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Effect of spacing and irrigation on seed production of a CMS-based pigeonpea hybrid

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ABSTRACT. The study was conducted to determine agronomic practices for optimizing hybrid seed production of a CMS-based pigeonpea hybrid ICPH 2671. The hybrid seed is produced by crossing ICPA 2043 (female parent) and ICPR 2671 (male parent). Seed set on the male-sterile plants occur due to pollen transfer from male to female parents and was mediated by insects. The treatments included two row ratios involving 4 male-sterile ICPA 2043:1 male-fertile ICPR 2671 (restorer) and 3 female:1 male; two irrigation frequencies (14 and 21 days interval); and seven plant spacings. The study revealed that the spacing of 75 cm x 30 cm with irrigation at every 14 days (5 irrigations during flower initiation till pod development) in the row ratios of 4:1 (2357 kg ha^{-1}) as well as 3:1 (2699 kg ha^{-1}) produced the highest yield. Results also revealed that the differences between the row spacing of 75 cm and 150 cm were significant for seed yield while the effect of irrigation frequencies and row ratios were non-significant for yield and yield contributing characters of ICPA 2043. Under high density, the plants were tall with erect branches, because of high inter-plant competition for light and produced relatively less biomass and seed yield. On the contrary under low densities, the plants were comparatively shorter and sturdier with semi-spreading branches and greater individual plant yield, biomass, stem thickness, and pods $plant^{-1}$. Such increases in low density, however, did not help plants to compensate and produce high seed yield that was obtained under closer spacings. The yield advantage at closer spacing was 30-60% more than that of wide spacing.

Keywords : *Agronomic practices, Cajanus cajan, CMS-based, hybrid seed production, irrigation frequency, pigeonpea, plant spacing.*

INTRODUCTION

Pigeonpea [*Cajanus cajan* (L.) Millspaugh] an important food legume for both tropics and sub-tropics is considered as the most valuable crop for sustainable agriculture. In India, pigeonpea is cultivated in 3.58 million hectares, accounting for 77.32% of the total global area of 4.63 million hectares (FAOSTAT, 2008). However, India experiences grain shortage of 1.5 – 2.8 million tons annually (CRNindia.com, 2008) due to low productivity of 685-700 kg ha^{-1} (FAOSTAT, 2008). This level of productivity has remained unchanged for the past decades, which poses a challenge to scientists and policy makers.

According to Saxena *et al.* (2000) the demand of pigeonpea is consistently increasing and to enhance its production, cultivation of hybrids is the answer. The limiting factor for farmers, in adopting this technology, is acquiring hybrid seeds yearly. The benefits derived from cultivating hybrids are not only its high yield but also reduction in seed rate, and greater resistance against diseases offsetting the higher seed cost (Saxena, 2006).

The important feature in any commercial hybrid breeding system is its seed production technology that will produce sufficient amount of seeds. The issues related to crop's low productivity have to be looked into the interactions of genetic materials with bio-physical resources like soil, water, and density. In pigeonpea, planting time, density and cropping pattern can drastically modify plant phenology (Lawn and Troedson, 1990) in manifesting crop productivity. Importantly, some agronomic practices such as proper timing during sowing, sufficient moisture, and pest/disease management are regarded as safeguards for seed production.

With the growing population and diminishing farm area, research must focus in increasing yield per unit area through appropriate agronomic practices (Ali and Kumar, 2000; Sekhon *et al.*, 1996) and the use of hybrid (Saxena, 2008). This experiment was conducted to identify the best plant spacing and irrigation frequency for optimizing yield of pigeonpea hybrid.

