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Research Paper

Effect of different planting geometry of transplanted pigeonpea (*Cajanus cajan*) as an intercrop in young arecanut (*Areca catechu*) garden at Southern Transitional Zone of Karnataka, India

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ABSTRACT

A field experiment was conducted during 2017–18, 2018–19 and 2019–20, to study the influence of planting methods on growth and productivity of pigeonpea [*Cajanus cajan* (L.) Millsp.]. The experiment was laid out in randomized complete block design with 8 treatment combinations and replicated thrice. Pooled data indicated that transplanted pigeonpea at 60 cm × 30 cm geometry gave significantly higher pigeonpea seed and stalk yield (2,353 and 6,533 kg/ha respectively), and it was followed by 60 cm × 60 cm spacing (2,072 and 5,852 kg/ha respectively). The above-mentioned treatments also recorded significantly higher total uptake of nitrogen (129.18 and 123.39 kg/ha respectively), phosphorus (36.84 and 32.40 kg/ha respectively) and potassium (62.57 and 57.58 kg/ha respectively), whereas, higher available nitrogen, phosphorus and potassium (246.64, 35.87 and 155.65 kg/ha respectively) were recorded in 180 cm × 30 cm. Further higher nitrogen, phosphorus and potassium content in arecanut leaf (*Areca catechu* L.) was observed in 60 cm × 60 cm (1.72 %), 120 cm × 30 cm (0.260 and 1.20 %) as compared to other planting geometry in young arecanut garden.

Key words: Nutrient, Pigeonpea, Transplanting, Yield, Uptake

Current climatic condition in agriculture is unpredictable for stable crop production and becoming uneconomical to the farmers in dryland areas. Appropriate cropping systems besides meeting the varied requirements of farmer, provide stability in rainfed agriculture and improve the total productivity through better utilization of natural resource. In Southern Transitional Zone of Karnataka, the fields which are used for the cultivation of rice (*Oryza sativa* L.) before are converted it into arecanut (*Areca catechu* L.) estate. Those fields have soft soil with good fertility and also continues water supply to the land, which made the best location to grow arecanut. Application of silt is most common in young arecanut gardens, which may affect the native soil fertility. Inclusion of legumes in arecanut gardens leads to increase in the soil fertility through biological fixation of atmospheric dinitrogen (N_2) by legume-rhizobial symbioses, and the buildup of slowly weathered nutrients in plant biomass. On account of biological nitrogen fixation, addition of considerable amount of organic matter through root biomass and leaf fall, deep root-systems, mobilization of nutrients, protection of soil against erosion and improving microbial biomass, they keep soil productive and alive by bringing qualitative changes in physical, chemical and biological properties (Bansal, 2011).

Pigeonpea [*Cajanus cajana* (L.) Millsp.] 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% of world's pigeonpea growing area and 85% of world's production of pigeonpea. As a soil ameliorant, pigeonpea is known to provide several benefits to the soil in which it is cultivated (Murali *et al.,* 2014). 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). Moreover, terminal moisture stress during reproductive stage further declines pigeonpea productivity. In order to ensure timely sowing due to the late onset of monsoon and to overcome the competitive suppression of transplanting pigeonpea seedlings may be one of the agronomic measures to overcome

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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. Hence a study was carried out to find out the effect of different planting geometry of transplanted pigeonpea as an intercrop in young arecanut garden on growth and productivity of pigeonpea.

MATERIALS AND METHODS

The experiment was conducted at Agricultural and Horticultural Research Station, Kathalagere, University of Agricultural and Horticultural Research Station, Shivamogga, Karnataka, India, during under rainfed condition during rainy (*kharif*) and winter (*rabi*) seasons (June–November) of 2017–18, 2018–19 and 2019–20. During the crop growth period, a total rainfall of 643.1 and 708 mm was received during both the years, which was optimum for good growth and higher yield. The soil of the experimental site is Typic Hapstaurt with pH of 6.8 and electrical conductivity of 0.18 dS/m. The soil is medium in organic carbon (0.61%) and low in available nitrogen (358.6 kg/ha) and medium in available P (22.5 kg/ha) and available K (237 kg/ha). The experiment was laid out in a randomized complete-block design, involving 8 treatments in 3 replications. The details of the treatments included transplanted pigeonpea at spacing of 60 cm × 30 cm, 60 cm × 60 cm, 120 cm × 30 cm, 120 cm × 60 cm, 150 cm × 30 cm, 150 cm × 60 cm, 180 cm × 30 cm and 180 cm × 60 cm. Indeterminate semi spreading, green podding, bold seeded pigeonpea variety 'BRG 2' (175–185 days maturity period) was selected. In order to raise seedlings of pigeonpea healthy, bold treated seeds were sown in black polythene bags (size 15 cm × 6 cm) filled with soil and vermicompost in the last week of May. Regular watering was 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 intrarow spacing of respective treatments and at each hill 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 recommended quantity of FYM (6 t/ha) was applied 2 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) was applied 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. Pigeonpea crop was harvested and threshed from the net plot area and produce was dried and recorded as net plot yield from which yield/ha was computed. Composite soil samples were used to assess soil-nutrient status. Fisher's method of analysis of variance was used for analysis and interpretation of the data (Panse and Sukhatme, 1967). 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

