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Light Transmission and growth analysis of pigeonpea in pigeonpea based cropping systems as influenced by planting methods, geometry and intercrops

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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 leaf area (88.20 dm^2), total dry matter (163.61 g $plant^{-1}$), leaf area duration (59.7 days) and light interception (90 %) 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. sole direct sown pigeonpea (90 cm × 30 cm) recorded significantly higher net assimilation rate (21.23 g/day/m^2) as compared to other intercropping systems and sole pigeonpea.

Keywords: Direct sowing, leaf area index, light transmission ratio, net assimilation rate pigeonpea, transplanting

Introduction
Increasing the productivity of crop to meet the current food requirement of millions in India poses a great challenge before planners, traders, administrators, scientists and farmers. The country will have to feed about 1.3 billion people by the year 2020 requiring 5-6 m t of additional food grains every year. Hence, the situation calls for efforts to intensify the production of crops in both time and space. This could be possible by developing location specific appropriate cropping system. Among the evolved agricultural practices, an intercropping has been proved as a boon to the Indian farmers. It is a mean to stabilize the crop productivity in dry land areas and to increase it in rainfed area under existing inadequate land and rainfall situations. One of the main reasons for higher yields in intercropping over sole cropping is that the component crops are able to use growth resources differently, so that when grown together, they complement each other and make better overall use of growth resources than grown separately (Willey, 1979) [1].

Under the dry climatic conditions of northern Karnataka, short duration *Kharif* legumes (greengram, blackgram and soybean) and pigeonpea crops are valuable crops. Pigeonpea being a predominantly rainfed crop is one of the most important and potential component of intercropping in semi-arid areas. It is generally intercropped with greengram, blackgram and soybean in dry farming areas of northern Karnataka. It is the most preferred soil restorative crop of rainfed areas as it extracts moisture and nutrients from deeper layer and makes this crop ideal for rainfed condition.

In India, pigeonpea occupies an area of about 5.40 m ha with a total production of 4.78 m t, with an average productivity of 885 kg ha^{-1}. It is grown mostly as a rainfed crop in dryland areas. Among the states, Maharashtra leads in both area (1.53 m ha) and production (1.46 m t) followed by Karnataka with an area and production of 1.21 m ha and 0.91 m t, respectively (Anon., 2017) [2]. Among the different pulses grown in Karnataka, pigeonpea holds first place both in area and production. Pigeonpea is largely grown in Northern parts of Karnataka, especially in Kalburgi, Vijayapur, Bidar and Raichur districts. Soil moisture related limitation is the major constraint for higher productivity of pigeonpea in Indian subtropics and complemented/supplemented with climatic aberrations experienced by the crop which is not conducive for its growth and development (Praharaj *et al*., 2015) [3].

Among the different agronomic options, timely sowing/planting, choice of a suitable planting geometry and plant population for a particular genotype are the most important factors which are responsible for enhancing the grain yield. In dry farming areas of northern Karnataka, the rainfall is not only scanty but also erratic.

Thus, soil moisture becomes the most limiting factor in pigeonpea production. In order to ensure timely sowing and adequate soil moisture availability under delayed onset of monsoon, the transplanting of pigeonpea seedlings would be one of the better agronomic measures to overcome delayed sowing (Rajesh *et al*., 2013) [4]. This technique involves raising of seedlings in a polythene bags in the nursery for a period of 25-30 days and then transplanting those seedlings in to the main field, immediately after soil wetting rains. The research studies showed that performance of transplanted pigeonpea was superior with respect to productivity and profitability as compared to direct sown crop (Pavan *et al*., 2009, Goud and Andhalkar, 2012 and Murali *et al*., 2014) [5, 6, 7]. Recently, transplanting method of pigeonpea cultivation is adopted technique in some districts of Karnataka and gaining importance in other pigeonpea growing regions as it is more productive and found handy during climatic aberrations. 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, it is proposed to take up the studies on intercropping of short duration pulses and legume oilseeds in transplanted pigeonpea *vis-a-vis* direct sown pigeonpea.

