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Time of planting and spacing effect on yield and yield contributing traits of extra-early pigeonpea

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ABSTRACT

A field experiment was conducted in rainy 2012 and 2013 season to study the effect of two planting dates (early - E_1 and late - E_2), nine spacing combinations and two extra-early genotypes (determinate (DT) ICPL 20338 and non-determinate (NDT) ICPL 20326) on yield and yield contributing traits of pigeonpea. The E_1 produced higher seed yield in both the DT (892.3 kg/ha) and NDT (1406.2 kg/ha) pigeonpea line. Highest grain yield was recorded with spacing of 30 cm x 20 cm in both the E_1 (1298.7 kg/ha) and E_2 (942.4 kg/ha) of DT line. While in NDT line, spacing of 45 cm x 30 cm in E_1 (1734.3 kg/ha) and 30 cm x 30 cm in E_2 (1511.4 kg/ha) recorded highest grain yield. Planting time showed non-significant effect on flowering and days to maturity in both, DT and NDT lines due to photo-insensitive nature of the extra early lines. These extra-early lines reported to be less affected by varying photoperiods and acceptable yield can be produced throughout the year with modification in the planting geometry. The present study and earlier results of testing these lines at Almora, Uttarakhand and Ludhiana, Punjab provides scope for expanding pigeonpea cultivation and production in wider latitudes/higher altitudes and into new niches especially in the rice-fallow cropping system.

Key words : *Determinate, Extra-early cultivars, Non-determinate lines, Pigeonpea, Planting & spacing.*

INTRODUCTION

Pigeonpea (*Cajanus cajan* (L.) Millspaugh) ranks sixth in area and production among pulses and is grown globally. The crop is mainly grown in 4.63 million hectares as rainfed crop in the arid and semi-arid tropics of Asia, Africa, Latin America and the Caribbean under subsistence agriculture (Mula and Saxena, 2010). In spite of cultivating 3.5 million hectares of pigeonpea (Saxena, 2006), India still experiences shortage of grain supply by about 1.5 to 2.0 million tons annually due to the low productivity estimated at 700 kg/ha (Saxena, 2009). The dominant cultivars grown in India are medium (150-180 days to mature) and long duration (>180 days to mature) type and require short days to induce flowering.

The possibility to increase production apart from breeding high yielding varieties and hybrids of early and medium duration lines is developing extra-early lines. Extra-early lines provide option for expansion of pigeonpea in non-traditional areas and new niches owing to their photo-insensitivity.

ICRISAT has made tremendous progress way back from 2006 in developing extra-early determinate (DT) and non-determinate (NDT) cultivars. To date, 12 determinate and 22 non-determinate lines are identified for multi-location testing. The newly developed extra-early pigeonpea lines can be grown in non-traditional areas and new niches such as the rice-fallow cropping system. These cultivars mature in 80-85 days for DT lines and 90-110 days for NDT lines. Also with this maturity duration, chances of growing two to three crop seasons within a single year is possible. Moreover, these cultivars have also been successfully cultivated up to 1250 msl in the hilly areas of Almora (Uttarakhand) with recorded yields of 1000-1500 kg/ha.

Since the material is unique in growth habit including photo-insensitivity, it is very essential to discover population dynamics to recommend the optimum spacing and time of planting in order to determine total seed yield which will be at par with the existing farmers practice of utilizing cultivars of medium and long duration type.

MATERIALS AND METHODS

A field experiment was conducted during rainy 2012 and 2013 cropping season at the ICRISAT, Patancheru, Telangana, India which represents the semi-arid tropics situated at the 17°30' N, 78°16' E, and altitude 545 msl.

The experimental material consists of two extra-early duration pigeonpea lines, one DT (ICPL 20338) and another NDT (ICPL 20326). The material was planted in two planting dates as early planting (E_1, June 25th) and as late planting (E_2, July 25th). The seed was sown on broad beds considering four row to row spacing's (30, 35, 40 & 45 cm) and three plant to plant spacing's (20, 30 & 40 cm). Nine different treatment combinations were formulated as 30 x 20 cm, 30 x 30 cm, 30 x

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40 cm, 35 x 20 cm, 35 x 30 cm, 40 x 20 cm, 40 x 30 cm, 45 x 20 cm and 45 x 30 cm. The nine treatment combinations were laid-out in RCB design in four replications. Recommended agronomic practices including a basal dose of di-ammonium phosphate of 100 kg/ha was applied uniformly to all the treatments. Observations on yield & yield attributes were collected on 5 continuous plants within each treatment. The total seed yield (kg/ha) was calculated on plot basis (Table 1, 2).

