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Effect of sowing and plant spacing on pigeonpea (*Cajanus cajan*) for higher productivity and profitability in India

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ABSTRACT

An experiment was conducted at the research farm of the Indian Agricultural Research Institute, New Delhi during 2016–17. The study was carried out in split-plot design having three dates of sowing (5 June, 21 June and 10 July) in main plot, and spacing (15 cm × 15 cm; 30 cm × 15 cm and 45 cm × 15 cm) in sub-plots with four replications. Results indicated that pigeonpea [*Cajanus cajan* (L.) Millsp.] sowing on 5 June and 21 June recorded significantly ($P \geq 0.05$) higher no. of pods/plant in 2016–17. Pigeonpea sowing on 5 June and 21 June recorded higher seed and stalk yield followed by 10 July. Pigeonpea sowing on 5 June recorded higher gross and net returns (86.75 and 54.75 × 10^3 ₹/ha, respectively). At flowering stage, leaf litter and root volume were recorded highest with the plant spacing at 45 cm × 15 cm (3.5 kg/ha and 2.85, respectively) in both years. Plant spacing at 45 cm × 15 cm recorded higher seed, stalk and biological yield followed by plant spacing at 35 cm × 15 cm and 15 cm × 15 cm. The gross returns and net returns were recorded higher with plant spacing at 45 cm × 15 cm (89 and 59 × 10^3 ₹/ha, respectively). Overall, it can be concluded that pusa arhar-16 can be sown from 5–21 June with plant spacing at 45 cm × 15 cm without any yield penalty in Indo-Gangetic Plains of India.

Key words: Crop productivity, Economics, Nitrogen uptake, Pusa Arhar-16

In India, pigeonpea (*Cajanus cajan* (L.) Millsp.) is one of the main *kharif* legume crop, covering 3.58 m ha with production of 14 mt (Economic Survey 2018). This crop is often rotated with wheat crop as pigenopea-wheat system under irrigated conditions while grown as sole crop in rainfed regions. In Indo-Gangetic Plains (IGP), the pigeonpea-wheat cropping system is suggested as a potential alternative to rice-wheat cropping system as former one is input intensive and threatening the sustainability of natural resources. The varieties of pigeonpea such as UPAS 120, Pusa 992 and Pusa 2002 are most commonly used by the farmers in the IGP under irrigated pigeonpea-wheat cropping system. These varieties take longer period to mature (230–260 days), and thereby delay the wheat sowing in the pigeonpea-wheat system (Sepat *et al*. 2014). The delayed wheat sowing upto January reduces the crop yield as it faces thermal heat stress at the time of maturity (Ram *et al.* 2011). However, such obstacle can be overcome by having the short duration varieties of pigeonpea which can ensure timely sowing of wheat crop, i.e. in November. An extra short duration variety of pigeonpea, i.e. Pusa Arahar -16 is developed at Indian Agricultural Research Institute, New Delhi to maximize the yield potential of pigeonpea-wheat cropping system (Annual Report 2017). The developed variety has a maturity period of 135 days, and therefore promotes timely sowing of wheat crop. In general, the earlier varieties of pigeonpea are recommended to sown during first fortnight of May. However, Pusa Arhar -16 has high plasticity period for sowing period, and therefore it can be extended upto July without any yield penalty.

To harness the optimum yield potential of Pusa Arhar-16, a short duration variety, there is a need to optimise the date of sowing and spacing. Keeping this in view, an experiment was conducted during 2016–17 to assess the effect of date of sowing and plant spacing on productivity and economics of newly developed extra-short duration variety of pigeonpea.

MATERIALS AND METHODS

The field experiment was conducted during 2016 and 2017 at the research farm of Indian Agricultural Research Institute, New Delhi (28°37‘N, 77°09‘E, 228.7 m amsl). The soil of the experimental site is sandy loam (15.6% clay, 18.2% silt, 66.2% sand) in texture having *p*H 7.9 (1:2.5 soil to water). The climate of the experimental site is semi-arid with mean annual rainfall of 750–800 mm, the distribution of which is unimodal with 75–80% rain occurring during the monsoon months (July–August). The total rainfall received during the period of experimentation

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in 2016–17 was 1157.2 and 856 mm, respectively. The mean pan evaporation during the maize growing period was 698 mm. The mean maximum and minimum temperature was 33 and 22 °C, respectively. The soil has 0.36% organic C, 163.7 kg/ha available N, 10.2 kg/ha 0.5 *M* $NaHCO_3$ extractable available P and 270 kg/ha NH_4OAc extractable available K (Prasad *et al*. 2006).