Yield parameters

Pooled data of transplanted pigeonpea with a planting geometry of 180 cm × 30 cm showed significantly higher yield parameters, viz. pods/plant and pod weight/plant (883 and 580 g/plant respectively), followed by 60 cm × 30 cm treatment (Table 1) This may be owing to wider availability of spacing, more availability of light and moisture, which made the plant to grow vigorously and this might have experienced less competition than narrow spacings. Pod weight/plant is also one of the important yield attributing traits. Significant differences in seed yield of pigeonpea was observed with closer spacing of 60 cm × 30 cm over other spacings, because of more plant population per unit area These results are in accordance with the findings of Pavan *et al.* (2009) and Mula *et al.* (2011).

Seed and stalk yield

The trend of pooled data with respect to seed and stalk yield followed similar pattern as that of individual years. The seed and stalk yield differed significantly due to different planting geometry treatments during individual years and in pooled analysis (Table 1). Higher seed and stalk yield was obtained with the spacing of 60 cm × 30 cm (2,353 and 6,533 kg/ha, respectively) and 60 cm × 60 cm (2,072 and 5,852 kg/ha respectively). This may be attributed to more plant population per unit area obtained higher economical and biological yield owing to better plant development, resulting in more uniform distribution of plants over cropped area coupled with greater light interception, moisture utilization, nutrient and solar energy availability under lower degree of inter-and intra-plant competitions. These favourable conditions for growth caused significantly higher values of yield components under. However, these higher values of yield components could not compensate for loss in yield due to lower plant population. Hence, wider spacing recorded significantly lower yield than closer spacing. Similar reductions in yield under wider spacing was reported by Shaik Mohammed (1997) and Parameswari *et al.* (2003) under winter season situation. The higher stalk yield with the higher plant population was owing to more plants/unit area. These results are in

Table 1. Effect of different planting density of pigeonpea on yield parameters and yield under young arecanut garden

Treatment	Pods/plant			Pod weight/plant (g)			Seed yield (kg/ha)			Stalk yield (kg/ha)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
T_1, 60 cm × 30 cm	656	806	731	431	506	469	2234	2471	2353	6147	6919	6533
T_2, 60 cm × 60 cm	615	702	659	416	487	452	1848	2296	2072	4961	6742	5852
T_3, 120 cm × 30 cm	583	618	601	391	453	422	1914	2156	2035	4879	6534	5707
T_4, 120 cm × 60 cm	527	545	536	376	441	409	1821	2050	1936	4925	6218	5572
T_5, 150 cm × 30 cm	491	704	598	357	419	388	1784	2021	1903	5081	5926	5504
T_6, 150 cm × 60 cm	468	575	522	338	392	365	1658	1975	1817	5234	5796	5515
T_7, 180 cm × 30 cm	769	996	883	541	618	580	1605	1918	1762	5148	5608	5378
T_8, 180 cm × 60 cm	628	751	690	424	485	455	1594	1870	1732	4985	5234	5110
SEm±	14	21	26	14	26	21	68	89	70	65	173	164
CD (P=0.05)	43	61	78	41	77	62	201	264	211	193	514	486

conformity with the findings of Legha and Dhingra (1992) and Mohite *et al.* (1993), who observed higher stalk yield with closer plant geometry. Nagamani *et al.* (1995) and Pavan *et al.* (2009) also recorded higher stalk yield with increase in number of plants per hectare. Further, the higher stalk yield with the higher plant population was owing to more number of plants/unit area and greater retention of dry-matter in stem. Over and above that, gap-filling through transplanted pigeonpea had some potential to give higher yield, as it could enable timely planting and maintenance of adequate plant population in pigeonpea, the twin issues related to realization of higher crop productivity in pigeonpea.