Materials and Methods

Soil and climate

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* and *Rabi* (June to January) seasons of 2016-17. 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}).

During the crop growth period, a total rainfall of 563.1 mm was received, which was optimum for good growth and higher yield.It helped for better growth and development of both the transplanted and direct sown pigeonpea. The mean maximum temperature during vegetative period of pigeonpea ranged from 26.3ºC (July) to 27.1ºC (September) and during reproductive stage ranged from 29.7ºC (October) to 30.8ºC (November) while the minimum temperature throughout the cropping period ranged from 14.4ºC (November) to 21ºC (June). The average mean monthly relative humidity during the vegetative growth period was ranged from 90.83 per cent (June) to 92.71 per cent (August) was slightly higher than average mean monthly relative humidity.

Experimental Design

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 treatment of transplanted pieonpea 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.

Planting material, planting and cultural practices

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 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.

Parameters measured

Observations on growth parameters such as leaf area, total dry matter production and per plant grain yield were recorded on five tagged plants selected from the net plot area.

Leaf area per plant

Leaf area (dm^2) was measured by disc method as suggested by Vivekanandan *et al*. (1972) [8]. Fifty leaf discs of known size from top middle and bottom leaves were taken through a cork borer from randomly selected leaves from five plants. Both disc and remaining leaves were oven dried at 65 to 70º C and leaf areas was calculated by using the following formula.

$$LA = \frac{Wa \times A}{Wd}$$

Where

LA = Leaf area (dm^2)

Wa = Oven dry weight of all leaves (inclusive of 50 disc weight) (g)

Wd = Oven dry weight of 50 disc (g)

A = Area of disc (dm^2)

Leaf area index

Leaf area index (LAI) was worked out by using the established formula (Sestak *et al*., 1971) [9]. The length and width of the fully opened and physiologically active leaves were measured on five plants per plot.

$$LAI = \frac{\text{Leaf area per plant } (dm^2)}{\text{Land area occupied by the plant } (dm^2)}$$

Leaf area duration

Leaf area duration (LAD) was worked out as per the formula (Radford, 1967) [10] given below and expressed in days.

$$\text{LAD (days)} = \frac{L_1 + L_2}{2} \times (t_2 - t_1)$$

Where, L_1 and $L_2$are leaf area index at times t_1 and t_2, respectively.

Net assimilation rate

Net assimilation rate was worked out by using established formula (Radford, 1967) [10] shown below.

$$\text{NAR (g/g/day)} = \frac{W_2 - W_1 \times \text{In}L_2 - \text{In}L_1}{t_2 - t_1 \times L_2 - L_1}$$

Where, W_1 and W_2 are total dry matter weights at times t_1 and t_2. L_1 and L_2 are leaf areas at times t_1 and t_2

Light transmission ratio

Light transmission by the canopies of pigeonpea was measured by Lux meter. The light intensity recorded above the canopies of pigeonpea crop and at the ground surface was recorded between 11.30 am and 12.30 pm. Based on these data, the light transmission ratio (LTR) was calculated by using the formula outlined by Yoshida *et al.* (1972) [11].

$$\text{LTR (\%)} = \frac{\text{Light intensity at ground surface } (I_C)}{\text{Light intensity above the canopy } (I_O)} \times 100$$

Percent light interception (PLI) was calculated by subtracting the LTR by unity (PLI= 100 - LTR).

Statistical analysis and interpretation of data

Fisher's method of analysis of variance was used for analysis and interpretation of the data as outlined by Panse and Sukhatme (1967) [12]. 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