MATERIALS AND METHODS

The male-sterile ICPA 2043 and male-fertile ICPR 2671 (restorer) parents were sown for seed production of hybrid ICPH 2671 in an isolated and uniform area of 0.3 hectare in Vertisols at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru on June 22, 2008. A basal dose of 100 kg ha^{-1} of di-ammonium phosphate was

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applied. The experiment was laid out in Randomized Complete Block Design (RCBD) with four replications. The parental lines were sown in two row ratios that involved 4 female to 1 male; and 3 female to 1 male. Within each row ratio, two different irrigations, two row spacings and seven plant to plant spacings were assessed. The female line with row to row spacing of 75 cm had four (30 cm, 50 cm, 75 cm, and 100 cm) plant to plant spacings; while in row spacing of 150 cm three plant to plant spacings (30 cm, 50 cm, and 75 cm) were evaluated. The length of each row was 5 m. The plant to plant spacing within single row of male line was 30 cm. During reproductive period, two irrigation levels (14 day and 21 day intervals) were applied. Normal cultural practices were followed uniformly to raise a good crop for all experimental units. Data on plant height at 50% flowering (cm), diameter of main stem (cm), weight of dry plant biomass at harvest (g), number of productive branches plant^{-1}, pods plant^{-1}, seeds pod^{-1}, 100-seed mass (g), and seed yield (g) plant^{-1} were recorded on ten randomly selected competitive plants within each treatment. To identify the best plant spacing for each row ratio and irrigation, analysis of variance for randomized complete block design (RCBD) was used. To test and compare the two row spacings (75 cm and 150 cm), a linear contrast was performed. For all the comparisons, analysis of variance and t-tests were performed to identify the treatments with the best yield and yield contributing characters of ICPA 2043.

RESULTS AND DISCUSSION

In India, pigeonpea production under traditional rainfed farming systems is generally low because of inherently low yielding cultivars and poor agronomic package. This has compelled the importation of pigeonpea from Myanmar and eastern and southern Africa (CRNIndia.com, 2008) to meet the domestic demand. The extensive testing of CMS-based hybrids revealed the presence of high levels of heterosis for seed yield in pigeonpea. To make the hybrid seed production commercially viable, optimum planting ratio of male and female parents, spacing, and irrigation should be determined. The information available on these aspects is meager and hence, a study was undertaken and the results are discussed below.

Effect of row ratio : There were significant (P<0.05) differences among the two row ratios for number of productive branches, seeds pod^{-1}, and 100-seed mass (g); while no significant differences were observed for plant height, diameter of main stem, pods plant^{-1}, and seed yield of ICPA 2043 (**Table 1**). Even though the yield contributing characters of ICPA 2043 differed between the two row ratios, the difference in seed yield was negligible. However, the t-test showed that the row ratio of 4:1 gave higher yield (1488.40 kg ha^{-1}) which was 12.58% higher than 3:1 row ratio due to an additional row of ICPA 2043. These results corroborated the findings of Saxena (2006) and Joshi et al. (1998) where row ratio 4:1 was effective in producing higher yield of the female parent.

Effect of irrigation : The results showed that yield components of ICPA 2043 except for seeds pod^{-1} in row ratio 4:1 and number of productive branches in row ratio 3:1 were not significantly (P<0.05) affected by irrigation treatments (**Table 2**). Likewise, there were no significant differences for seed yield between two irrigation frequencies for both the row ratios. The t-test revealed that irrigation at every 14 days (5 irrigations) in 4:1 row ratio resulted in high seed yield of 1536.20 kg ha^{-1}; while in 3:1 ratio, irrigation at every 21 days (3 irrigations) registered high yield of 1309.82 kg ha^{-1}. However, the increase in yield in 4:1 row ratio with irrigation at every 14 days compared with every 21 days is insignificant (6.22%). On the other hand, in 3:1 row ratio, increase in yield with the 21-day irrigation interval compared with the 14-day irrigation schedule was negligible (1.34%). The results are in

Table 1. Analysis of variance and t-test for various characters of ICPA 2043 in row ratios of 4:1 and 3:1