The experiment was conducted in split-plot design with three replications. In main plot, three date of sowing such as 05 June, 21 June and 10 July while three row spacing i.e. 30 cm × 15 cm; 30 cm × 30 cm and 45 cm × 15 cm was taken in sub-plots. A gross plot size of 15.0 m × 2.8 m with a net plot size of 13.2 m × 1.4 m was taken during each year in fixed layed plots. In every year, the pigeonpea variety i.e. Pusa Arhar 16 was sown as per the treatments. A seed rate of 25 kg, 22 kg and 20 kg was used for the spacing of 30 cm × 15 cm; 30 cm × 30 cm and 45 cm × 15 cm, respectively. The desired spacing at the time of seeding was maintained as per the treatments by tractor drawn plot planter. A uniform dose of 40 kg N, 26 kg P, and 33 kg K/ha was applied through urea, single super phosphate and muriate of potash, respectively. Full amount of N, P and K were applied at the time of sowing. A total two irrigations were applied at pre-flowering and pod filling stage. Three sprays of chlorantranilliprole 18.5 SC was made at the pre-flowering and pod filling stage. The crop sown on 05 June and 21 June was harvested during the second and third week of October, respectively in each year. However, crop sown on 10 July was harvested on first week of November in every year. Treatment means separation was done by using Fishers LSD at 5% significance level when *F* tests indicated that significant differences existed ($P<0.05$) (Payne RW 2009).

RESULTS AND DISCUSSION

Growth attributes: In 2016–17, the date of sowing significantly influenced the growth attributes such as plant height and dry matter production at flowering except no. of branches/plant (Table 1). In 2016, early sowing on 5 June and 21 June recorded taller plants (105 and 100 cm, respectively) compared to 10 July (84 cm). However, in 2017, pigeonpea sown on 5 June recorded the highest plant height (99 cm). Likewise, dry matter production at flowering observed higher with 5 June (48 and 50 g/plant in 2016 and 2017, respectively) and 21 June (85 and 80 g/plant in 2016 and 2017, respectively) compared to 10 July during (38 and 76 g/plant in 2016 and 2017, respectively). In 2016, the amount of high rainfall (1157.2 cm) significantly enhanced the plant height compared to dry matter accumulation. However, in 2017, the optimum utilization of rainfall water enhanced the cell elongation (Ram *et al.* 2011) and thereby plant growth which resulted in to higher dry matter accumulation compared to 2016.

In addition, plant spacing also influenced the parameters of plant height, no. of branches/plant and dry matter accumulation in 2016–17 (Table 1). Spacing at 15 cm × 15 cm and 35 cm × 15 cm recorded a higher plant height (mean 100 and 93 cm, respectively) compared to spacing at 45 cm × 15 cm (91 cm) in 2016 and 2017. The no. of branches/plant was observed higher with spacing at 35 cm × 15 cm and 45 cm × 15 cm than spacing at 15 cm × 15 cm in 2016–17. In 2016, the dry matter accumulation/plant was not influenced with plant spacing. However, in 2017, spacing at 45 cm × 15 cm recorded the highest dry matter accumulation/plant (87 g/plant) followed by plant spacing at 35 cm × 15 cm (82 g/plant) and 15 cm × 15 cm (72 g/plant). A closer spacing produced the taller and lanky plants over the wider spacing as the competition for space and light occurred among the plants. In contrary to plant height, wider spacing promoted cell expansion and thereby higher growth, branching and accumulation of higher dry matter compared to close spacing at 15 cm × 15 cm (Sepat *et al*. 2015).