Leaf area, leaf area index and total dry matter production

Leaf area, leaf area index (LAI) and total dry matter (TDM) production were significantly affected by planting methods, geometry and intercrops (Table 1 & 2). At 60 days after transplanting (DAT) / days after sowing (DAS), significantly higher leaf area plant^{-1} (88.20 dm^2), LAI (1.23) and TDM production (163.61 g plant^{-1}) were recorded with sole transplanted pigeonpea at a planting geometry of 120 cm × 60 cm as compared to leaf area, LAI and TDM of pigeonpea in intercropping systems and sole direct sown and other transplanted pigeonpea treatments except transplanted pigeonpea at 120 cm × 60 cm geometry with greengram which was on par. Sole transplanted pigeonpea (120 cm × 60 cm) and transplanted pigeonpea (120 cm × 60 cm) with intercropping of greengram, soybean and blackgram were significantly superior with respect to leaf area, LAI and TDM production over direct sown sole pigeonpea as well as intercropping at 120 cm × 60 cm and 90 cm × 30 cm planting geometries. Significantly lower leaf area plant^{-1} (11.23 dm^2) LAI (0.42) and TDM production (32.40 g plant^{-1}) were observed in direct sown pigeonpea (90 cm × 30 cm) + soybean (1:2) and was on par with direct sown pigeonpea (120 cm × 60 cm) + greengram and blackgram intercropping and sole direct sown pigeonpea at 90 cm × 30 cm spacing.

Similar trend was observed with respect to leaf area, LAI and TDM production at all the stages of the crop growth. Leaf area and LAI of all the treatments were maximum at 120 DAT/ DAS and TDM accumulation was maximum at harvest stage with respect to all the treatments (Table 2).

Table 1: Leaf area, leaf area index and leaf area duration of pigeonpea as influenced by planting method, geometry and intercrops.

Tr. No	Treatments	Leaf area (dm^2 plant^{-1})			Leaf area index			LAD (days)	
		60 DAT/ DAS	90 DAT/ DAS	120 DAT/ DAS	60 DAT/ DAS	90 DAT/ DAS	120 DAT/ DAS	60 -90 DAT/ DAS	90-120 DAT/ DAS
T1	Transplanted pigeonpea (120cm × 60cm) + soybean (1:2)	80.92	181.31	282.69	1.12	2.52	3.93	54.6	96.7
T2	Transplanted pigeonpea (120cm × 60cm) + greengram (1:2)	82.44	182.25	289.90	1.14	2.53	4.03	55.1	98.4
T3	Transplanted pigeonpea (120cm × 60cm) + blackgram (1:2)	79.45	174.48	269.80	1.10	2.42	3.75	52.9	92.6
T4	Direct sown pigeonpea (120cm × 60cm) + soybean (1:2)	34.59	102.33	182.48	0.48	1.42	2.53	28.5	59.3
T5	Direct sown pigeonpea (120cm × 60cm) + greengram (1:2)	35.25	99.55	175.31	0.49	1.38	2.43	28.1	57.3
T6	Direct sown pigeonpea (120cm × 60cm) + blackgram (1:2)	31.68	95.54	165.44	0.44	1.33	2.30	26.5	54.4
T7	Direct sown pigeonpea (90cm × 30cm) + soybean (1:2)	11.23	30.72	54.75	0.42	1.14	2.03	23.3	47.5
T8	Direct sown pigeonpea (90cm × 30cm) + greengram (1:2)	11.46	31.27	58.90	0.42	1.16	2.18	23.7	50.1
T9	Direct sown pigeonpea (90cm × 30cm) + blackgram (1:2)	11.65	31.55	60.85	0.43	1.17	2.25	24.0	51.3
T10	Sole transplanted pigeonpea (120cm × 60cm)	88.20	198.31	318.94	1.23	2.75	4.43	59.7	107.8
T11	Sole direct sown pigeonpea (120cm × 60cm)	38.01	117.65	201.09	0.53	1.63	2.79	32.4	66.4
T12	Sole direct sown pigeonpea (90cm × 30cm)	12.78	42.93	66.78	0.47	1.59	2.47	31.0	61.0
	S.Em.+	2.14	5.96	10.14	0.03	0.10	0.16	1.85	3.68
	LSD (0.05)	6.28	17.48	29.74	0.10	0.28	0.47	5.43	10.80

