3:1									
Every 18 days	209.11	2.51	1.37	16.72	641.15	3.67	10.05	104.59	814
Every 14 days	216.91	2.71	1.19	16.23	706.51	3.59	10.10	103.66	909
P (<0.05)	0.004	<.0001	0.12	0.44	0.27	0.01	0.85	0.90	0.22

Table 3. Interactive effect of row spacing, row ratio with irrigation for various agronomic and yield traits of 'ICPA 2043'

Row spacing	Plant height at 50% flowering (cm)	Stem diameter (cm)	Biomass (kg)	Branches (no.)	Pods/ plant (no.)	Seeds/ pod (no.)	Weight of 100 seeds (g)	Yield	
								Per plant (g)	Per ha (kg)
Interactive effect of row spacing in row ratio 4:1 with irrigation every 18 days									
75 cm	201.85	2.46	0.95	17.73	504.02	3.71	10.51	73.13	873
150 cm	203.36	3.13	1.65	19.34	890.92	3.66	9.81	112.78	659
P(<0.05)	0.63	0.0003	0.001	0.35	0.003	0.003	0.02	0.09	0.09
Interactive effect of row spacing in row ratio 4:1 with irrigation every 14 days									
75 cm	209.29	2.59	1.01	14.26	562.45	3.69	9.43	69.25	929
150 cm	208.61	3.42	2.19	24.18	960.45	3.68	9.14	104.32	651
P(<0.05)	0.82	<.0001	<.0001	0.07	0.002	0.74	0.15	0.02	0.09
Effect of row spacing in 4:1 row ratio									
P(<0.05)									0.02
Interactive effect of row spacing in row ratio 3:1 with irrigation every 18 days									
75 cm	207.21	2.25	0.77	15.67	506.77	3.63	9.70	69.43	814
150 cm	211.01	2.76	1.62	17.77	775.57	3.70	10.41	139.74	814
P(<0.05)	0.10	<.0001	<.0001	0.05	0.01	0.12	0.04	0.0004	0.99
Interactive effect of row spacing in row ratio 3:1 with irrigation every 14 days									
75 cm	220.32	2.41	1.05	15.69	486.10	3.58	10.17	82.41	1078
150 cm	213.50	3.00	1.69	16.78	926.97	3.59	10.02	124.90	741
P(<0.05)	0.14	0.0004	0.02	0.27	0.002	0.82	0.60	0.006	0.02
Effect of row spacing in 3:1 row ratio									
P(<0.05)									0.04

spacings under both irrigation levels significantly influenced the seed yield.

The study showed that 75 cm row spacing in the 3:1 row ratio gave the highest seed yield of 1078 kg/ha, which is 16.01% higher than its counterpart in the 4:1 row ratio (Table 3). The results further showed that in both row ratios, seed yield in row spacing of 75 cm was superior over 150 cm except in 3:1 planting at 18 days irrigation interval, which corroborated the findings of Rao *et al.* (1983) but refuted to the findings of Singh *et al.* (1983). However, these results corresponds to the findings of Mula *et al.* (2010) where row spacing of 75 cm, irrespective of irrigation levels, produced higher seed yield vis a vis 150 cm even though individual plants at 150 cm row spacing have thicker stem, more dry biomass, more number of productive branches and more number of pods than at 75 cm.

Plant spacing and irrigation effect: The effect of plant spacing and irrigation influenced the seed yield and other plant traits in both the row ratios. The diameter of main stem, dry biomass, pods/plant, seeds/pod, and seed yield/plant were significantly (P<0.05) different among spacings of the two irrigation levels in 4:1 and 3:1 row ratios. In addition, the weight of 100-seed in the 4:1 row ratio and seed yield/ha in the 3:1 row ratio was significantly different (Table 4). These attributes further prove that the different spacings have influenced seed yield of 'ICPA 2043' which corresponds to the findings of Mula *et al.* (2010), but is not in conformity to the findings of Siag and Verma (1994) where seed yield and yield contributing characters of pigeonpea were not significantly influenced by plant spacing. However, the study further revealed that at closer planting distance, seed yield tends to be on higher side than the wider spacing due to higher plant density per unit area, which conforms to the findings of Mula *et al.* (2010). Plant spacing of 75 cm × 30 cm with irrigation at every 14 days in the 4:1 and 3:1 row ratios registered the highest seed yield of 1529 kg/ha and 1872 kg/ha, respectively (Table 4). The

Table 4. Interactive effect of plant spacing for various agronomic and yield and yield traits of 'ICPA 2043' under different irrigation treatments in row ratios of 4:1 and 3:1