Nutrient uptake

Significantly higher total uptake of nitrogen (129.18 and 123.39 kg/ha respectively), phosphorus (36.84 and 32.40 kg/ha, respectively) and potassium (62.57 and 57.58 kg/ha respectively) were recorded under 60 cm × 30 cm and 60 cm and 60 cm planting geometry treatments respectively (Table 2). Nutrient uptake was also influenced by intercultural operations carried out at optimum time. Further application of inorganic nutrients possibly increased the concentration of N, P and K ions of soil solution and ultimately affected the formation of more nodules, vigorous root development, better N fixation and better development of plant growth leading to higher photosynthetic activity and translocation of photosynthates to the sink which in turn resulted in better uptake of nutrients (Kumar and Singh, 2011).

Availability of nutrients

Significantly higher available nitrogen, phosphorus and potassium (246.64, 35.87 and 155.65 kg/ha respectively) were recorded in 180 cm × 30 cm planting geometry, followed by 150 cm × 60 cm (245.34 kg/ha of nitrogen), 180 cm × 30 cm (32.39 kg/ha of phosphorus) and 150 cm × 60 cm (151.46 kg/ha of potassium) (Table 3). Higher availability of N, P and K over other spacings was because of inefficient utilization of nutrients from the soil by lesser plant population per unit area. There was no interaction between availability of nutrients and plant densities for any of the sites evaluated. This finding indicated that, increasing availability of nutrients in fields with reduced plant population, or increasing plant population but reducing N rates is not feasible for improving pigeonpea production. This trend contradicts Dong *et al*. (2012), who found that cotton (*Gossypium* sp.) yield could be maximized using low plant density at a high nutrients application rate or high plant density at any nutrients rate. Considering that cultivation of transplanted pigeonpea is expanding in the tropics with limited scientific validation of best management practices.

Table 2. Effect of different planting density of pigeonpea on total nutrient uptake under young arecanut garden

Treatment	Total nutrient uptake (kg/ha)								
	Nitrogen			Phosphorus			Potassium		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
T_1, 60 cm × 30 cm	121.64	136.72	129.18	34.41	39.26	36.84	58.72	66.42	62.57
T_2, 60 cm × 60 cm	114.57	132.21	123.39	29.32	35.47	32.40	55.28	59.88	57.58
T_3, 120 cm × 30 cm	108.14	120.53	114.34	26.29	29.81	28.05	45.73	48.59	47.16
T_4, 120 cm × 60 cm	118.27	127.36	122.82	29.04	34.11	31.58	49.26	54.18	51.72
T_5, 150 cm × 30 cm	111.85	122.71	117.28	26.28	30.51	28.40	46.16	50.83	48.50
T_6, 150 cm × 60 cm	104.56	113.69	109.13	24.19	28.15	26.17	41.26	45.68	43.47
T_7, 180 cm × 30 cm	116.92	127.51	122.22	28.37	31.49	29.93	47.22	51.86	49.54
T_8, 180 cm × 60 cm	92.83	107.36	100.10	25.93	28.74	27.34	43.13	46.95	45.04
SEm±	5.65	5.84	6.84	1.23	1.31	1.63	1.99	2.02	2.06
CD (P=0.05)	16.80	17.35	20.32	3.66	3.90	4.84	5.92	6.01	6.14

Table 3. Effect of different planting density of pigeonpea on available nutrient status (kg/ha) of the soil under younger arecanut garden

Treatment	Available nutrient status (kg/ha)								
	Nitrogen			Phosphorus			Potassium		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
T_1, 60 cm × 30 cm	228.81	236.29	232.55	21.32	24.58	22.95	132.42	142.69	137.56
T_2, 60 cm × 60 cm	231.66	240.82	236.24	23.71	28.45	26.08	135.39	146.25	140.82
T_3, 120 cm × 30 cm	236.74	244.38	240.56	26.46	30.17	28.32	137.52	145.71	141.62
T_4, 120 cm × 60 cm	229.41	236.16	232.79	23.82	26.49	25.16	135.78	142.36	139.07
T_5, 150 cm × 30 cm	235.26	248.36	241.81	26.64	29.28	27.96	139.27	151.80	145.54
T_6, 150 cm × 60 cm	238.92	251.75	245.34	32.39	36.07	34.23	143.94	155.06	149.50
T_7, 180 cm × 30 cm	240.08	253.19	246.64	32.87	38.16	35.52	148.02	163.28	155.65
T_8, 180 cm × 60 cm	236.58	249.70	243.14	30.26	38.53	34.40	143.48	159.44	151.46
SEm±	2.34	3.17	2.68	2.58	2.97	3.03	2.06	3.33	2.37
CD (P=0.05)	6.97	9.41	7.97	7.68	8.82	9.01	6.14	8.96	7.04