Higher growth attributes in transplanted pigeonpea might be due to early planting of 3 weeks grown up pigeonpea seedlings and relatively longer days available with higher photoperiod. In transplanted pigeonpea, the seedlings were raised earlier in the polythene bags for a certain period (3 weeks), after planting it develops vigorous root system and improves the utilization of natural resources mainly solar radiation, soil moisture, space and nutrients more efficiently as compared to direct sown pigeonpea. In transplanted pigeonpea, the crop was already established as it was 25-30 days advantage over direct sown pigeonpea and the component intercrops have least competition on pigeonpea hence it performed better and yield of pigeonpea with intercropping with greengram and soybean were on par with transplanted sole counterparts at 120 cm x 60 cm. These results are in accordance with the findings of Malik (2009) [13], Poornima *et al.* (2009) [14], Goud and Andhalkar (2012) [6], Praharaj *et al.* (2015) [3] and Mohanadas (2016) [15] in pigeonpea. Pavan *et al.* (2009) [5] reported that transplanted pigeonpea at the spacing of 150 cm x 30 cm recorded

significantly higher plant height (197.00 cm) and higher leaf area per plant was recorded in wider row spacing of transplanted pigeonpea at 120 cm x 60 cm which was found to be significantly superior over dibbled pigeonpea.

Leaf area duration

Leaf area duration (LAD) is product of leaf area and the time period which leaf area is maintained. It is a useful parameter, not only for predicting the efficiency of photosynthetic system but also for dry matter production. It indicates the maintenance of assimilatory surface area over a period of time, which is a prerequisite for the prolonged photosynthetic activity and the ultimate productivity in crop plants.

During.60 to 90 DAT/DAS, sole transplanted pigeonpea at a planting geometry of 120 cm × 60 cm recorded significantly higher LAD (59.7 days) as compared to LAD of pigeonpea in intercropping systems and sole direct sown and other transplanted pigeonpea treatments except transplanted pigeonpea at 120 cm × 60 cm geometry with greengram (55.1 days) which was on par (Table 1).Sole transplanted pigeonpea at planting geometry of 120 cm × 60 cm spacing and transplanted pigeonpea (120 cm × 60 cm) with intercropping greengram (55.1 days), soybean (54. 6 days) and blackgram (52.9 days) were significantly superior over direct sown sole pigeonpea as well as intercropping at 120 cm × 60 cm and 90 cm × 30 cm planting geometries. Significantly lower LAD (23.3 days) was observed in direct sown pigeonpea (90 cm × 30 cm) + soybean (1:2) and was on par with direct sown pigeonpea intercropped with greengram, soybean and blackgram at both 120 cm × 60 cm and 90 cm × 30 cm spacings. Similar trend was observed during reproductive/flowering stage (90 to 120 DAT/DAS). LAD was maximum during 90 to 120 DAT/ DAS in all the treatments.

The increase in LAD could be mainly due to the maintenance of more green leaf area. In the present investigation, LAD increased at increasing rate upto harvest due to increased leaf area. Transplanted pigeonpea at 120 cm x 60 cm planting geometry both in sole as well as in intercropping recorded significantly higher LAD as compared to direct sown pigeonpea. It is mainly due to higher leaf area production in transplanted piegonpea due early establishment and higher photosynthetic activity over direct sown pigeonpea. These results are in conformity with Pothalkar (2007) [16] who observed higher LAD due to higher LAI in pigeonpea.

Table 2: Total dry matter production and net assimilation rate of pigeonpea as influenced by planting methods, geometry and intercrops