Spacing (cm)	Plant height at 50% flowering (cm)	Stem diameter (cm)	Biomass (kg)	Branches (no.)	Pods/ plant (no.)	Seeds/ pod (no.)	Weight of 100 seeds (g)	Yield	
								Per plant (g)	Per ha (kg)
Irrigation every 18 days in row ratio 4:1									
75×30	205.75	1.99	0.68	15.78	293.90	3.80	10.58	43.84	1062
75×50	199.25	2.32	0.73	16.80	367.70	3.55	10.34	60.27	878
75×75	198.90	2.67	1.08	17.58	612.60	3.68	10.44	73.23	708
75×100	203.50	2.84	1.31	20.75	741.90	3.81	10.68	115.20	839
150×30	208.50	2.59	0.97	20.77	478.40	3.76	9.40	68.83	834
150×50	202.90	3.15	1.46	15.62	768.00	3.64	9.43	71.78	523
150×75	201.15	3.27	1.81	20.48	1126.20	3.65	10.02	123.42	597
150×100	200.90	3.53	2.37	20.48	1191.10	3.58	10.36	187.09	681
Irrigation every 14 days in row ratio 4:1									
75×30	205.15	2.07	0.69	12.48	413.10	3.66	9.57	63.11	1529
75×50	212.00	2.50	0.88	14.38	445.90	3.72	9.75	60.59	882
75×75	215.00	2.73	1.19^{f}	14.00	753.40	3.71	9.50	79.14	765
75×100	205.00	3.04	1.28	16.18	637.40	3.69	8.88	74.17	540
150×30	211.50	2.78	1.51	16.45	711.70	3.57	9.38	71.42	866
150×50	207.40	3.43	2.00	21.33	968.40	3.72	8.53	95.16	693
150×75	206.90	3.57	2.50	33.47	1103.00	3.65	9.20	112.20	543
150×100	208.65	3.89	2.77	25.47	1058.70	3.77	9.44	138.49	504
P(<0.05)	0.28	<.0001	<.0001	0.49	0.0005	0.03	0.002	0.05	0.11
Irrigation every 18 days in row ratio 3:1									
75×30	207.75	1.93	0.49	13.78	429.50	3.61	9.56	46.92	1050
75×50	208.90	2.12	0.73	16.57	449.10	3.64	9.94	71.25	958
75×75	205.30	2.34	0.80	14.42	528.30	3.65	9.70	79.11	707
75×100	206.90	2.61	1.07	17.93	620.20	3.63	9.59	80.45	541
150×30	207.25	2.35	1.12	18.10	571.60	3.61	9.74	93.67	1047
150×50	212.80	2.68	1.53	16.68	729.80	3.78	10.47	141.85	953
150×75	212.25	2.89	1.71	18.27	897.70	3.75	10.86	152.05	678
150×100	211.75	3.11	2.11	18.02	903.20	3.64	10.55	171.41	576
Irrigation every 14 days in row ratio 3:1									
75×30	217.75	2.17	1.06	14.27	373.30	3.58	9.69	83.67	1872
75×50	222.80	2.34	0.99	14.90	512.00	3.59	10.59	87.73	1179
75×75	223.75	2.50	1.10	16.87	615.20	3.53	10.08	89.39	798
75×100	217.00	2.63	1.06	16.73	443.90	3.64	10.33	68.86	463
150×30	215.50	2.62	1.32	16.37	562.10	3.67	9.62	85.78	965
150×50	209.75	2.87	1.66	16.48	898.60	3.60	10.05	130.15	875
150×75	214.25	3.18	1.82	15.87	1064.20	3.69	10.46	154.15	688
150×100	214.50	3.35	1.98	18.40	1183.00	3.41	9.95	129.54	435
P (<0.05)	0.27	<.0001	0.003	0.23	0.003	0.02	0.72	0.0007	0.001

difference in yield increase in 3:1 compared to 4:1 ratio was 22.41%. These results also refuted the findings of Saxena (2006) where row ratio of 4:1 with planting distance of 100 cm × 50 cm increased seed yield by as much as 164% as compared with the yield obtained from plant spacing of 75 cm × 30 cm. The 3:1 row ratio having plant spacing of 75 cm × 30 cm with irrigation at every 14 days was superior amongst the treatments.

This study further showed that as plant density increases, there was a progressive reduction on yield and yield traits of individual plants which conforms to the findings of Mula *et al.* (2010). Ahlawat and Saraf (1981) reported that with wider spacing the number of pods/plant was more due to more number of branches. However, the vegetative and yield characters did not gain any advantage to the total seed yield as compared with closer plant spacing as found in conformity with Sekhon *et al.* (1996). Likewise, at closer planting distance, seed yield varies remarkably under different spacing and irrigation levels (Mula *et al.* 2010).

The agronomic traits of 'ICPA 2043' are an indicator of the extent to which a crop shows its potential in producing quality seeds. There were significant (P<0.05) differences in most of the agronomic traits of pigeonpea using different plant spacings for both the row ratios and irrigation treatments. It

can be inferred that pigeonpea yield tends to be higher at closer spacing and a progressive decline with wider spacing. With wider planting distance, the mean value per plant for a trait was higher as compared to closer spacing. This study showed that planting distance of 75 cm × 30 cm with irrigation at every 14 days in 4:1 and 3:1 row ratios produced the highest seed yield of 1529 kg/ha and 1872 kg/ha, respectively. For both planting ratios, row spacing of 75 cm was superior over 150 cm. The response of irrigation at every 14 days (3 irrigations during flower initiation till pod development) and 18 days (2 irrigations) to seed yield of 'ICPA 2043' was not significant. The row ratio of 3:1 provided marginally higher seed yield than 4:1.

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