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Productivity and economics of pigeon pea (*Cajanus cajan* L.) based intercropping systems as influenced by different planting patterns

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Abstract
A field experiment entitled "Productivity of pigeon pea (*Cajanus cajan* L.) Based intercropping systems as influenced by different planting patterns" was conducted at Students' Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana, during *kharif* 2015 and 2016. The soil of the experimental site was loamy sand, normal pH and electrical conductivity, low in organic carbon and available N, medium in available P and K. In the experiment, three intercrops *viz*. cowpea fodder, maize fodder and groundnut were intercropped with pigeon pea at 50cm × 25cm, 75cm × 18.8cm and 100cm × 12.5cm (1+1) planting patterns and were compared with sole pigeon pea in randomized block design. Different intercrops were also grown as sole in the experiment to calculate the different intercropping indices. The results showed that growth, yield and yield attributes of pigeon pea were not significantly influenced by different intercropping systems and planting patterns. Among the different intercropping systems and planting patterns, pigeon pea (50cm × 25cm) + maize fodder (1+1) was found to be significantly superior as compared to sole pigeon pea and other intercropping systems, because it recorded significantly higher pigeon pea equivalent yield and economic returns.

Keywords: Economics, growth attributes, pigeon pea equivalent yield, yield attributes

Introduction
Pulses play an important role in Indian agriculture. India is a premier pulse growing country. Pigeon pea (*Cajanus cajan* L.) is the second most important pulse crop of the country after chickpea. In Punjab, it is grown during *kharif* season. During 2015-16, area under pigeon pea and its production were 2.6 thousand hectares and 2.63 thousand tonnes, respectively and average yield was 1013 kg/ha (Anonymous, 2017) [2]. pigeon pea is a long duration crop with initial slow growth rate, so there is ample scope of growing short duration inter crops which help in getting additional yield and income. Intercropping is an advanced agro-technique, which involves growing of two or more than two crops in the same field at the same time. Mixed or intercropping systems help in protecting the farmer from risks and are a good insurance option, since if one crop fails, the other may survive (Agegnehu *et al.*, 2008) [1]. In India, pigeon pea is generally intercropped with maize, sesamum, soybean, urdbean, mungbean and groundnut. Different maturing habits, growth patterns, nutrient and water requirements and rooting patterns of these crops make them suitable to grow as intercrop with pigeon pea. There is possibility of growing crops like cowpea fodder and maize fodder with pigeon pea due to its initial slow growth rate. Demand of fodder has increased over last few decades because of increase in dairy units. Presently, pigeon pea is grown as sole crop in Punjab. There exists scope of growing some intercrops during its early growth stages, as 45-60 days of its initial growth period is very slow. So, to take the advantage of this initial slow period, some short duration crops can be grown *viz*. maize fodder, cowpea fodder and groundnut, etc. The productivity of different intercrops and their effects on growth and yield of pigeon pea are still not known under Punjab condition and keeping in view the above stated facts, the present study was carried out during two consecutive *kharif* seasons.

Material and Methods

The present study was conducted during two consecutive *kharif* seasons of 2015 and 2016 at the research farm of Department of Agronomy, Punjab Agricultural University, Ludhiana, India. Ludhiana has sub-tropical and semi-arid climate with cold winters and hot dry summers. The soil was low in available N (196 and 197.5 kg ha-1) and organic carbon (OC) (0.31 and 0.27%). However, soil was medium in available P (18.8 and 20.5kg ha-1) and available K (213 and 216 kg ha-1) during 2015 and 2016, respectively. The soil pH (7.2 and 7.1) and electrical conductivity (0.31 and 0.25) were within the normal and safer range for growing good crop. The experiment was laid out in a randomized block design with 13 treatment combinations: pigeon pea (50cm x 25cm) + cowpea fodder, pigeon pea (50cm x 25cm) + maize fodder, Pigeon pea (50 cm x 25 cm) + groundnut, Pigeon pea (75cm x 18.8cm) + cowpea fodder, Pigeon pea (75cm x 18.8cm) + maize fodder, Pigeon pea (75cm x 18.8cm) + groundnut, Pigeon pea (100cm x 12.5cm) + cowpea fodder, Pigeon pea (100cm x 12.5cm) + maize fodder, Pigeon pea (100cm x 12.5cm) + groundnut, Sole pigeon pea (50cm × 25cm), Sole cowpea fodder (30cm), Sole maize fodder (30cm), and Sole groundnut (30cm × 15cm) and having one row of intercrops with row to row ratio of 1:1. All these treatments were replicated thrice. Crops were grown as per package of practices for *kharif* crops of Punjab. Sowing of pigeon pea was done manually through pora method and intercrops were sown in between two rows of pigeon pea. The recommended doses of fertilizers for pigeon pea (15 kg N, 40 kg P_2O_5 and 30 kg K_2O ha^{-1}) were applied at sowing. Fertilizer doses as per recommendations were applied to intercrops on area basis for all the treatments. Nitrogen, phosphorus and potassium nutrients were applied through urea, single super phosphate and muriate of potash, respectively. Fodder crops were harvested at 45 DAS, whereas groundnut and pigeon pea were harvested on 2 November 2015 and 26 October 2016. The pigeon pea equivalent yield was computed by converting the yield of intercrops to pigeon pea yield, based on their market prices. The data collected from the experiment was subjected to statistical test by following 'Analysis of variance technique' and critical difference (CD) values at 5% level of probability were computed for making comparison between treatments.