Row ratio (cm)	Plant height at 50% flowering (cm)	Stem diameter (cm)	Biomass (g)	Branches (no.)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	Weight of 100 seeds (g)	Yield plant^{-1} (g)	Yield ha^{-1} (kg)
4:1	186.20^{a}	2 32^{a}	831.38^{a}	17.69^{a}	676.52^{a}	3.99^{b}	12.52^{b}	142.51^{a}	1488.40^{a}
3:1	189 94^{a}	2.30^{a}	873.84^{a}	15.12^{b}	592.65^{a}	4.17^{a}	13.01^{a}	134.61^{a}	1301.10^{a}
R^2	0.02	0.002	0 009	0.27	0.05	0.09	0.24	0.009	0.75
MSE	220.93	0 07	50518.97	4.59	37397.25	0.08	0.20	1828.49	193534.23
Mean	188.07	2.31	852.61	16.41	634.59	4.08	12.76	138.56	1394.73
CV (%)	7.90	11.83	26.36	13.05	30.47	7.04	3.47	30.86	31.54
P(<0.05)	0.35	0.73	0.48	<.0001	0.11	0.02	0.0001	0.49	0.13
LSD	7.96	0.15	120.43	1.15	103.62	0.15	0.24	22.91	241.68

Note : Values in the columns bearing different superscripts differ significantly at P<0.05

Table 2. Analysis of variance and t-test for various characters of ICPA 2043 under different irrigation frequency in row ratios of 4:1 and 3:1

Row ratio (cm)	Plant height at 50% flowering (cm)	Stem diameter (cm)	Biomass (g)	Branches (no.)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	Weight of 100 seeds (g)	Yield plant^{-1} (g)	Yield ha^{-1} (kg)
Row ratio 4:1									
Every 14 days	188.08^{a}	2.30^{a}	841.01^{a}	17.87^{a}	700.74^{a}	3.80^{b}	12.63^{a}	144.40^{a}	1536.20^{a}
Every 21 days	184.33^{a}	2.35^{a}	821.76^{a}	17.51^{a}	652.31^{a}	4.18^{a}	12.40^{a}	140.62^{a}	1440.60^{a}
R^2	0.65	0.60	0.81	0.63	0.44	0.87	0.53	0.64	0.81
MSE	12.39	0.05	20118.07	3.02	60511.23	0.02	0.23	1250.44	156645.27
Mean	186.20	2.32	831.38	17.69	676.52	3.99	12.52	142.51	1488.40
CV (%)	6.65	9.89	17.06	9.83	36.36	3.21	3.83	24.81	26.59
P(<0.05)	0.44	0.56	0.72	0.59	0.61	<.0001	0.22	0.78	0.51
LSD	10.12	0.19	115.82	1.42	200.86	0.10	0.39	28.87	323.17
Row ratio 3:1									
Every 14 days	187.06	2.32	910.64	16.55	622.04	4.24	13.08	132.91	1292.31
Every 21 days	192.81	2.28	837.04	13.69	563.27	4.10	12.94	136.31	1309.82
R^2	0.50	0.80	0.76	0.73	0.73	0.49	0.31	0.93	0.92
MSE	241.55	0.03	25058.50	2.90	12603 57	0.11	0.22	288.51	56042.53
Mean	189.94	2.30	873.84	15.12	592.65	4.17	13.01	134.61	1301.07
CV (%)	8.18	8.19	18.11	11.26	18.94	7.88	3.63	12.62	18.19
P(<0.05)	0.34	0.57	0.24	0.007	0.18	0.28	0.44	0.61	0.85
LSD	12.69	0.15	129.26	1.39	91.67	0.27	0.39	13.87	193.30

Note : Values in the columns bearing different superscripts differ significantly at P<0.05

conformity with the findings of Reddy et al. (1984) and Kumar Rao et al. (1992) where no major interactions were observed between the two irrigation levels and plant densities on various agronomic characters. The study further revealed that irrigations applied between flower initiation and pod development was a major factor in producing ample seeds of ICPA 2043. This was also demonstrated by Bhan and Khan (1979) where a single irrigation during pod-filling stage gave higher yield of pigeonpea.

Effect of row spacing : In the row ratio of 4:1, seeds pod^{-1} and yield ha^{-1} differed significantly (P<0.05) in the two row spacings (75 cm and 150 cm) with irrigation at every 14 days. In the irrigation treatment at every 21 days, there were significant differences on the diameter of main stem, weight of dry biomass, and number of pods plant^{-1}. In row ratio of 3:1, there were significant differences for biomass production, number of pods plant^{-1}, and yield plant^{-1} with irrigation at every 14 days. A 21-day interval in irrigation resulted in a significant differences in the two row spacing (75 cm and 150 cm) with respect to the diameter of main stem, weight of biomass, yield plant^{-1} and yield ha^{-1}. However, irrespective of irrigation, both row spacings were significantly different in yield ha^{-1} in row ratio 4:1 and 3:1 (**Table 3**).