Table 1 Effect of date of sowing and plant spacing on growth attributes of pigeonpea during 2016–17

Treatment	Plant height (cm)		No. of branches/plant		Dry matter production at flowering (g/plant)		Root volume at flowering		No of pods/plant		No of seeds/pod (mean of two years)	100-seed weight (g) (mean of two years)	Leaf litter fall at flowering (kg/ha) (mean of two years)
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017			
Date of sowing													
5 June	105	99	15	15	48	85	3.47	3.60	27	38	4.0	5.20	4.70
21 June	100	95	15	14	50	80	3.28	3.40	24	36	3.0	5.20	4.60
10 July	84	88	12	12	38	76	3.00	2.80	20	25	3.0	4.80	3.40
SEm	3.50	3.41	1.12	1.09	2.12	1.94	0.04	0.04	0.97	1.31	0.06	1.12	0.03
CD (P=0.05)	11.20	10.90	NS	NS	NS	6.20	0.14	0.13	3.10	4.20	NS	NS	0.11
Plant spacing (cm)													
15 × 15	102	98	12	11	41	72	2.70	2.90	20	28	3.0	4.50	3.50
35 × 15	95	93	14	15	45	82	3.29	3.30	24	35	3.0	5.30	4.50
45 × 15	92	91	16	15	50	87	3.76	3.60	27	36	4.0	5.40	4.70
SEm	2.57	2.04	0.94	0.93	2.44	1.41	0.03	0.03	0.88	1.06	0.05	0.03	0.02
CD (P=0.05)	8.21	6.52	3.01	2.98	7.80	4.52	0.09	0.09	2.80	3.40	NS	0.08	0.07

Yield components: The different date of sowing significantly influenced the leaf litter fall, root volume at flowing and no. of pods/plant in pigeonpea during 2016–17 (Table 1). At flowering stage, a high leaf litter fall was in pigeonpea was recorded at 5 June (4.8 kg/ha) and 21 June (4.7 kg/ha) compared to sowing at 10 July (3.2 kg/ ha). Similarly, at flowering stage, the root volume was the highest with 5 June (3.47 and 3.6 in 2016 and 2017, respectively) followed by 21 June (3.28 and 3.4 in 2016 and 2017, respectively) and 10 July (3.00 and 2.8 in 2016 and 2017, respectively) in both years. Pigeonpea sowing on 5 June and 21 June recorded significantly higher no. of pods/plant than the rest of treatments in 2016 and 2017. The lowest no. of pods/plant recorded with 10 July (20 and 25 in 2016 and 2017, respectively). On the other hand, no. of seeds/pod and 100-seed weight were not influenced with different date of sowing over the years.

The plant spacing significantly influenced various parameters except 100-seed weight of pigeonpea over the years. At flowering stage, leaf litter and root volume were recorded highest with the plant spacing at 45 cm × 15 cm (3.5 kg/ha and 2.85, respectively) followed by 35 cm × 15 cm (4.5 kg/ha and 2.89, respectively) and 15 cm × 15 cm (4.7 kg/ha and 3.5, respectively) in both years. In 2016, no. of pods/plant were recorded highest with plant spacing at 45 cm × 15 cm (no. 27/plant) followed by plant spacing at 35 cm × 15 cm (no. 24/plant) and 15 cm × 15 cm (no. 20/plant). However, in 2017, plant spacing at 45 cm × 15 cm and 35 cm × 15 cm were found at par with no. of pods/plant. A higher no of branches/plant at wider spacing promoted the high leaf litter fall and root growth compared to narrow spacing. A less competition for space, light and nutrients (Sepat *et al.* 2014) at optimum spacing of 45 cm × 15 cm enhanced the branching and related parameters in pigeonpea crop.

Yield: The components of yield were significantly influenced with the various date of sowing except harvest index of pigeonpea (Table 2). Pigeonpea sowing on 5 June and 21 June recorded higher seed and stalk yield followed by 10 July. However, in and biological yield, sowing date 5 June recorded the highest values (5.56 t/ha and 5.34 t/ha in 2016 and 2017, respectively) followed by 21 June and 10 July. In 2016, a higher rainfall in pigeonpea promoted enhanced vegetative growth, and thereby the crop could not able to divert towards grain formation. However, in 2017, optimum rain water and sowing ensured to realize the highest potential of pigeonpea crop in term of seed formation. Sowing beyond 21 June reduced the seed yield in pigeonepa as the effective sunshine decreased which reduced the photo-synthetic efficiency of the crop (Ram *et al.* 2011). The yield of pigeonpea was influenced with different plant spacing in 2016 and 2017 except harvest index (Table 2). Plant spacing at 45 cm × 15 cm and 35 cm × 15 cm recorded higher seed and stalk yield followed by plant spacing at 15 cm × 15 cm. The reduced growth parameters at closer spacing (15 cm × 15 cm) were the main reason for low yield compared to optimum plant spacing at 35 cm × 15 cm and 45 cm × 15 cm. Furthermore, the crowded plant population at 15 cm × 15 cm promoted higher competition for nutrient, light and space (Sepat *et al.* 2015).

