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Effect of planting methods, geometry and intercrops on growth and productivity of pigeonpea in pigeonpea based cropping systems

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Abstract
A field experiment was conducted to study the influence of planting methods, geometry and intercrops on growth and productivity of pigeonpea at College of agriculture, Dharwad, India, during 2016-17. The experiment was laid out in randomized complete block design with twelve treatment combinations and replicated thrice. Sole transplanted pigeonpea at 120cm × 60cm geometry produced significantly higher values of plant growth parameters and pigeonpea grain yield (2,662 kg ha^{-1}) as compared to intercropped transplanted pigeonpea (120cm × 60cm) and direct sown sole pigeonpea as well as intercropping systems at 120cm × 60cm and 90cm × 30cm geometries. Among the intercropping systems, transplanted pigeonpea (120cm x 60cm) intercropping with greengram recorded significantly higher growth parameters and pigeonpea grain yield (2,550 kg ha^{-1}) and transplanted pigeonpea (120cm x 60cm) intercropping with blackgram recorded significantly pigeonpea equivalent yield (3,987 kg ha^{-1}) as compared to other intercropping systems and sole pigeonpea.

Keywords: Direct sowing, growth, pigeonpea, transplanting, yield

Introduction
It is well known that the crop production is unstable and at times uneconomic due to vagaries of monsoon in dry land areas of scarcity zone. Appropriate intercropping systems besides meeting the varied requirements of farmer, provide stability in rainfed agriculture and improve the total productivity through better utilization of natural resource. Pigeonpea being a long duration crop and slow growing at initial stages provide opportunity for intercropping of short duration pulses and oilseed in between the rows. Such crop intensification systems help in better use of available natural resources such as soil, space, moisture and it is the promising way to boost total productivity of pulses.

Pigeonpea (*Cajanus cajana* L.) is one of the major grain legume crops of tropical and subtropical regions and it is grown predominantly under rainfed conditions. India accounts for 90 per cent of world's pigeonpea growing area and 85 per cent of world's production of pigeonpea. In India, it is grown in an area of 3.47 M ha with an annual production of 2.55 MT and productivity of 711 kg ha^{-1} (Anon., 2015) [1]. As a soil ameliorant, pigeonpea is known to provide several benefits to the soil in which it is cultivated. When pigeonpea is grown as a sole crop, it is relatively inefficient because of its slow initial growth rate and low harvest index (Willey *et al*., 1980) [2] and the initial slow growth rate and deep root system of pigeonpea offers good scope for intercropping with fast growing early maturing and shallow rooted crops (Ramamoorthy *et al*., 2004) [3]. Therefore a short duration intercrop can be grown in between pigeonpea, which helps in efficient utilization of available resources for enhancing the productivity and profitability.

Intercropping of pigeonpea with soybean, greengram and blackgram reduce growth and yield of pigeonpea because of higher competitive ability over pigeonpea as they have a faster vegetative growth during early stage (Billore *et al*. 2009) [4]. Moreover, terminal moisture stress during reproductive stage further declines pigeonpea productivity. In order to ensure timely sowing due to late onset of monsoon and to overcome the competitive suppression by intercrops, transplanting of pigeonpea seedlings may be one of the agronomic measures to overcome delayed sowing. This technique involves raising of seedlings in the polythene bags in nursery and transplanting these seedlings in the main field after certain age. As established seedlings, these pick up growth quickly under field condition and can be more competitive. Intercropping in transplanted pigeonpea also offers greater scope for crop intensification as in direct sown crop, however such studies are very much limited. With this background, the present study was undertaken involving intercropping of short duration pulses and legume oilseed with transplanted pigeonpea *vis-a-vis* direct sown pigeonpea with the objective of

evaluating the effect of planting methods, geometries and intercrops on the growth and productivity of pigeonpea

Materials and Methods

The experiment was conducted at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka at 15^0 26' N latitude and 75^0 7' E longitude with an altitude of 678 m above mean sea level under rainfed condition during *Kharif* (June-September) and *Rabi* (October-January) seasons of 2016-17. During the crop growth period, a total rainfall of 563.1 mm was received which was optimum for good growth and higher yield. The soil of the experimental site is *Typic Hapstaurt* with pH of 7.1 and electrical conductivity of 0.32 dS m^{-1}. The soil is medium in organic carbon (0.52%) and low in available nitrogen (243 kg ha^{-1}) and medium in available P (27 kg ha^{-1}) and available K (283 kg ha^{-1}). The experiment was laid out in a randomized complete block design involving 12 treatments in 3 replications. The details of the treatments included transplanted pigeonpea at 120 cm x 60 cm planting geometry, direct sown pigeonpea at 120 cm x 60 cm and 90 cm x 30 cm planting geometries with intercropping of soybean, greengram and blackgram at 1:2 row proportion and sole treatments of transplanted and direct sown pigeonpea.