Tr. No	Treatments	Total dry matter production (g/plant)				Net assimilation ratio (g/day/m^2)	
		60 DAT/ DAS	90 DAT/ DAS	120 DAT/ DAS	At harvest	60 - 90 DAT/ DAS	90-120 DAT/ DAS
T_1	Transplanted pigeonpea (120 cm × 60 cm) + soybean (1:2)	150.10	564.70	816.30	963.93	11.09	3.69
T_2	Transplanted pigeonpea (120 cm × 60 cm) + greengram (1:2)	152.93	567.64	837.12	976.14	10.98	3.85
T_3	Transplanted pigeonpea (120 cm × 60 cm) + blackgram (1:2)	147.38	543.44	779.09	933.67	10.91	3.61
T_4	Direct sown pigeonpea (120 cm × 60 cm) + soybean (1:2)	58.14	210.56	269.53	326.72	8.13	1.42
T_5	Direct sown pigeonpea (120 cm × 60 cm) + greengram (1:2)	55.91	204.84	258.95	311.21	8.02	1.32
T_6	Direct sown pigeonpea (120 cm × 60 cm) + blackgram (1:2)	53.26	196.58	242.32	290.22	8.30	1.19
T_7	Direct sown pigeonpea (90 cm × 30 cm) + soybean (1:2)	32.40	147.80	182.09	222.03	19.78	2.78
T_8	Direct sown pigeonpea (90 cm × 30 cm) + greengram (1:2)	33.04	150.40	195.87	232.05	19.84	3.46
T_9	Direct sown pigeonpea (90 cm × 30 cm) + blackgram (1:2)	33.60	151.76	213.69	246.66	19.72	4.65
T_{10}	Sole transplanted pigeonpea (120 cm × 60 cm)	163.61	609.66	860.73	1033.05	10.95	3.30
T_{11}	Sole direct sown pigeonpea (120 cm × 60 cm)	63.89	242.09	297.02	358.02	8.45	1.18
T_{12}	Sole direct sown pigeonpea (90 cm × 30 cm)	48.04	206.50	250.61	281.24	21.23	2.75
	S.Em. +	4.32	17.99	24.16	17.11	0.26	0.36
	L.S.D. (0.05)	12.68	52.77	70.85	50.19	0.76	1.07

Net assimilation rate

Another parameter that is determined by the LAI of two consecutive growth stages is Net assimilation rate (NAR). It is the rate of increase in dry matter per unit leaf area which indicates the assimilatory capacity of plant. In this experiment NAR is significantly affected by planting methods, geometry and intercropping systems (Table 2).

Maximum NAR was observed during 60 to 90 DAT/DAS and significantly higher NAR (21.23 g/day/m2) was recorded with sole direct sown pigeonpea at 90 cm × 30 cm spacing. Sole direct sown pigeonpea at 90 cm × 30 cm spacing and direct sown pigeonpea (90 cm × 30 cm) with intercropping greengram (19.72 g/day/m2), soybean (19.78 g/day/m2) and blackgram (19.72 g/day/m2) were significantly superior over both transplanted and direct sown sole pigeonpea as well as intercropping at 120 cm × 60 cm planting geometry (Table 2). During 90 to 120 DAT/DAS, NAR was significantly higher (4.65 g/day/m2) in direct sown pigeonpea (90 cm × 30 cm) intercropping with blackgram and transplanted pigeonpea (90 cm × 30 cm) intercropped with greengram (3.85 g/day/m2), soybean (3.69 g/day/m2) and blackgram (3.61 g/day/m2) were found on par. Lowest NAR (1.18 g/day/m2) was recorded with sole direct sown pigeonpea at 120 cm x 60 cm spacing and was on par with direct sown pigeonpea (120 cm × 60 cm) intercropped with blackgram (1.19 g/day/m2), greengram (1.32 g/day/m2) and soybean (1.42 g/day/m2).

Significant reduction of NAR in direct sown pigeonpea at 120 cm x 60 cm planting geometry both in sole as well as intercropping is mainly due to lower dry matter accumulation per unit time and unit leaf area because of lesser population per unit land area. Lower NAR in transplanted pigeonpea both in sole as well as intercropping over direct sown pigeonpea (90 cm x 30 cm) is mainly due increased LA and LAI which might have increased the mutual shading of leaves and led to decreased photosynthesis per unit leaf area. These results are in harmony with the results of Sheldrake and Narayanan

(1979) [17] in pigeonpea and Addo-Quaye *et al*. (2011) [18] in maize-soybean intercropping system. NAR declined as the growth progressed and rise in shading due to increase in LAI accounted for the decline. Buttery (1969) [19] noted a decline in NAR as the season progressed and attributed this primarily to increasing LAI.

Light transmission ratio and percent light interception in pigeonpea

The better use of resources can be supported by observations on light transmission ratio (LTR), which showed significant difference due to planting methods, geometry and intercrops (Table 3).