Economics: Different date of sowing significantly influenced the gross returns, net returns and B:C ratio except cost of cultivation (Table 2). The requirement of all the inputs remained constant in cost of cultivation (32 × 10^3 ₹/ha), irrespective of date of sowing. Pigeonpea sowing on 5 June recorded higher gross and net returns (86.75 and 54.75 × 10^3 ₹/ha, respectively) followed by 21 June (82.50 and 50.50 × 10^3 ₹/ha, respectively) and 10 July (73.75 and 41.75 × 10^3 ₹/ha, respectively) over the years. The influence of date of sowing on seed yield influenced the net returns. The B:C ratio also followed the same trend, and pigeonpea sowing on 5 June recorded the highest B:C ratio (1.71) followed by 21 June (1.58) and 10 July (1.30). The requirement of different seed amount at different plant spacing significantly

Table 2 Effect of date of sowing and plant spacing on yield and economics of pigeonpea in 2016-17

Treatment	Seed (t/ha)		Stalk (t/ha)		Biological (t/ha)		Harvest index		Cost of cultivation (10^3 × ₹/ha)	Gross return (10^3 × ₹/ha)	Net returns (10^3 × ₹/ha)	B:C ratio
	2016	2017	2016	2017	2016	2017	2016	2017	Mean of two years			
Date of sowing												
5 June	1.65	1.82	3.69	3.74	5.34	5.56	0.31	0.33	32.0	86.75	54.75	1.71
21 June	1.58	1.72	3.52	3.68	5.10	5.40	0.31	0.32	32.0	82.50	50.50	1.58
10 July	1.41	1.54	3.30	3.42	4.71	4.96	0.30	0.31	32.0	73.75	41.75	1.30
SEm	0.06	0.07	0.07	0.06	0.08	0.07	0.13	0.10	-	1.55	1.55	0.19
CD (P=0.05)	0.19	0.21	0.21	0.19	0.25	0.23	NS	NS	-	4.95	4.95	0.62
Spacing (cm)												
15 × 15	1.40	1.49	3.32	3.4	4.72	4.89	0.30	0.30	34.0	72.25	38.25	1.13
35 × 15	1.55	1.72	3.48	3.62	5.03	5.34	0.31	0.32	32.0	81.75	49.75	1.55
45 × 15	1.69	1.87	3.70	3.80	5.39	5.67	0.31	0.33	30.0	89.00	59.00	1.97
SEm	0.05	0.06	0.04	0.05	0.07	0.06	0.11	0.10	-	1.19	1.19	0.16
CD (P=0.05)	0.16	0.18	0.13	0.17	0.22	0.19	NS	NS	-	3.82	3.82	0.5

influenced the cost of cultivation (Table 2). Plant spacing at 15 cm × 15 cm recorded higher cost of cultivation (34 × 10^3 ₹/ha) followed by 35 cm × 15 cm (32 × 10^3 ₹/ha) and 45 cm × 15 cm (30 × 10^3 ₹/ha). The gross returns and net returns were recorded higher with plant spacing at 45 × 15 cm (89 and 59 × 10^3 ₹/ha, respectively) followed by 35 cm × 15 cm (81.75 and 49.75 × 10^3 ₹/ha, respectively) and 15 cm × 15 cm (72.25 and 38.25 × 10^3 ₹/ha, respectively). The B:C ratio also followed the same trend, found higher with plant spacing at 45 cm × 15 cm (1.97) followed by 35 cm × 15 cm (1.55) and 45 cm × 15 cm (1.13).

On the basis of above research findings, it can be concluded that Pusa Arhar-16 can be sown from 5 June to 21 June with plant spacing at 45 cm × 15 cm without any yield penalty in Indo-Gangetic Plains of India.

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