Pigeonpea variety 'TS 3R', soybean variety 'JS 335', greengram variety 'DGGV 2' and blackgram variety 'DBGV 5' were used. Pigeonpea and intercrops seeds were dry seed dressed with Trichoderma at the rate of 4g kg^{-1} seeds and later treated with Rhizobium and *Pseudomonas fluroscence* a P solubilizing culture at the rate of 500g ha^{-1} seed. In order to raise seedlings of pigeonpea healthy bold treated seeds were sown in black polythene bags (size 15cm x 6cm) filled with soil and vermicompost in the last week of May. Regular watering was then done to raise the seedlings for a period of 4 weeks in the nursery. Transplanting of pigeonpea seedlings, direct sowing of pigeonpea and intercrops seeds were done at the onset of the rains during the last week of June. Marking with the help of marker was done as per the row and intra row spacing of respective treatments and at each hills small pits were opened with the help of pickaxe to a depth of 15-20 cm and then pigeonpea seedlings were transplanted after removing the polythene cover without disturbing the soil at the root zone of the pigeonpea seedling. The row spacing adopted for intercrops in transplanted pigeonpea and direct sown pigeonpea (120 cm x 60 cm) was 40 cm x 7.5 cm and in intercrops with direct sown pigeonpea (90 cm x 30 cm) was 30 cm x 10 cm. The recommended quantity of FYM (6 t ha^{-1}) was applied two weeks before sowing and transplanting of the crop. The entire quantity of recommended dose of fertilizer for pigeonpea (25:50:0 kg $N:P_2O_5:K_2O$ ha^{-1}) and $2/3^{rd}$ of recommended dose of fertilizer for soybean (26.6:53.3:16.6 kg $N:P_2O_5:K_2O$ ha^{-1}), greengram (16.6:33.3:0 kg $N:P_2O_5:K_2O$ ha^{-1}) and blackgram (16.6:33.3:0 kg $N:P_2O_5:K_2O$ ha^{-1}) in the form of urea, diammonium phosphate (DAP) and muriate of potash were applied at the time of sowing and transplanting as basal dose at 5 cm deep and 5 cm away from the seeds and seedlings, then covered with soil.

Observations on growth parameters such as plant height, number of primary and secondary branches $plant^{-1}$, number of root nudules, leaf area $plant^{-1}$, leaf area index and total dry matter production were recorded on five tagged plants selected from the net plot area. Chlorophyll content was measured by using SPAD – 502 chlorophyll meter. A polythene sheet of 1 m^2 area was spread in between two rows of the crop and at harvest of the crop the leaf fall was collected from one square meter area from each treatment and expressed in kg per hectare. Pigeonpea and inter crops were harvested and threshed from the net plot area and produce was dried and recorded as net plot yield from which yield per hectare was computed. Pigeonpea equivalent yield (PEY) was calculated by converting the yield of intercrops into PEY on the basis of prevailing market prices during the year by using the following formula.

$$PEY = \text{Yield of pigeonpea in intercropping system (kg ha}^{-1}) + \frac{\text{Yield of intercrops (kg ha}^{-1}) \times \text{Market price of intercrops (₹ kg}^{-1})}{\text{Market price of pigeonpea (₹ kg}^{-1})}$$

Fisher's method of analysis of variance was used for analysis and interpretation of the data (Panse and Sukhatme, 1967) [5]. The level of significance used in F and t tests was P=0.05. Critical differences were calculated wherever F tests were significant.