Table 3: Light transmission ratio and percent light interception by pigeonpea canopy as influenced by planting methods, geometry and intercrops

Tr. No.	Treatments	Light transmission ratio (%)			Light interception (%)		
		60 DAT/ DAS	90 DAT/ DAS	120 DAT/ DAS	60 DAT/ DAS	90 DAT/ DAS	120 DAT/ DAS
T_1	Transplanted pigeonpea (120 cm × 60 cm) + soybean (1:2)	16.84	13.76	10.46	83.16	86.24	89.54
T_2	Transplanted pigeonpea (120 cm × 60 cm) + greengram (1:2)	15.56	12.48	10.27	84.44	87.52	89.73
T_3	Transplanted pigeonpea (120 cm × 60 cm) + blackgram (1:2)	15.61	12.78	10.30	84.39	87.22	89.70
T_4	Direct sown pigeonpea (120 cm × 60 cm) + soybean (1:2)	23.92	19.30	16.66	76.08	80.70	83.34
T_5	Direct sown pigeonpea (120 cm × 60 cm) + greengram (1:2)	24.75	19.62	17.22	75.25	80.38	82.78
T_6	Direct sown pigeonpea (120 cm × 60 cm) + blackgram (1:2)	25.42	19.97	17.33	74.58	80.03	82.67
T_7	Direct sown pigeonpea (90 cm × 30 cm) + soybean (1:2)	19.11	17.68	13.69	80.89	82.32	86.31
T_8	Direct sown pigeonpea (90 cm × 30 cm) + greengram (1:2)	18.86	16.85	13.18	81.14	83.15	86.82
T_9	Direct sown pigeonpea (90 cm × 30 cm) + blackgram (1:2)	18.43	16.29	12.37	81.57	83.71	87.63
T_{10}	Sole transplanted pigeonpea (120 cm × 60 cm)	15.43	12.19	10.00	84.57	87.81	90.00
T_{11}	Sole direct sown pigeonpea (120 cm × 60 cm)	22.22	19.19	15.32	77.78	80.81	84.68
T_{12}	Sole direct sown pigeonpea (90 cm × 30 cm)	17.70	16.20	13.11	82.30	83.80	86.89
	S.Em. +	0.94	0.64	0.57	0.94	0.64	0.57
	L.S.D. (0.05)	2.77	1.88	1.68	2.77	1.88	1.68

LTR was highest during early stage of pigeonpea, later it declined as the growth progressed and it was *vice-versa* withpercent light interception (PLT). At 120 DAT/DAS, significantly higher LTR (17.33) of pigeonpea was recorded with direct sown pigeonpea at a planting geometry of 120 cm × 60 cm spacing with blackgram intercropping as compared to LTR of pigeonpea in other intercropping systems and sole direct sown and transplanted pigeonpea treatments except direct sown pigeonpea at 120 cm × 60 cm geometry with greengram (17.22 %) and soybean (16.66 %) intercropping systems which were on par and similar trend was fallowed during 60 and 90 DAT/DAS. This is mainly due to lower leaf area and LAI which in turn lower canopy coverage over transplanted pigeonpea.

Significantly lower LTR(10 %)and higher PLI (90 %) at 120 DAT/DAS were observed in sole transplanted pigeonpea (120 cm × 60 cm) and were on par with transplanted pigeonpea (120 cm × 60 cm) + greengram (10.27 % and 89.73 %, respectively), blackgram (10.30 % and 89.70 %, respectively) and soybean intercropping (10.46 % and 89.54, respectively) and which were significantly superior to direct sown sole pigeonpea as well as intercropping at 120 cm × 60 cm and 90 cm × 30 cm planting geometry. Lower interception was observed in direct sown pigeonpea (120 cm × 60 cm) + blackgram (74.58 % and 82.67 %, at 60 and 120 DAS respectively). Significantly higher light interception by transplanted pigeonpea as compared to direct sown pigeonpea was mainly due to quick growth and good canopy coverage which helped in better interception of light and utilization of other resources. Similarly, Udhaya and Latha (2015) [20] observed 87.8 per cent light interception in intercropped pigeonpea (120 cm × 30 cm) intercropped with greengram at 1:3 row proportions at 40 days after sowing.