Results and Discussion

Plant height

Plant height is an important reliable index of plant growth at a given time period during the growth period. Its measurement is often used to monitor the effect of different treatments on crop growth. The data on periodic plant height was recorded at 30, 60, 90 and 120 days after sowing (DAS) and at maturity. However, data at maturity is presented in table 1. The data indicated that there was a progressive increase in plant height with the advancement of crop age during both the years. Due to indeterminate nature of the crop a plant height increased with advancement of crop age and reached to maximum at harvest. The data showed that plant height of pigeon pea was significantly influenced by different intercropping system and planting patterns but was not significantly affected at maturity during both the years. The lowest plant height was recorded at all growth stages where maize fodder was grown. However, at maturity, plant height was not significantly influenced by different planting patterns and intercropping systems during both the years. At the early stages of pigeon pea, decrease in plant height may be due to higher demand of nutrients for growth and development of intercrops particularly maize fodder but after harvesting of fodder crops the competition for nutrient and other resources was reduced. Kumar *et al.* (2013) [4], Malik *et al.* (2013) [9] and Kumawat *et al.* (2013b) [8] also reported that plant height at maturity was not significantly affected by to different intercropping systems and planting patterns.

Dry matter accumulation (DMA)

DMA is an important parameter reflecting the growth and metabolic efficiency of plant which ultimately influences yield of crop. DMA in pigeon pea plant increased with advancement in crop age and reached maximum at harvest (Table 1). At all the growth stages of pigeon pea, DMA was not significantly influenced by different intercropping systems and planting patterns. However, maximum DMA was observed in pigeon pea + groundnut (100cm × 12.5cm) as compared to all other intercropping systems at maturity. Kumar *et al.* (2013) [4] and Kumawat *et al.* (2012) [7] also reported that DMA in pigeon pea was not significantly affected by different intercropping systems.

Number of pods per plant

Number of pods per plant were higher in 2016 than that obtained in 2015 (Table 1). Number of pods per plant were not significantly influenced by differentinter cropping systems and planting patterns. However, higher number of pods per plant were observed in sole pigeon pea during both the years. Similar findings were reported by Kumawat *et al.* (2013a) [6] and Malik *et al.* (2013) [9] with different intercropping systems.

Number of seeds per pod

The data presented in table 1 revealed that intercropping systems and planting patterns did not significantly affect the number of seeds per pod during both the years of study. The results were in conformity with the finding of Nandhani and Latha (2014) [10] and Patel *et al*. (2013) [12] who reported that number of seeds per pod were not significantly influenced by different intercropping systems.

1000 seed weight

Planting patterns and intercropping systems did not show any significant effect on difference in 1000 seed weight during both the years (Table 1). However, minimum 1000 seed weight was observed in intercropping of maize (fodder) with pigeon pea. Srichandan and Mangaraj (2015) [13] and Malik *et al*. (2013) [9] also reported similar findings with different and intercropping system.

Table 1: Growth and yield attributes of pigeon pea in intercropping system as influenced by different intercrops and planting patterns

Intercropping system	Planting pattern	Plant height (cm)		DMA (g/plant)		Number of pods/plant		Seed per pod		1000 seed weight (g)	
		2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Pigeon pea + cowpea fodder	50 cm × 25 cm	274.4	274.7	223.6	224.3	119	125	3.7	3.9	61	61.2
Pigeon pea + maize fodder	50 cm × 25 cm	270.7	272.6	221.4	219.7	118.3	121.1	3.3	3.6	59.5	60
Pigeon pea + groundnut	50 cm × 25 cm	274.4	274.8	225.0	225.7	122	127.7	3.7	3.9	60.6	61
Pigeon pea + cowpea fodder	75 cm × 18.8 cm	274.6	274.2	225.6	226.3	129	131.8	3.7	3.9	61.1	61.2