Results and Discussion

Growth parameters of pigeonpea

Sole transplanted pigeonpea with planting geometry of 120 cm × 60 cm recorded significantly higher plant height (179.82 cm), number of primary branches per plant (9.33), secondary branches per plant (28.27), total dry matter production per plant (1,033.05 g) and leaf litter fall (1,104 kg ha^{-1}) compared to direct sown sole pigeonpea as well as intercropping systems both at 120 cm × 60 cm and at 90 cm × 30 cm spacing's (Table 1). However, it was at par with transplanted pigeonpea at 120 cm × 60 cm spacing with greengram intercropping system with respect to number of primary branches and leaf litter. Same trend was followed with respect to SPAD values (31.8 and 40.9, at 60 and 90 DAT/ DAS respectively), number of root nodules per plant (8.73 and 9.33, 60 and 80 DAT/ DAS respectively) and at 90 and 120 days after transplanting (DAT)/ days after sowing (DAS) leaf area (198.31 dm^2 $plant^{-1}$ and 318.94 dm^2 $plant^{-1}$, respectively) and leaf area index (2.75 and 4.43, respectively) (Table 2). This might be due to the advantage of transplanting 3 weeks old seedlings with well-established root system and exposure of the plants to relatively longer days required for optimum growth of the plants. In addition, the vigorous root system of the transplanted seedlings improved the utilization of natural resources such as solar radiation, soil moisture, space and nutrients more efficiently than direct sown pigeonpea plants. These results are in accordance with the findings of Malik (2009) [6], Praharaj *et al*. (2015) [7] and Mohanadas (2016) [8] in pigeonpea. Pavan *et al*. (2011) [9] reported that transplanted pigeonpea at 150 cm x 30 cm spacing recorded significantly higher plant height (197.00 cm). Transplanted pigeonpea at 120 cm x 90 cm row spacing recorded significantly higher number of primary branches $plant^{-1}$ (37.40) at harvest which was significantly superior when compared to 90 cm x 20 cm row spacing with dibbled pigeonpea (28.27).

Table 1: Growth parameters of pigeonpea as influenced by planting methods, geometries and intercrops

T. No.	Treatment details	Plant height (cm)	No. of primary branches plant^{-1}	No. of secondary branches plant^{-1}	TDM (g plant^{-1})	Leaf Litter (kg ha^{-1})	Total biomass production (kg ha^{-1})
T_1	Transplanted pigeonpea (120 cm × 60 cm) + soybean (1:2)	175.33	9.00	24.53	963.93	1,084	18,655
T_2	Transplanted pigeonpea (120 cm × 60 cm) + greengram (1:2)	176.67	9.07	25.87	976.14	1,094	17,320
T_3	Transplanted pigeonpea (120 cm × 60 cm) + blackgram (1:2)	175.08	8.93	23.27	933.67	1,082	17,800
T_4	Direct sown pigeonpea (120 cm × 60 cm) + soybean (1:2)	153.42	5.87	16.47	326.72	690	12,519
T_5	Direct sown pigeonpea (120 cm × 60 cm) + greengram (1:2)	152.83	5.73	15.80	311.21	677	11,062
T_6	Direct sown pigeonpea (120 cm × 60 cm) + blackgram (1:2)	152.25	5.60	15.60	290.22	672	11,470
T_7	Direct sown pigeonpea (90 cm × 30 cm) + soybean (1:2)	161.83	4.73	10.87	222.03	791	14,270
T_8	Direct sown pigeonpea (90 cm × 30 cm) + greengram (1:2)	161.08	4.87	11.20	232.05	808	13,360
T_9	Direct sown pigeonpea (90 cm × 30 cm) + blackgram (1:2)	162.08	4.87	11.87	246.66	830	14,755
T_{10}	Sole transplanted pigeonpea (120 cm × 60 cm)	179.82	9.33	28.27	1033.05	1,104	13,602
T_{11}	Sole direct sown pigeonpea (120 cm × 60 cm)	155.08	6.13	17.40	358.02	693	8,982
T_{12}	Sole direct sown pigeonpea (90 cm × 30 cm)	164.12	5.60	13.07	281.24	834	10,627
	S.Em. ±	0.72	0.10	0.51	17.11	36	363
	L.S.D. (0.05)	2.24	0.30	1.30	50.19	107	1065

Total biomass production of the system was significantly higher with transplanted pigeonpea (120 cm x 60 cm) with soybean intercropping system (18,655 kg ha^{-1}) as compared to other transplanted and direct sown pigeonpea treatments except transplanted pigeonpea (120 cm x 60 cm) with blackgram intercropping system (17,800 kg ha^{-1}) which was on par (Table 1). This might be due to higher growth attributes and total dry matter production of component crops. These findings are in conformity with the results of Goud and Andhalkar (2012) [10].