To find out the effect of planting distance in optimizing seed yield of extra-early pigeonpea, analysis of variance was employed to determine the best spacing combination. Data were analyzed separately for DT and NDT genotypes across two planting dates using REML (Restricted Maximum Likelihood) mixed model analysis.

RESULTS AND DISCUSSION

Agronomic traits of ICPL 20338 : The analysis of variance and data on various yield and related traits is presented in Table 1 for determinate genotype ICPL 20338.

Table 1. Effect of planting time and spacing on yield and yield contributing characters in determinate pigeonpea genotype ICPL 20338

Treatments		Days to 50 % flowering	Days to 80 % maturity	Plant height (cm)	Branches /plant (no.)	Pods /plant (no.)	Seeds /pod (no.)	100 seed weight (g)	Yield /plant (g)	Total yield (kg/ha)
Planting Time										
Early (E_1)		52.1	83.7	60.6^{a}	8.9^{a}	75.1^{a}	3.7	7.3^{a}	15.9^{a}	892.3^{a}
Late (E_2)		49.9	81.9	51.2^{b}	6.8^{b}	35.5^{b}	3.7	6.5^{b}	8.2^{b}	509.0^{b}
Spacing	**Density** (plant/ha)									
30x20	166,667	50.2	82.0	49.3^{c}	3.6^{b}	32.7^{b}	3.5^{c}	6.8	6.7^{d}	1120.6^{a}
30x30	111,111	53.6	85.3	47.2^{c}	3.4^{b}	30.4^{b}	3.5^{c}	6.6	6.2^{d}	684.2^{bc}
30x40	83,333	51.9	83.5	46.6^{c}	3.8^{b}	34.1^{b}	3.5^{c}	6.8	7.2^{d}	599.8b^{cd}
35x20	142,857	50.1	81.4	61.2^{ab}	9.6^{a}	55.4^{a}	3.8^{b}	7.0	13.4^{bc}	726.8^{bc}
35x30	95,238	50.1	82.1	57.2^{b}	10.3^{a}	73.8^{a}	3.8^{b}	7.1	16.1^{ab}	531.0^{cd}
40x20	125,000	51.3	82.8	64.6^{a}	10.7^{a}	65.7^{a}	3.8^{b}	7.0	12.7^{bc}	802.9^{b}
40x30	83,333	48.7	81.4	60.7^{ab}	10.4^{a}	83.9^{a}	4.0^{a}	7.4	19.0^{a}	688.1^{bc}
45x20	111,111	50.3	81.5	59.3^{b}	9.6^{a}	63.6^{a}	3.8^{b}	6.5	15.3^{abc}	755.3^{bc}
45x30	74,074	53.0	85.4	57.2^{b}	9.4^{a}	58.1^{a}	3.8^{b}	7.0	11.7^{c}	397.1^{e}
Planting Time × Spacing										
E_1 * (30x20)		50.9	84.3	51.2	4.0	35.9	3.5	7.2	7.8	1298.7
E_1 * (30x30)		53.6	87.0	51.6	4.2	33.5	3.5	7.2	7.2	797.3
E_1 * (30x40)		51.9	84.5	48.3	4.2	36.3	3.3	7.6	7.9	659.3
E_1 * (35x20)		50.8	81.1	68.0	11.1	78.0	4.0	7.0	17.1	934.8
E_1 * (35x30)		50.9	82.6	61.0	10.7	105.8	3.9	7.6	22.4	697.0
E_1 * (40x20)		54.2	83.9	71.3	12.2	94.8	3.8	7.0	17.5	1096.6
E_1 * (40x30)		48.8	80.6	64.6	11.5	121.5	4.1	7.6	27.3	994.6
E_1 * (45x20)		52.1	81.9	64.6	11.2	87.8	3.9	7.2	20.9	1063.5
E_1 * (45x30)		55.6	87.4	64.5	10.8	82.1	3.9	7.6	15.0	488.4
E_2 * (30x20)		49.4	79.7	47.4	3.1	29.5	3.6	6.3	5.7	942.4
E_2 * (30x30)		53.5	83.5	42.7	2.5	27.3	3.6	6.1	5.2	571.1
E_2 * (30x40)		51.9	82.4	44.8	3.3	31.8	3.7	6.0	6.5	540.3
E_2 * (35x20)		49.4	81.7	54.3	8.1	32.8	3.6	7.0	9.7	518.8
E_2 * (35x30)		49.3	81.6	53.3	9.9	41.8	3.8	6.7	9.8	364.9
E_2 * (40x20)		48.4	81.6	57.8	9.1	36.6	3.7	7.0	8.0	509.3
E_2 * (40x30)		48.6	82.1	56.7	9.2	46.3	4.0	7.2	10.8	381.5
E_2 * (45x20)		48.4	81.1	54.0	8.0	39.3	3.7	5.8	9.7	447.1
E_2 * (45x30)		50.4	83.4	49.9	7.9	34.0	3.7	6.3	8.4	305.8
Analysis of variance										
Planting time		3.46	3.41	68.81**	30.39**	159.15**	0.75	22.92**	73.03**	45.88**
Spacing		0.80	1.17	15.17**	32.51**	18.21**	6.94**	1.02	11.21**	5.59**
Planting time × Spacing		0.40	0.50	1.48	0.82	9.04**	2.44	1.32	3.75*	1.25