Pigeon pea + maize fodder	75 cm × 18.8 cm	274.1	274.1	225.1	225.8	117	123.6	3.3	3.6	60.7	60.6
Pigeon pea + groundnut	75 cm × 18.8 cm	275.1	275.4	225.9	226.6	131.7	133.4	3.7	3.7	59.8	60.4
Pigeon pea + cowpea fodder	100 cm × 12.5 cm	275.1	275.4	226.8	227.5	127.3	132.9	4	4	60	60.6
Pigeon pea + maize fodder	100 cm × 12.5 cm	275.0	275.1	225.3	225.9	121	123.9	3.7	3.9	60.7	60.8
Pigeon pea + groundnut	100 cm × 12.5 cm	275.0	275.2	228.1	228.7	132	134.1	4	4.1	60	60.9
Sole Pigeon pea	50 cm × 25 cm	275.7	276.0	227.3	227.6	132.7	135.9	4	4.2	60.3	61.2
CD (5%)	0	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Seed yield and intercrop yield

Seed yield of pigeon pea was not significantly affected by different planting patterns and intercropping systems and planting pattern during both the years (Table 2). This might be due to statistically similar number of pods per plant, seeds per pod and 1000 seed weight under these treatments which have direct influence the seed yield of pigeon pea. However, maximum seed yield was obtained with sole pigeon pea during both the years. Kumawat *et al*. (2015) [5] and Malik *et al*. (2013) [9] also investigated that seed yield was not significantly affected by different planting patterns and intercropping systems.

Maximum yield of intercrops was produced under sole cropping as compared to that intercropped with pigeon pea during both the growing seasons of 2015 and 2016. Under the sole cropping, optimum plant population was maintained which resulted the higher yield of intercrops. Further, it was recorded that cowpea intercropped with pigeon pea at 50cm × 25cm spacing gave 56.2 and 68.1 per cent, pigeon pea at 75cm × 18.8cm spacing gave 47.1 and 49.5 per cent and pigeon pea at 100cm × 12.5cm spacing gave 40 and 41.6 per cent green fodder yield of sole cowpea during 2015 and 2016, respectively. In intercropping system maize green fodder yield was 71.5 and 70.6 per cent with pigeon pea (50cm × 25cm), 56.7 and 50.2 per cent with pigeon pea (75cm × 18.8cm) and 44.2 and 45.8 with pigeon pea (100cm × 12.5cm) during the respective years. The intercropping of groundnut with pigeon pea (50cm × 25cm) produced 26.4 and 25.8 percent, with pigeon pea (75cm × 18.8cm) gave 23.2 and 19.4 per cent and with pigeon pea (100cm × 12.5cm) gave 20.8 and 14.5 per cent of sole crop yield during respective years.

Pigeon pea equivalent yield

The data presented in table 2 revealed that the differences in pigeon pea equivalent yield were significant during both the years. The data showed that all the intercropping systems gave significantly higher pigeon pea equivalent yield as compared to sole pigeon pea. Among the different intercropping systems, pigeon pea (50cm × 25cm) + maize fodder recorded maximum pigeon pea equivalent yield of 20.6 and 21.0 q ha^{-1} during 2015 and 2016, respectively and it was significantly higher than sole pigeon pea at 50 cm × 25 cm (12.5 and 13.4 q ha^{-1}), and all other intercropping systems during 2015 and 2016, respectively. Higher pigeon pea equivalent yield in pigeon pea (50cm × 25cm) + maize fodder may be because of maize fodder yield was higher in this intercropping system as compared to other intercropping systems. Koli *et al.* (2013) [3] also reported that pigeon pea intercropped with different vegetables gave significantly higher pigeon pea equivalent yield as compared to sole pigeon pea. Pandey *et al*. (2013) [11] also observed that intercropping of maize and urdbean in pigeon pea recorded significantly higher pigeon pea equivalent yield than sole pigeon pea.

Net return

The data presented in table 2 revealed that net returns were significantly influenced by different intercropping systems and planting patterns during both the years. Maximum net returns of (Rs 68.7 and Rs 77.6 thousand ha^{-1}) were recorded in pigeon pea (50cm × 25cm) + maize fodder which were significantly superior to all other intercropping systems. This may be due to less cost of cultivation maize fodder as compared to groundnut and higher yield and market price as compared to cowpea fodder which ultimately increased the net returns. However, net returns obtained under pigeon pea (50cm × 25cm) + cowpea fodder, pigeon pea (50cm × 25cm) + groundnut, pigeon pea (75cm × 18.8cm) + cowpea fodder, pigeon pea (75cm × 18.8cm) + maize fodder, pigeon pea (75cm × 18.8cm) + groundnut, pigeon pea (100cm × 12.5cm) + cowpea fodder, pigeon pea (100cm × 12.5cm) + maize fodder, pigeon pea (100cm × 12.5cm) + groundnut intercropping systems were significantly higher than that obtained under sole pigeon pea. Among different sole crops, maximum net returns of 40.2 thousand Rs ha^{-1} were obtained from maize fodder during 2015 while in 2016 maximum net return was recorded with sole pigeon pea 43.5 thousand Rs ha^{-1}. During both the years, sole groundnut recorded lowest net returns of 9.4 and 11.6 thousand Rs ha^{-1}. This was because of excessive rainfall and not proper growth of groundnut due to shading affect. Pandey *et al*. (2013) [11] and Tiwari *et al*. (2011) [14] also reported that pigeon pea intercropped with urdbean and maize gave higher net returns than that of sole pigeon pea.