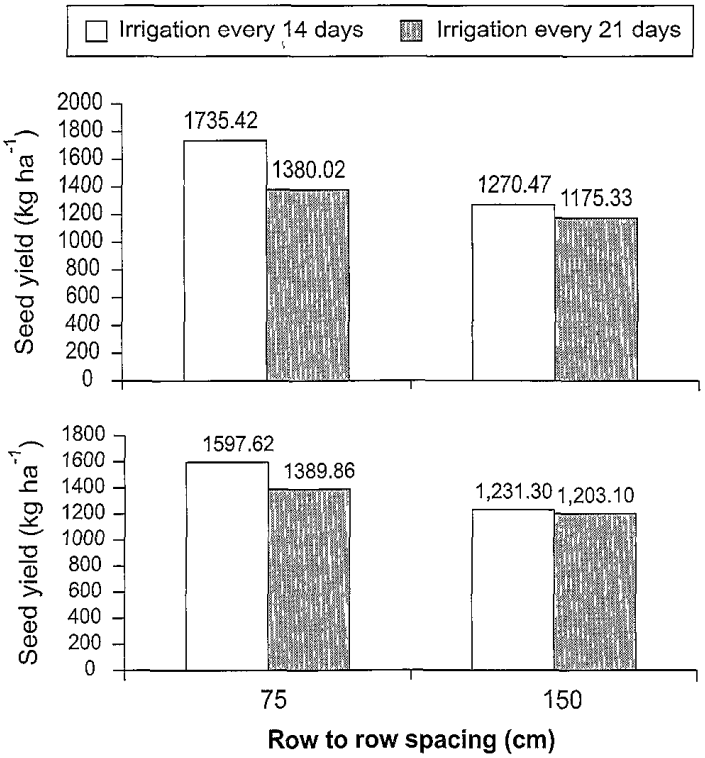

Fig. 1. Seed yield of ICPA 2043 at two row spacings, irrigations under 4:1 (upper graph) and 3:1 (lower graph) row ratios

Table 3. Analysis of variance for various characters of ICPA 2043 under different row spacing and irrigation in row ratios of 4:1 and 3:1

Row ratio (cm)	Plant height at 50% flowering (cm)	Stem diameter (cm)	Biomass (g)	Branches (no.)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	Weight of 100 seeds (g)	Yield plant^{-1} (g)	Yield ha^{-1} (kg)
Effect of row spacing (75 cm and 150 cm) in row ratio 4:1 with irrigation at every 14 days									
75	193.01	2.23	807.72	16.62	666.55	3.88	12.74	131.86	1735.42
150	181.48	2.39	885.43	18.80	746.37	3.69	12.49	161.12	1270.47
MSE	126.23	0.04	17446.14	3.05	67586.81	0.003	0.15	582.98	52553.42
P(<0.05)	0.11	0.19	0.32	0.06	0.59	0.001	0.28	0.07	0.01
Effect of row spacing (75 cm and 150 cm) in row ratio 4:1 with irrigation at every 21 days									
75	186.15	2.22	689.15	17.72	552.65	4.15	12.49	122.76	1597.62
150	181.90	2.52	998.60	17.23	785.23	4.22	12.28	164 44	1231.30
MSE	110.62	0.02	16041.65	2.93	26772.44	0.03	0.31	1995.11	285198.77
P(<0.05)	0.48	0.02	0.004	0.61	0.04	0.48	0.53	0.13	0.25
Effect of row spacing (75 cm and 150 cm) in 4:1									
MSE									156645.27
P(<0.05)									0.02
Effect of row spacing (75 cm and 150 cm) in row ratio 3:1 with irrigation at every 14 days									
75	191.95	2.22	804.1	16.98	553.35	4.35	13.06	114.08	1380.02
150	180.53	3.52	1052.73	15.99	713.63	4.10	13.10	158.03	1175.33
MSE	306.85	0.03	18814.40	1.38	10886.28	0.91	0.12	408.14	112309.22
P(<0.05)	0.27	0.26	0.01	0.17	0.03	0.27	0.82	0.007	0.30
Effect of row spacing (75 cm and 150 cm) in row ratio 3:1 with irrigation at every 21 days									
75	195.32	2.14	694.27	13.25	508.12	4.13	12.88	107.41	1389.86
150	189.47	2.56	1027.43	14.30	636.87	4.06	13.01	174.85	1203.10
MSE	171.26	0.03	26850.35	1.98	16415.39	0.07	0.34	216.96	9005.27
P(<0.05)	0.44	0.006	0.009	0.22	0.11	0.66	0.71	0.0001	0.01
Effect of row spacing (75cm and 150cm) in 3:1									
MSE									56042.53
P(<0.05)									0.05