Days to 50% flowering and days to maturity were not significant for planting time, spacing and its interaction indicating photo-insensitive nature of this line. In general, E_2 flowered and matured earlier than E_1. Time of planting significantly affected plant height of ICPL 20338 where E_1 exhibited higher plant height (60.6 cm) as compared to E_2 (51.2 cm) which corresponds to the findings of Ram *et al.* (2011). Spacing of 40 x 20 cm resulted in highest plant height (64.6 cm) followed by 35 x 20 cm (61.2 cm) and 40 x 30 cm (60.7 cm) where narrow row to row spacing of 30 cm resulted in lower plant height. This suggest that, wider row to row and narrow plant to plant spacing helps to attain good plant height and this might be due to competition of plants for light and space.

Planting time and spacing significantly affected number of branches of ICPL 20338 however it showed non-significant interaction effect. Results showed that E_1 produced more number of branches (8.9) compared to E_2 (6.8). Maximum branches (10.7) were recorded with spacing of 40 x 20 cm and all the spacing combinations with row to row spacing of 35 cm and above found at par with each other which conforms to the findings of Ram *et al.* (2011).

Number of pods/plant was significantly affected with planting time, spacing and its interaction. It was observed that number of pods/plant was reduced to half in late planting E_2 (35.5) as compared to early planting E_1 (75.1) and spacing of 40 x 30 cm resulted in highest pod set (83.9). In both the E_1 and E_2, spacing of 40 cm x 30 cm resulted in highest pod set. Planting time showed non-significant influence on number of seeds/pod which is in conformity to the findings of Reddy *et al.* (2012). Spacing showed highly significant effect on number of seeds/pod where 40 x 30 cm planting distance gave the highest number of seeds/pod (4.0). Similar results were also reported by Islam *et al.* (2008) where wider row to row spacing showed significant effect on number of seeds/pod.

The 100 seed weight showed significant differences in E_1 & E_2 where E_1 recorded higher seed mass (7.3 g) as compared to E_2 (6.5 g) but the spacing and its interaction effect was not-significant which is consistent with the findings of Fakir *et al.* (2007), Reddy *et al.* (2012), and Ram *et al.* (2011). The reason for higher 100 seed mass in E_1 was due to higher growth & accumulation of photosynthetic assimilates as compared to E_2.