Availability of nutrients at different depths during 2019 and 2020

Available nutrient status at 0–30 cm depth: The data revealed (Table 4) that, significant influence of treatments on availability of nutrients which was higher in 120 cm × 30 cm (295.34 kg/ha of nitrogen), 120 cm × 60 cm (49.79 and 303.41 kg/ha of phosphorus and potassium respectively), followed 60 cm × 60 cm (274.59 kg/ha of nitrogen), 150 × 60 cm (45.03 kg/ha of phosphorus) and 120 × 30 cm (287.55 kg/ha of potassium) as compared to rest of the treatments. The treatments with application of chemical fertilizers resulted in excess deposition of available K in both surface and subsurface zone. The improvement in soil-N status subsequent to the legumes due to the biological nitrogen fixation. Further, it is evident that there is a variation among the legumes in accumulation of N and its availability to the intercrops crops can be seen among the legume crops. These results are in accordance with the findings of Lal and Singh (2007) and Sharma and Behera (2009) also reported that, only 30% of N and 66% of P from legume residues is likely to be used by the first crop, the remaining maybe available to the perennial intercrop and to a little extent to the subsequent crops raised on the same land. Further, high lignin in pigeonpea or high polyphenol in hairy indigo were expected to influence the rates of N mineralization. In particular, roots of pigeonpea residues showed surprisingly fast decomposition and net N release patterns mainly due to their high N-concentration (Sakala *et al*., 2000).

Available nutrient status at 30–60 cm depth

Significantly higher availability of nutrients at 30 cm–60 cm depth was analyzed in 120 cm × 30 cm (242.68 kg/ha of nitrogen), 120 cm × 60 cm (36.79 kg/ha of phosphorus) and 150 cm × 60 cm (229.53 kg/ha of potassium) and it was followed by 150 cm × 60 cm (235.63 and 31.48 kg/ha of nitrogen and phosphorus respectively) and rest of the treatments were at par with each other (Table 5). As compared to 0–30 cm depth, the subsurface soils contained comparatively less available N, P and K content. Application of inorganic fertilizer coupled with irrigation might be the reason; it leads to the binding of cations and organic

Table 4. Available nutrient status (0–30 cm depth) of the soil during growth period of arecanut

Treatment	Available nutrient status (kg/ha)								
	Nitrogen			Phosphorus			Potassium		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
T_1, 60 cm × 30 cm	237.56	249.02	243.29	24.56	22.43	23.49	229.68	236.21	232.95
T_2, 60 cm × 60 cm	269.37	279.80	274.59	31.29	30.39	30.84	244.93	243.13	244.03
T_3, 120 cm × 30 cm	290.12	300.55	295.34	33.87	34.99	34.43	288.89	286.20	287.55
T_4, 120 cm × 60 cm	248.74	252.68	250.71	49.12	50.47	49.79	301.45	305.37	303.41
T_5, 150 cm × 30 cm	259.06	263.90	261.48	43.18	44.63	43.91	269.60	270.94	270.27
T_6, 150 cm × 60 cm	269.37	274.96	272.17	44.86	45.19	45.03	282.61	289.84	286.23
T_7, 180 cm × 30 cm	248.74	259.06	253.90	35.75	34.77	35.26	219.81	226.12	222.97
T_8, 180 cm × 60 cm	241.59	247.96	244.78	34.21	36.48	35.35	207.62	212.28	209.95
SEm±	4.13	5.08	4.27	3.36	4.22	3.72	15.20	16.01	16.60
CD (P=0.05)	12.28	15.09	11.48	10.94	12.53	11.05	45.13	47.54	49.28

Table 5. Available nutrient status (30–60 cm depth) of the soil during growth period of arecanut

Treatment	Available nutrient status (kg/ha)								
	Nitrogen			Phosphorus			Potassium		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
T_1, 60 cm × 30 cm	197.66	214.17	205.92	15.35	14.70	15.02	176.94	169.01	172.97
T_2, 60 cm × 60 cm	239.80	198.16	218.98	22.12	24.37	23.25	218.66	185.86	202.26
T_3, 120 cm × 30 cm	245.55	239.80	242.68	27.20	31.15	29.17	200.41	186.65	193.53
T_4, 120 cm × 60 cm	219.26	250.29	234.78	35.77	37.80	36.79	221.18	227.05	224.11
T_5, 150 cm × 30 cm	222.08	230.09	226.09	28.10	30.24	29.17	214.86	218.02	216.44
T_6, 150 cm × 60 cm	229.42	241.83	235.63	29.00	31.48	30.24	233.82	225.24	229.53
T_7, 180 cm × 30 cm	208.54	243.97	226.26	23.81	25.50	24.66	195.90	199.40	197.65
T_8, 180 cm × 60 cm	201.28	222.68	211.98	16.38	19.93	18.16	186.58	199.03	192.81
SEm±	8.11	9.75	8.44	3.66	3.91	4.70	10.18	11.30	9.96
CD (P=0.05)	24.08	28.96	25.06	10.89	11.61	13.96	30.53	33.57	29.59