Benefit cost ratio

Benefit cost ratio obtained from different intercropping systems varied significantly during both the years (Table 2). In 2015, maximum benefit cost ratio of 1.9 was recorded with pigeon pea (50cm × 25cm) + maize fodder intercropping system, which was statistically at par with pigeon pea (75cm × 18.8cm) + maize fodder intercropping system which recorded benefit cost ratio of 1.7. However, during 2016, maximum benefit cost ratio of 2.2 was obtained from pigeon pea (50cm × 25cm) + maize fodder, which was at par with that obtained from pigeon pea (75cm × 18.8cm) + maize fodder 2.1 and pigeon pea (100cm × 12.5cm)+ maize fodder 2.0 but significantly higher than all other intercropping systems and sole pigeon pea during 2015 and 2016. pigeon pea (50cm × 25cm) + groundnut, pigeon pea (75cm × 18.8cm) + groundnut, pigeon pea (100cm × 12.5cm) + groundnut recorded less benefit cost ratio than sole pigeon pea because cost of cultivation of pigeon pea + groundnut was higher as compared to pigeon pea + cowpea fodder and pigeon pea + maize fodder. Among the sole crops, cowpea fodder recorded maximum benefit cost ratio during both the years. Kumawat *et al.* (2013a) [6] also reported that intercropping of black gram with pigeon pea under different planting patterns gave higher B: C as compared to sole pigeon pea. Similar findings were observed by Pandey *et al.* (2013) [11] and Tiwari *et al*. (2011) [14] when urdbean was intercropped with pigeon pea.

Table 2: Yield of pigeon pea, pigeon pea equivalent yield (PEY) and economics of different pigeon pea intercropping as influenced by different intercrops and planting patterns

Intercropping system	Planting pattern	Pigeon pea seed yield q/ha		Intercrop yield q/ha		PEY q/ha		Net return10^3 Rs/ha		B C ratio	
		2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Pigeon pea + cowpea fodder	50 cm × 25 cm	12.2	13.1	135.8	150	16.3	17.2	47.2	61	1.3	1.7
Pigeon pea + maize fodder	50 cm × 25 cm	11.8	12.3	293.3	295	20.6	21	68.7	77.6	1.9	2.2
Pigeon pea + groundnut	50 cm × 25 cm	12.3	13.2	3.2	3.3	15	15.9	36.5	46.5	0.9	1.1
Pigeon pea + cowpea fodder	75 cm × 18.8 cm	12.2	13.1	113.8	120	15.6	16.1	45.4	56.1	1.3	1.6
Pigeon pea + maize fodder	75 cm × 18.8 cm	11.9	12.6	232.5	240	18.9	19.6	61.2	72	1.7	2.1
Pigeon pea + groundnut	75 cm × 18.8 cm	12.3	13.1	2.9	2.4	14.7	15.1	37.4	44.9	1	1.2
Pigeon pea + cowpea fodder	100 cm × 12.5 cm	12.2	13.2	100.8	96.7	15.3	15.7	44.6	55.4	1.3	1.7
Pigeon pea + maize fodder	100 cm × 12.5 cm	11.9	12.9	181.3	191.7	17.3	18.5	55.3	66.4	1.6	2
Pigeon pea + groundnut	100 cm × 12.5 cm	12.3	13.3	2.6	1.8	14.4	14.7	38.5	45.6	1	1.3
Sole Pigeon pea	50 cm × 25 cm	12.5	13.4	----	----	12.5	13.4	34.5	43.5	1.1	1.4
sole cowpea	30 cm	----	----	242.4	241.7	7.3	6.1	23.4	24.5	2.5	2.6
sole maize fodder	30 cm	----	----	410.6	418.3	12.3	12.3	40.2	43.4	2.1	2.2
sole groundnut	(30 cm × 15 cm)	----	----	12.5	12.4	10.4	9.4	9.4	11.6	0.2	0.3
CD (5%)	CD (5%)	NS	NS	----	----	1.3	1.2	6.4	5.2	0.2	0.2

Conclusion

It was concluded that pigeon pea + maize fodder (50cm × 25 cm) intercropping system was the best intercropping which gave higher pigeon pea equivalent yield and net returns as compared to other intercropping systems.

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