Among the yield component, grain yield/plant (g) and total grain yield kg/ha was significantly influenced by planting time and spacing factor. Early sown crop exhibited highest grain yield/plant (15.9 g) and similar trend was noticed for total grain yield (892.3 kg/ha). Spacing using 40 x 30 cm recorded highest grain yield/plant (19.0 g) followed by 35 x 30 cm (16.1 g). Total grain yield kg/ha showed an opposite trend as compared to grain yield/plant due to variation in plant population influenced by planting geometry. Highest grain yield of 1120.6 kg/ha was recorded in spacing of 30 x 20 cm which suggest that plant population of 166,667 is optimum to obtain higher seed yield which corresponds to the findings of Tuppad *et al.* (2012). Accordingly, planting time and spacing showed non-significant interaction for total grain yield (kg/ha) where highest yield was recorded with spacing of 30 x 20 cm in both E_1 (1298.7 kg/ha) and E_2 (942.4 kg/ha).

Agronomic traits of ICPL 20326 : The analysis of variance and data on various yield and related traits of the non-determinate genotype ICPL 20326 is presented in **Table 2**.

There was no significant effect of planting time, spacing and its interaction on flowering, maturity and number of seeds/pod for ICPL 20326 but E_2 flowered and matured 2 to 3 days earlier than E_1. This slight difference in flowering and maturity confirms findings of Vales *et al.* (2012) for photo-insensitivity of this material. Plant height was significantly influenced by planting time where highest plant height (101.4 cm) was achieved in E_1 as compared to E_2 (95.3 cm). However, spacing and its interaction was not significant as shown in Table 2.

Number of branches revealed similar trend with respect to planting time and spacing. The highest number of branches (8.3) was recorded in E_1 compared to E_2 (6.3). Spacing of 45 x 30 cm produced highest number of branches (9.6) followed by and at par with spacing of 35 x 30 cm (9.4), 40 x 30 cm (9.2) and 35 x 20 cm (8.3). However, highly significant interaction effect was recorded for number of branches/plant in E_1 with spacing of 35 x 30 cm (12.5) followed by 40 x 30 cm (11.9) and 45 x 30 cm (10.9) which conforms to the findings of Hammerton (1976).

Number of pods/plant significantly affected with planting time and spacing but the interaction effect was not significant. The highest number of pods/plant were recorded in E_1 (123.3) compared to E_2 (80.3). Whereas planting distance of 45 x 30 cm produced the highest number of pods/plant (169.9) which is on par with rest of the spacing combinations. The late sown crop recorded higher 100 seed mass (7.5 g) as compared to E_1 (6.9 g). This may be due to less insect damage and continuous rainfall during harvesting (**Fig. 1**) which is in conformity to the findings of Mash (1994).

Grain yield/plant and total grain yield differed significantly for planting time and spacing. Early planting recorded significantly higher grain yield/plant (25 g) and total grain yield (1406.2 kg/ha) as compared to E_2 (16.7 g/plant and 1238.0 kg/ha, respectively) which is directly attributed to more number of branches and number of pods/plant. The results are in conformity with findings of Islam *et al.* (2008) where late planted pigeonpea recorded drastic reduction in grain yield. Considering spacing factor, highest grain yield/plant was recorded in 45 x 30 cm (27.3 g) and 45 x 20 cm (26.3 g). Highest total grain yield (kg/ha) was noted in spacing of 35 x 30 cm (1456.8 kg/ha) followed by 45 x 30 cm (1422.3 kg/ha) while spacing of 30 x 40 cm showed lowest grain yield (951.9 kg/ha) which correspond to the findings of Tuppad *et al.* (2012).

Table 2. Effect of planting time and spacing on yield and yield contributing characters of non- determinate pigeonpea genotype ICPL 20325