acids resulting in leaching of soluble solids, reduces the nutrient-retention capacity of the soil resulted lesser availability of nutrients under subsurface zone of soil in the above treatments. Compounds such as polyphenols in decomposing residues, could decrease the rate of litter decomposition and N mineralization by inhibiting the enzyme activity of the decomposer community or complexation of proteins at subsurface layer of the soil (Handayanto *et al.,* 1997). Increased root proliferation in arecanut due to intercropping would increase organic matter content in soil. It was observed that, intercropping legumes increased the content of available nitrogen and other nutrients in arecanut plantation. Several advantages like fixation of N, recycling of nutrients in the soil profile, prevention of soil erosion and improved soil fertility are reported owing to intercropping with leguminous green-manure crops or cover crops in arecanut. It was further noticed that, intercropping with legumes in arecanut gardens could add on an average 10 kg green manure/palm which could meet 69 to 89% of N requirement, 28 to 43% P and 29–38% of K. Fungal and bacterial population was relatively more under intercropping situations than in sole crop of arecanut (Sujatha and Bhat, 2015).

Nutrient content (%) in arecanut leaf for two consecutive years

Significantly higher nutrients content (Table 6) was observed with spacing of 60 cm × 60 cm and 120 cm × 30 cm (1.72 and 1.71% of nitrogen respectively), 120 cm × 30 cm and 150 cm × 60 cm (0.260 and 0.250% of phosphorus respectively) and 120 cm × 30 cm and 120 cm × 60 cm (1.20 and 1.18% of potassium respectively). Higher dry-matter accumulation in different plant parts (leaf, stem and reproductive parts) with wider spacings resulted in higher total dry-matter/plant, which may increases availability of nutrients to the arecanut. Inclusion of legumes in the arecanut plantations add sufficient amount of organic matter to the soil and solubilize plant nutrients and improve physical conditions of the soil by accelerating porosity, aeration and water-holding capacity. It is also well documented fact that, legume residues with inorganic fertilizers in the soil not only acts as storehouse of macro- and micronutrients but also favourably affect physical and chemical characteristics of soil and plant (Bhriguvanshi, 1988).

Thus it may be concluded that higher seed and stalk yield was obtained with the spacing of 60 cm × 30 cm (2,353 and 6,533 kg/ha respectively) and 60 cm × 60 cm

Table 6. Nitrogen, phosphorus and potassium content (%) in arecanut leaf across, the years

Treatments	Nitrogen			Phosphorus			Potassium		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
T_1, 60 cm × 30 cm	1.32	1.34	1.33	0.17	0.19	0.180	1.11	1.13	1.12
T_2, 60 cm × 60 cm	1.70	1.74	1.72	0.20	0.21	0.205	1.12	1.15	1.14
T_3, 120 cm × 30 cm	1.72	1.70	1.71	0.25	0.27	0.260	1.19	1.21	1.20
T_4, 120 cm × 60 cm	1.46	1.51	1.49	0.23	0.26	0.245	1.17	1.19	1.18
T_5, 150 cm × 30 cm	1.63	1.65	1.64	0.21	0.22	0.215	1.13	1.14	1.14
T_6, 150 cm × 60 cm	1.55	1.59	1.57	0.24	0.26	0.250	1.10	1.12	1.11
T_7, 180 cm × 30 cm	1.50	1.56	1.53	0.21	0.23	0.220	1.14	1.15	1.15
T_8, 180 cm × 60 cm	1.55	1.62	1.59	0.20	0.21	0.205	1.16	1.18	1.17
SEm±	0.10	0.11	0.11	0.016	0.02	0.013	0.016	0.02	0.016
CD (P=0.05)	0.30	0.32	0.33	0.05	0.06	0.04	0.05	0.06	0.05

(2,072 and 5,852 kg/ha respectively). Significantly higher nitrogen (1.72%), phosphorus (0.260%) and potassium (1.20%) content in arecanut leaves was observed with spacing of 60 cm × 60 cm and 120 cm × 30 cm respectively. Higher available nitrogen, phosphorus and potassium (246.64, 35.87 and 155.65 kg/ha respectively) were recorded in 180 cm × 30 cm planting geometry. Inclusion of legumes as intercrop in arecanut acts as an supplemental addition of organics improving the growth of arecanut substantially increased the fertility status of the soil.

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