The study suggested that the row spacing of 75 cm, irrespective of irrigation frequencies, produced the highest seed yield ha^{-1} of ICPA 2043 (**Fig.1**). Row spacing of 75 cm in 4:1 ratio resulted in the highest increase in seed yield at 26.79% and 22.93% in irrigation at every 14 days and 21 days, respectively. In 3:1 ratio, there was a minimal increase in seed yield for row spacing of 75 cm at 14.83% with irrigation at every 14 days and 13.44% in irrigation at every 21 days. Reflecting that the yield tends to be higher at closer row spacing where plant density was higher, which conforms to the findings of Abrams and Julia (1973) and Chauhan (1990). They demonstrated that high plant populations do not necessarily reduce yield. Although, the yield was significantly different among the two row spacings with irrigation at every 14 days in 4:1 ratio and irrigation at every 21 days in 3:1 ratio, the variation was not significant which conforms to the findings of Siag and Verma (1994) where the seed yield and yield contributing characters of pigeonpea were not significantly influenced by plant spacing.

Effect of plant spacing and irrigation : Plant spacing and irrigation within 4:1 row ratio did not significantly ($P<0.05$) affect seed yield and yield contributing characters of CMS-line ICPA 2043. Although there were differences in various agronomic parameters among the treatments, but these differences were found to be non significant except for the biomass yield and seeds pod^{-1} (**Table 4**) which is in contrast to the findings of Abrams and Julia (1973) where row spacing and plant population had no effect on the number of seeds pod^{-1}. Plant density either at closer or wider spacing did not increase seed yield and it is in accordance to observations of Lawn and Troedson (1990) where plant population and spatial arrangements, which exploit biomass production, may not necessarily maximize seed yield. Seed yield was accounted for by higher number of pods plant^{-1} recorded under low plant density, which is in conformity with the findings of Tripathi (1986) and Sodavadiva et al. (2009) where seed yield plant^{-1} had significant and positive association with the number of branches plant^{-1}, pods plant^{-1}

Table 4. Analysis of variance and t-test for various characters of ICPA 2043 under different plant spacing and irrigation in row ratios of 4:1 and 3:1