Treatments		Days to 50 % flowering	Days to 80 % maturity	Plant height (cm)	Branches /plant (no.)	Pods /plant (no.)	Seeds /pod (no.)	100 seed weight (g)	Yield /plant (g)	Total yield (kg/ha)
Planting Time										
Early (E_1)		59.1	91.2	101.4^{a}	8.3^{a}	123.3^{a}	3.8	6.9^{b}	25.0^{a}	1406.2^{a}
Late (E_2)		57.1	89.6	95.3^{b}	6.3^{b}	80.3^{b}	3.8	7.5^{a}	16.7^{b}	1238.0^{b}
Spacing	**Density** (plant/ha)									
30x20	166,667	57.0	89.3	98.2	4.9^{d}	74.6^{b}	3.7	6.7	14.9^{d}	1227.9^{a}
30x30	111,111	58.1	90.2	87.8	4.2^{d}	71.2^{b}	3.8	7.3	15.6^{d}	1399.8^{a}
30x40	83,333	55.8	87.8	90.8	5.3^{d}	76.9^{b}	3.7	6.7	14.6^{d}	951.9^{b}
35x20	142,857	56.5	88.8	101.5	8.3^{abc}	99.2^{b}	4.0	7.5	20.0^{bcd}	1393.6^{a}
35x30	95,238	58.9	91.8	101.0	9.4^{ab}	115.0^{b}	3.9	7.2	24.7^{abc}	1456.8^{a}
40x20	125,000	60.2	93.1	98.8	7.0^{c}	83.3^{b}	3.8	7.6	19.2^{cd}	1284.0^{a}
40x30	83,333	60.6	93.1	101.5	9.2^{ab}	115.7^{c}	3.9	7.1	24.8^{abc}	1368.7^{a}
45x20	111,111	58.7	90.6	102.5	8.0^{bc}	110.7^{b}	3.9	7.2	26.3^{ab}	1394.3^{a}
45x30	74074	57.2	89.3	103.2	9.6^{a}	169.9^{a}	3.6	7.4	27.3^{a}	1422.3^{a}
Planting Time × Spacing										
E_1 * (30x20)		57.4	90.0	106.5	5.4	86.6	3.5	6.3	18.7	1097.6
E_1 * (30x30)		61.3	94.2	91.6	4.1	73.6	3.8	7.1	17.6	1288.3
E_1 * (30x40)		57.4	89.6	91.6	5.5	79.8	3.5	6.5	16.9	878.1
E_1 * (35x20)		55.9	87.4	102.7	9.1	131.1	3.9	7.3	25.9	1528.1
E_1 * (35x30)		60.8	93.9	105.5	12.5	139.6	3.9	6.7	28.6	1706.0
E_1 * (40x20)		63.0	94.6	100.3	7.6	90.8	3.8	7.5	21.9	1201.8
E_1 * (40x30)		59.5	91.1	103.0	11.9	159.2	3.9	6.6	35.9	1663.6
E_1 * (45x20)		60.1	91.9	104.5	8.1	118.8	3.8	7.3	28.0	1558.4
E_1 * (45x30)		56.4	88.1	106.7	10.9	230.2	3.8	6.9	31.0	1734.3
E_2 * (30x20)		56.5	88.5	89.8	4.4	62.5	3.8	7.1	11.0	1358.3
E_2 * (30x30)		54.8	86.2	84.0	4.3	68.8	3.9	7.5	13.6	1511.4
E_2 * (30x40)		54.2	85.9	89.9	5.1	74.0	3.9	7.0	12.3	1025.6
E_2 * (35x20)		57.0	90.1	100.2	7.4	67.3	4.0	7.8	14.1	1259.0
E_2 * (35x30)		56.9	89.6	96.4	6.3	90.3	3.9	7.6	20.7	1207.7
E_2 * (40x20)		57.4	91.6	97.3	6.3	75.8	3.8	7.8	16.6	1366.2
E_2 * (40x30)		61.7	95.0	99.9	6.5	72.2	3.9	7.6	13.7	1073.8
E_2 * (45x20)		57.3	89.3	100.4	7.9	102.6	3.9	7.2	24.7	1230.2
E_2 * (45x30)		57.9	90.5	99.6	8.3	109.5	3.5	7.9	23.6	1110.2
Analysis of variance										
Planting time		4.05	2.09	6.42*	42.68**	19.01*	1.02	12.88**	28.78**	8.64**
Spacing		1.21	1.35	2.25	18.98**	4.42*	1.41	1.63	4.89**	3.29*
Planting time × Spacing		1.11	1.43	0.43	5.79**	1.88	0.90	0.48	1.61	4.57**

Highly significant interaction effect of planting time and spacing was recorded for total grain yield as shown in **Fig. 2.** Spacing of 45 x 30 cm in E_1 resulted in highest grain yield (1734.3 kg/ha) whereas spacing of 30 x 30 cm provided highest grain yield (1511.4 kg/ha) in E_2. This shows that E_1 pigeonpea suffers from plant to plant competition due to more growth rate as compared to late planting which is in conformity to the findings of Reddy *et al.* (2012), Rani and Reddy (2010) where they found significant yield reduction in late sown crop.