Among all the intercropping treatments, transplanted pigeonpea at planting geometry of 120 cm × 60 cm spacing intercropped with greengram, soybean and blackgram produced significantly higher growth attributes as compared to direct sown pigeonpea intercropping with soybean, greengram and blackgram at both 120 cm × 60 cm and 90 cm × 30 cm geometry. This may be attributed to better acquisition of growth resources by the well-established transplanted seedlings which ultimately reduced the intensity of competition by the intercrops. In contrast, the direct sown pigeonpea plots experienced severe competition for growth resources from the fast growing intercrops. These findings are in conformity with the findings of Goud and Andhalkar (2012) [10] in transplanted pigeonpea + soybean system and Poornima *et al*. (2009) [11] in transplanted pigeonpea with pigeonpea + finger millet intercropping system. Murali *et al.* (2014) [12] revealed that transplanting of 5 weeks old seedlings of pigeonpea as intercrop with finger millet produced significantly higher pigeonpea plant height (177 cm) and number of primary branches plant^{-1} (17.2) as compared to direct sown pigeonpea as intercrop (163 cm plant height and 9.2 primary branches).

System productivity

Transplanted pigeonpea (120 cm x 60 cm) intercropping with blackgram at 1:2 row proportion recorded significantly higher pigeonpea equivalent yield (3,987 kg ha^{-1}) as compared to other intercropping systems and sole crops except transplanted pigeonpea (120 cm x 60 cm) with intercropping of soybean and greengram which were on par. Significantly lower pigeonpea equivalent yield (1,705 kg ha^{-1}) was recorded with sole direct sown pigeonpea at 120 cm x 60 cm spacing which was at par with sole direct sown pigeonpea with 90 cm x 30 cm (Fig.1). Higher pigeonpea equivalent yield with pigeonpea transplanted at 120 cm x 60 cm was 50, 45 and 43 per cent with intercropping of blackgram, soybean and greengram respectively over sole pigeonpea at 120 cm x 60 cm. Transplanted pigeonpea performed better under wider row spacing of 120 cm x 60 cm and provided good opportunity to grow intercrops mainly soybean, greengram and blackgram at 1:2 row proportions and helped to get higher system productivity and income. Hence, it was compared with direct sown pigeonpea at 120 cm x 60 cm and recommended geometry of 90 cm x 30 cm. This was attributed to additional yield of all the three component crops and their better performance in transplanted pigeonpea with higher market prices. These results confirm the findings of Kumawat *et al*. (2013) [13] and Srichandan and Mangaraj (2015) [14].

Table 2: SPAD values, root nodules, leaf area and leaf area index of pigeonpea as influenced by planting methods, geometries and intercrops

T. No.	Treatment details	Chlorophyll content (SPAD values)		No. of root nodules plant^{-1}		Leaf area (dm^2 plant^{-1})		Leaf area index	
		60 DAT/ DAS	90 DAT/ DAS	60 DAT/ DAS	80 DAT/ DAS	90 DAT/ DAS	120 DAT/ DAS	90 DAT/ DAS	120 DAT/ DAS
T_1	Transplanted pigeonpea (120 cm × 60 cm) + soybean (1:2)	32.2	39.6	8.27	9.00	181.31	282.69	2.52	3.93
T_2	Transplanted pigeonpea (120 cm × 60 cm) + greengram (1:2)	32.1	40.4	8.33	9.07	182.25	289.90	2.53	4.03
T_3	Transplanted pigeonpea (120 cm × 60 cm) + blackgram (1:2)	32.6	39.6	8.20	8.93	174.48	269.80	2.42	3.75
T_4	Direct sown pigeonpea (120 cm × 60 cm) + soybean (1:2)	25.1	38.1	5.27	5.80	102.33	182.48	1.42	2.53
T_5	Direct sown pigeonpea (120 cm × 60 cm) + greengram (1:2)	25.0	37.6	5.13	5.73	99.55	175.31	1.38	2.43
T_6	Direct sown pigeonpea (120 cm × 60 cm) + blackgram (1:2)	25.2	38.9	5.20	5.60	95.54	165.44	1.33	2.30
T_7	Direct sown pigeonpea (90 cm × 30 cm) + soybean (1:2)	25.1	36.5	4.20	4.73	30.72	54.75	1.14	2.03
T_8	Direct sown pigeonpea (90 cm × 30 cm) + greengram (1:2)	26.6	37.0	4.27	4.80	31.27	58.90	1.16	2.18
T_9	Direct sown pigeonpea (90 cm × 30 cm) + blackgram (1:2)	25.8	36.3	4.27	4.87	31.55	60.85	1.17	2.25
T_{10}	Sole transplanted pigeonpea (120 cm × 60 cm)	31.8	40.9	8.73	9.33	198.31	318.94	2.75	4.43
T_{11}	Sole direct sown pigeonpea (120 cm × 60 cm)	24.2	37.6	5.80	6.13	117.65	201.09	1.63	2.79
T_{12}	Sole direct sown pigeonpea (90 cm × 30 cm)	24.2	36.9	5.07	5.60	42.93	66.78	1.59	2.47
	S.Em. ±	0.8	0.8	0.08	0.10	5.96	10.14	0.10	0.16
	L.S.D. (0.05)	2.4	2.4	0.24	0.29	17.48	29.74	0.28	0.47