Row ratio (cm)	Plant height at 50% flowering (cm)	Stem diameter (cm)	Biomass (g)	Branches (no.)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	Weight of 100 seeds (g)	Yield plant^{-1} (g)	Yield ha^{-1} (kg)
Row ratio 4 female:1 male			**Irrigation at every 14 days**						
75 x 30	193.60^{ab}	2.03^{c}	572.30^{d}	18.35^{ab}	491.40^{a}	4.20^{abc}	12.56^{ab}	103.21^{c}	2357.10^{a}
75 x 50	186.50^{abcd}	2.24^{abc}	602.00^{d}	17.15^{ab}	459.00^{a}	4.15^{abc}	12.24^{ab}	100.58^{c}	2215.00^{ab}
75 x 75	166.80^{cd}	2.12^{bc}	608.80^{d}	17.48^{ab}	594.60^{a}	4.27^{ab}	11.90^{b}	139.80^{bc}	1769.50^{abc}
75 x 100	197.70^{ab}	2.49^{abc}	973.50^{abc}	17.88^{ab}	665.60^{a}	3.96^{cd}	13.23^{a}	147.45^{abc}	1018.00^{bc}
150 x 30	188.00^{abcd}	2.34^{abc}	834.80^{abcd}	16.73^{ab}	696.80^{a}	4.31^{a}	12.35^{ab}	132.14^{bc}	1382.20^{abc}
150 x 50	185.45^{abcd}	2.60^{ab}	1111.00^{a}	16.22^{b}	850.40^{a}	4.32^{a}	12.20^{ab}	141.09^{bc}	1174.40^{abc}
150 x 75	172.25^{bcd}	2.62^{a}	1050.00^{ab}	18.73^{ab}	808.50^{a}	4.02^{bcd}	12.30^{ab}	220.10^{a}	977.90^{b}
			Irrigation at every 21 days						
75 x 30	201.20^{a}	2.09^{c}	575.30^{d}	20.12^{a}	533.10^{a}	4.00^{cd}	12.80^{ab}	115.10^{bc}	1979.10^{abc}
75 x 50	191.05^{abc}	2.26^{abc}	753.80^{bcd}	18.88^{ab}	444.00^{a}	3.78^{de}	12.69^{ab}	108.60^{c}	1581.10^{abc}
75 x 75	189.05^{abcd}	2.19^{abc}	921.80^{abc}	18.55^{ab}	809.60^{a}	3.81^{de}	12.72^{ab}	150.85^{abc}	1458.70^{abc}
75 x 100	190.75^{abc}	2.37^{abc}	980.00^{abc}	17.67^{ab}	879.50^{a}	3.95^{cd}	12.75^{ab}	152.89^{abc}	1113.00^{bc}
150 x 30	198.20^{ab}	2.30^{abc}	1034.90^{ab}	16.98^{ab}	660.90^{a}	3.59^{e}	12.55^{ab}	156.88^{abc}	1901.40^{abc}
150 x 50	163.55^{d}	2.24^{abc}	699.50^{cd}	16.70^{ab}	704.50^{a}	3.64^{e}	12.26^{ab}	135.23^{bc}	984.40^{bc}
150 x 75	182.75^{abcd}	2.62^{a}	921.90^{abc}	16.17^{b}	873.70^{a}	3.85^{de}	12.66^{ab}	191.24^{ab}	925.60^{c}
R^2	0.65	0.60	0.81	0.63	0.44	0.87	0.53	0.64	0.59
MSE	153.55	0.05	20118.07	3.02	60511.23	0.02	0.23	1250.44	331025.94
Mean	186.20	2.32	831.38	17.69	676.52	3.99	12.52	142.51	1488.40
CV (%)	6.65	9.89	17.06	9.83	36.36	3.21	3.83	24.81	38.65
P(<0.05)	0.17	0.25	0.01	0.61	0.66	0.0006	0.53	0.16	0.27
LSD	26.77	0.50	306.42	3.76	531.43	0.27	1.04	76.39	1243.00
Row ratio 3 female:1 male			**Irrigation at every 14 days**						
75 x 30	205.85^{a}	2.00^{cd}	688.50^{cde}	12.52^{d}	584.20^{bcd}	4.22^{a}	12.95^{a}	120.67^{cde}	2699.30^{a}
75 x 50	194.40^{ab}	2.05^{cd}	639.60^{de}	13.77^{bcd}	414.40^{cd}	4.23^{a}	13.05^{a}	79.83^{f}	1072.90^{ef}
75 x 75	194.20^{ab}	2.40^{abc}	691.00^{cde}	12.58^{d}	488.20^{bcd}	4.18^{a}	12.71^{a}	111.98^{def}	1000.00^{ef}
75 x 100	186.85^{ab}	2.10^{bcd}	758.00^{bcde}	14.12^{bcd}	545.70^{bcd}	3.85^{a}	12.83^{a}	117.16^{cde}	787.30^{ef}
150 x 30	175.90^{ab}	2.22^{bcd}	857.00^{abcde}	13.27^{cd}	678.60^{ab}	3.94^{a}	12.50^{a}	123.27^{cde}	1677.60^{bc}
150 x 50	199.55^{ab}	2.75^{a}	1105.30^{a}	14.12^{bcd}	581.50^{bcd}	4.05^{a}	13.33^{a}	142.49^{bcd}	777.50^{d}
150 x 75	192.95^{ab}	2.70^{a}	1120.00^{a}	15.50^{abcd}	650.50^{abc}	4.20^{a}	13.20^{a}	258.79^{a}	1154.20^{def}
			Irrigation at every 21 days						
75 x 30	193.65^{ab}	1.86^{d}	569.80^{e}	18.38^{a}	359.60^{d}	4.32^{a}	13.13^{a}	87.39^{ef}	1954.80^{b}
75 x 50	189.80^{ab}	2.17^{bcd}	704.30^{cde}	18.72^{a}	512.10^{bcd}	4.55^{a}	13.10^{a}	118.71^{cde}	1595.50^{bcd}
75 x 75	197.50^{ab}	2.37^{abc}	1012.30^{abc}	16.15^{abcd}	643.20^{abc}	4.51^{a}	12.98^{a}	130.44^{cd}	1164.80^{de}
75 x 100	186.85^{ab}	2.49^{ab}	930.00^{abcd}	14.67^{bcd}	698.50^{ab}	4.01^{a}	13.03^{a}	119.80^{cde}	805.00^{ef}
150 x 30	186.35^{ab}	2.18^{bcd}	1065.90^{ab}	16.27^{abc}	564.90^{bcd}	4.02^{a}	13.11^{a}	150.40^{bc}	1681.40^{bc}
150 x 50	172.25^{b}	2 36^{abc}	1099.90^{ab}	14.70^{bcd}	874.10^{a}	3.99^{a}	13.27^{a}	177.46^{b}	1192.50^{cde}
150 x 75	192.95^{ab}	2.50^{ab}	992.40^{abc}	17.00^{ab}	701.90^{ab}	4.29^{a}	12.93^{a}	146.22^{bcd}	652.10^{f}
R^2	0.50	0.80	0.76	0.73	0.73	0.49	0.31	0.93	0.92
MSE	241.55	0 035	25058.50	2.90	12603.57	0.11	0.22	288.51	56042.53
55	0.035	25058.50	2.90	12603.57	0.11	0.22	288.51	56042.53	
Mean	189.94	2.30	873.84	15.12	592.65	4.17	13.01	134.61	1301.07
CV (%)	8.18	0.19	18.11	11.26	18.94	7.88	3.63	12.62	18.19
P(<0.05)	0.76	0.01	0.03	0.04	0.04	0.69	0.92	<.0001	<.0001
LSD	33.58	0.41	341.98	3.68	242.54	0.71	1.02	36.70	511.43