Grain weight of pigeonpea

Significantly higher grain weight (212.5 g plant^{-1}) of pigeonpea was recorded with sole transplanted pigeonpea at a planting geometry of 120 cm × 60 cm as compared to grain weight of pigeonpea in intercropping systems and other sole direct sown and transplanted pigeonpea treatments except transplanted pigeonpea at 120 cm × 60 cm geometry with greengram (206.7 g plant^{-1}), sobean (201.9 g plant^{-1}) and blackgram (201.1 g plant^{-1}) intercropping systems which were on par (Fig. 1). Sole transplanted pigeonpea at planting geometry of 120 cm × 60 cm, transplanted pigeonpea (120 cm × 60 cm) with intercropping of greengram, soybean and blackgram were significantly superior with respect to grain weight of pigeonpea over direct sown sole pigeonpea as well as intercropping with 120 cm × 60 cm and 90 cm × 30 cm planting geometries. Significantly lower grain weight of pigeonpea (54.8 g plant^{-1}) was observed in direct sown crop (90 cm × 30 cm) + soybean (1:2) and was on par with direct sown pigeonpea (90 cm × 30 cm) + greengram (55.0 g plant^{-1}) and blackgram (57.6 g plant^{-1}) intercropping systems.

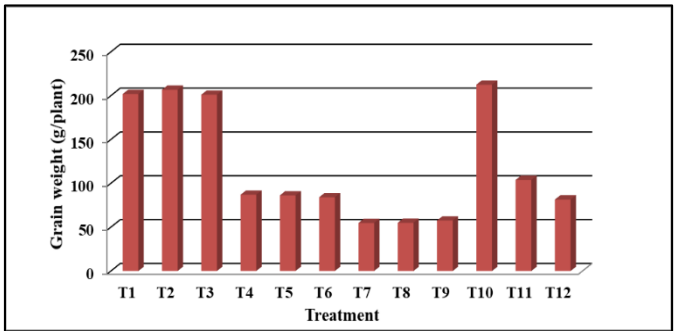

Fig1: Grain yield of pigeonpea as influenced by planting methods, geometry and intercrops

This higher grain weight in transplanted pigeonpea was mainly attributed to higher efficiency in translocation of photosynthates to the reproductive parts which may be due to higher production of photosynthates by higher photo synthetically active vegetation of early established transplanted pigeonpea which supplemented by more total dry matter accumulation by plants with higher greater photosynthetic activity of the plant which in turn depends upon the assimilatory surface area mainly leaf area, leaf area

index and leaf area duration. The results are in conformity with the findings obtained by Poornima *et al*. (2010) [14] and Mallikarjun *et al.* (2014) [21]. Murali *et al.* (2014) [7] recorded transplanting of five weeks old pigeonpea seedlings produced more number of pods plant^{-1} (277) and higher 100-grain weight (12.4 g) resulting in significantly higher grain yield plant^{-1} (100.6 g) over direct sowing (153 pods plant^{-1} and 11.4 100grain weight). Mohanadas (2016) [15] also reported higher grain yield plant per plant (178.42 g) in pigeonpea transplanted at 120 cm.

Conclusions

It can be concluded that, sole transplanted pigeonpea (120 cm x 60 cm) found superior than direct sown pigeonpea at 120 cm × 60 cm and 90 cm × 30 cm planting geometry, and transplanted pigeonpea (120 cm × 60 cm) intercropping with short duration pulses (greengram, blackgram and soybean) at 1:2 row proportion found superior than intercropping of direct sown pigeonpea both at 120 cm × 60 cm and 90 cm × 30 cm planting geometries and sole pigeonpea treatments for leaf area, LAI, LAD, TDM, LTR, PLI and grain yield of pigeonpea, hence it can be recommended for adaptation in pigeonpea growing areas of northern Karnataka.

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