Sole transplanted pigeonpea with planting geometry of 120 cm × 60 cm recorded significantly higher pigeonpea grain yield (2,662 kg ha^{-1}) as compared to transplanted pigeonpea (120 cm x 60 cm) with blackgram intercropping and direct sown pigeonpea sole as well as intercropping systems both at 90 cm × 30 cm and 120 cm × 60 cm planting geometries. However, it was at par with transplanted pigeonpea at 120 cm × 60 cm spacing with greengram (2,550 kg ha^{-1}) and soybean (2,537 kg ha^{-1}) intercropping systems (Fig.1). Among the intercropping systems, transplanted pigeonpea at planting geometry of 120 cm × 60 cm spacing intercropped with greengram, soybean and blackgram recorded significantly higher pigeonpea grain yield (2,550 kg ha^{-1}, 2,537 kg ha^{-1} and 2,334 kg ha^{-1}, respectively) as compared to direct sown pigeonpea intercropping with soybean, greengram and blackgram at both 120 cm × 60 cm and 90 cm × 30 cm geometries. Higher pigeonpea grain yield in sole transplanted pigeonpea at planting geometry of 120 cm × 60 cm spacing over sole direct sown pigeonpea at planting geometry of 90 cm × 30 cm spacing (34%) and 120 cm × 60 cm spacing (56%) and in transplanted pigeonpea intercropping systems over direct sown pigeonpea intercropping systems were mainly attributed to higher growth and yield attributes which were significantly superior to direct sown pigeonpea. These findings are in conformity with the results of Mallikarjun *et al.* (2014) [15], Praharaj *et al*. (2015) [7] and Goud and Andhalkar (2012) [10] in transplanted pigeonpea + soybean system, Poornima *et al*. (2009) [11] and Murali *et al.* (2014) [12] in transplanted pigeonpea with finger millet intercropping system. Pavan *et al*. (2011) [9] reported the superiority of transplanted pigeonpea with respect to grain yield (2.39 t ha^{-1}) of pigeonpea as compared to direct dibbling (2.13 t ha^{-1}) and drill sown pigeonpea (1.69 t ha^{-1}).

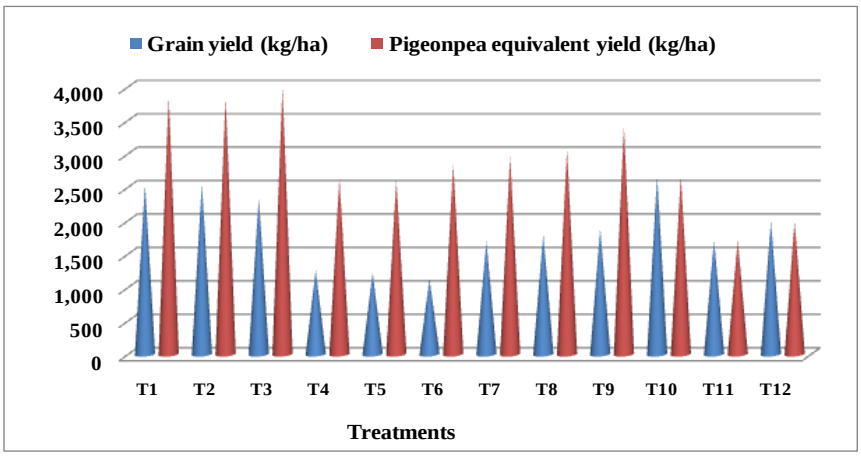

Fig 1: Grain and equivalent yield of pigeonpea in pigeonpea based cropping systems as influenced by planting methods, geometries and intercrops

Conclusion

From the above results it can be concluded that, sole transplanted pigeonpea found superior as compared to direct sown pigeonpea at 120 cm × 60 cm and 90 cm × 30 cm planting geometry with respect to growth parameters, pigeonpea grain yield and system productivity. Among the intercropping systems, transplanted pigeonpea (120 cm × 60 cm) intercropped with greengram, soybean and blackgram at 1:2 row proportion was superior as they recorded higher pigeonpea yield and pigeonpea equivalent yield with higher growth and yield parameters as compared to growing of intercrops in sole direct sown pigeonpea and sole pigeonpea.

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