Note : Values in the columns bearing different superscripts differ significantly at P<0.05

and 100-seed mass (g). According to Akinola and Whiteman (1975) and Sheldrake *et al.* (1979) the number of pods plant^{-1} is the component through which variation in seed yield is principally expressed. They likewise stated that the reduction in seeds pod^{-1} (rarely by more than 50%) and seed size (20%) may be reduced by the treatments or environmental conditions during growth development. The spacing at 75 cm x 30 cm with irrigation at every 14 days gave the highest (Figure 2) yield of 2357 kg ha^{-1} (6.0 - 60.7% higher than other treatments). The increase in yield in this treatment was attributed to increase in plant density per unit area which conforms to the findings of Singh *et al.* (1971), Natarajan and Wiley (1980), Sekhon *et al.* (1996), and Kumar Rao *et al.* (2001) in pigeonpea.

In 3:1 row ratio, there were significant ($P<0.05$) differences among treatments for stem diameter, biomass, number of branches, and number of pods plant^{-1}. Seed yield was found to be affected by the number of branches, number of pods plant^{-1}, number of seeds pod^{-1}, and 100-seed weight (Table 4), which corresponds to the findings of Beohar and Nigam (1972) and Dahiya et al. (1978). They established that yield was positively associated with the pods plant^{-1}, seeds pod^{-1}, and 100-seed weight. The spacing of 75 cm x 30 cm and irrigation at every 14 days gave the highest seed yield of 2699 kg ha^{-1} (27.6% - 75.8% superior to other treatments) (**Figure 2**). This showed that pigeonpea yields tend to be high at closer spacings. A progressive decline in yield with wider spacing observed in the present study conforms to the findings of Wilsie (1935), Veerasway *et al.* (1972), Natarajan and Wiley (1980), and Sekhon *et al.* (1996).