In both extra-early DT and NDT lines, early sown crop exhibited higher seed yield as compared to late sown crop. The time of planting showed non-significant effect on flowering and maturity in both DT and NDT lines due to photo insensitivity, however both pigeonpea lines matured earlier in late sown crop. In DT line, spacing of 30 x 20 cm recorded highest seed yield in both the early (1298.7 kg/ha) and late (942.4 kg/ha) plantings. In case of NDT line, highest seed yield was recorded in spacing of 45 x 30 cm in early planting (1734.3 kg/ha) and 30 x 30 cm in late (1511.4 kg/ha) planting than rest of the spacing

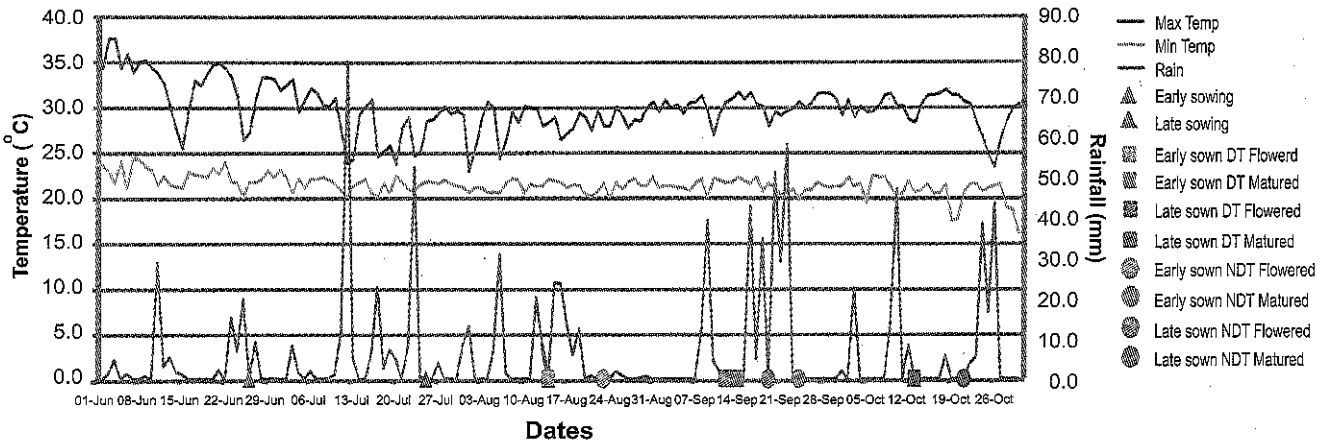

Fig. 1. Weather graph of entire experimental duration and phenological events

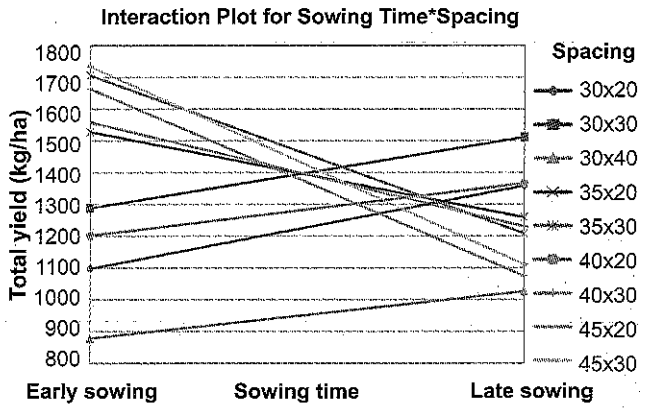

Fig. 2. Least squares (LS) means for planting time x spacing interaction

combinations. Although the seed yield is reduced in late sown crop as compared to the early sown crop, the yield gap can be compensated by modifying planting geometry.

These extra-early lines can be claimed to be less affected by varying photoperiods and can be grown in any season without any significant yield loss. These extra-early pigeonpea lines can be expanded to wider latitudes/higher altitudes with great potential to adopt rice-fallow cropping system. In the changing climate scenario, these lines will gain importance due to its flexibility in planting time where most of the medium and long duration lines cannot perform well due to erratic rain fall pattern.

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