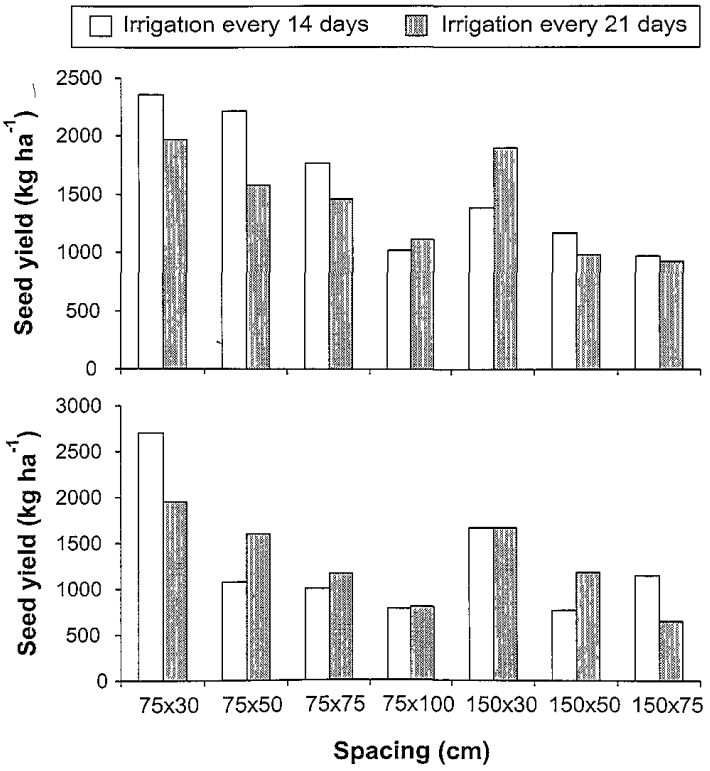

Fig. 2. Seed yield of ICPA 2043 at different plant spacings, irrigations under 4:1 (upper graph) and 3:1 (lower graph) row ratios

Generally in this study, individual plant traits like stem diameter, biomass, pods plant^{-1} and seed yield plant^{-1} were higher at wider spacing, however this increase could not compensate in seed yield obtained by closer spacing due to increase in plant population. For both the row ratios, spacing of 75 cm x 30 cm resulted in highest seed yield as compared to other treatments which is not in agreement with the findings of Saxena (2008) where spacing of 100 cm x 50 cm out-yielded 75 cm x 30 cm by as much as 164%.

CONCLUSIONS

The agronomic performance of ICPA 2043, the female parent line of hybrid ICPH 2671, is an important indicator of the extent to which a crop shows its potential in producing significant quantities of cross-pollinated seeds. In this study, different planting distances under both the irrigation frequencies in the row ratio of 4:1 exhibited significant differences for biomass and number of seeds pod^{-1}; whereas in the 3:1 row ratio, stem diameter, biomass, number of pods plant^{-1}, and seed yield exhibited significant variations under both irrigation frequencies. Overall, the spacing of 75 cm x 30 cm with irrigation at every 14 days in row ratio 4:1 and 3:1 produced the highest seed yield of 2357.10 kg ha^{-1} and 2699.30 kg ha^{-1}. The response of row spacing with irrigation of every 14 day interval in row ratio of 4:1 and irrigation at every 21 days in row ratio of 3:1 significantly affected the seed yield of ICPA 2043. However, the total effects of irrigations and row ratios did not influence seed yield and yield-contributing characters of ICPA 2043. Therefore, it was concluded from this study that closer plant density produced taller plants due to erect and compact branching. This phenology exposes the plants to relatively less quantum of sunlight while at wider spacing the plants tend to be short and sturdy with spreading branches and intercept more and evenly distribution of sunlight. Likewise, with wide spacing, the yield and yield contributing characters were of high magnitude as compared to the close spacing. However, at closer spacing, the seed yield per unit area was superior to wider spacing.

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