



Symbiotic characters, thermal requirement, growth, yield and economics of pigeonpea (*Cajanus cajan*) genotypes sown at different dates under Punjab conditions

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Abstract: A field experiment was conducted during *kharif* (rainy season) 2008 and 2009 at research farm of the Punjab Agricultural University, Ludhiana, to study the effect of four/three sowing dates (1 May, 15 May, 1 June and 15 June in 2008 and 15 May, 1 June and 15 June in 2009) on the symbiotic characters, thermal requirement, growth, productivity and economics of four pigeonpea genotypes (AL 201, AL 1507, AL 1578 and AL 1593). Days taken to 50% flowering, physiological maturity, and various agroclimatic indices i.e. AGDD, AHTU, APTU and HUE decreased with delay in sowing. The crop sown on 15 May recorded the highest nodule dry weight plant⁻¹. The grain yield was significantly higher for the 15 May sowing compared to the 15 June sowing. During the two years, the crop sown on 15 May registered on average 6.7 and 48.0 percent higher grain yield than the 1 June and 15 June sowings, respectively. The crop sown on 15 May gave the maximum gross returns, net returns and benefit-cost (B:C) ratio. Among the genotypes, AL 1507 recorded the highest nodule number plant⁻¹ and AL 1578 recorded the maximum nodule dry weight plant⁻¹. Genotypes AL 1507, AL 1578 and AL 1593 registered on average 19.4, 19.2 and 20.0 percent higher grain yield relative to AL 201, respectively. The genotype AL 1507 in 2008 and AL 1593 in 2009 performed better in terms of heat use efficiency for grain yield.

Keywords: Agroclimatic indices, Economics, Genotypes, Nodulation, Sowing dates

INTRODUCTION

Pigeonpea [*Cajanus cajan* (L.) Millsp.] is well adapted to arid and semi-arid climates of the tropical and sub-tropical regions of the world (Rao *et al.* 2003). Pigeonpea is a leguminous crop that has been cultivated for human consumption and many other uses in many parts of the world. During 2012-13, in India, it was cultivated on an area of 3.69 million hectares with a production of 2.75 million tonnes and productivity of 753 kg ha⁻¹ (INDIASTAT, 2014). It contains high level of proteins and important amino acids such as methionine, lysine and tryptophan. Sowing time, a non-monetary input, has considerable influence on growth and yield of pigeonpea crop (Wilson *et al.* 2012, Egbe *et al.* 2013). Sowing at the optimum time gives higher yields due to suitable weather conditions that prevail at all the growth stages. Early sown crop may accumulate excessive dry matter resulting in reduced pod development, while late sown crop may have less biomass accumulation and consequently reduced yields. Delayed sowings beyond the optimum period result in low grain yields of pigeonpea (Kumar *et al.* 2008). In addition, genotypes may vary in productivity (Singh

2006, Egbe and Vange 2008, Bhavi *et al.* 2013, Umesh *et al.* 2013) and the yield potential of the genotypes can be fully exploited by providing appropriate micro-climate temperature at different growth and development phases.

Earlier, the recommended time of sowing of pigeonpea in Punjab state was the first fortnight of June. However, with the changing climate, the optimum time of sowing may vary. Furthermore, when the crop is sown during first fortnight of June, many times the maturity of the crop is delayed (Ram *et al.* 2011), causing delayed harvesting of pigeonpea and consequently delayed sowing of succeeding wheat crop and ultimately low productivity (Tomar *et al.* 2014). Moreover, long duration genotypes produce higher yield than early maturing genotypes, but they take more time to mature which may delay the sowing of succeeding crop. Performance of new genotypes under different sowing time needs to be tested. Keeping these factors in mind, the present experiment was conducted to study the effect of sowing time on the symbiotic parameters, thermal requirement, growth, yield and economics of pigeonpea genotypes under Punjab conditions.

MATERIALS AND METHODS

A field experiment was conducted during *khariif* (rainy season) 2008 and 2009 at the research farm of the Punjab Agricultural University, Ludhiana (30° 54'N, 75° 48'E, altitude 247 m), India. The soil of the experimental site was low in organic carbon (0.36), low in available nitrogen, medium in available phosphorus (17.5 kg ha⁻¹) and potassium (152 kg ha⁻¹) with a pH of 8.4. During the crop growing season, total 975.3 and 818.0 mm of rainfall was received during 2008 and 2009, respectively. The experiment was laid out in split-plot design with four replications. The treatments included four/three dates of sowing (1 May, 15 May, 1 June and 15 June in 2008 and 15 May, 1 June and 15 June in 2009) in main plots and four genotypes (AL 201, AL 1507, AL 1578 and AL 1593) in sub plots. Nutrients viz. 15 kg nitrogen and 40 kg P₂O₅ ha⁻¹ were applied entirely as basal dose to the crop and the crop was sown in rows 50 cm apart using a seed rate of 15 kg ha⁻¹. Each sub plot measured 6.0 m × 2.5 m. Weeds were controlled by pendimethalin (Stomp 30 EC) @ 0.45 kg ha⁻¹ as pre-emergence spraying 500 litres of water followed by hand weeding six weeks after sowing. The crop was raised with the recommended package of practices (PAU 2008).

Days taken to 50% flowering and maturity were recorded for each genotype sown on different dates. Growing degree days (or heat units) were determined as per Nuttonson (1955):

$$GDD = \left(\frac{T_{max} + T_{min}}{2} \right) - T_b$$

Where,

T_{max}, maximum temperature (°C) during a day

T_{min}, minimum temperature (°C) during a day

T_b, base temperature of 10.0 °C

Heliothermal units (HTU), the product of GDD and corresponding actual sunshine hours for that day, were computed on daily basis as follows:

$$HTU = GDD \times \text{Actual sunshine hours}$$

Photothermal units (PTU), the product of GDD and corresponding day length for that day, were computed on daily basis as follows:

$$PTU = GDD \times \text{Day length}$$

where day length refers to maximum possible sunshine hours.

$$\text{Heat use efficiency (HUE)} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Accumulated GDD (heat units) (}^{\circ}\text{C day)}}$$

Growing degree days, heliothermal units and photothermal units were accumulated from the date of sowing to 50% flowering and maturity to give accumulated indices. Heat use efficiency was calculated after harvesting of the crop.

Five plants plot⁻¹ were randomly selected for counting nodules and nodule weight. These plants were uprooted 45 days after sowing (DAS). After counting, the nodules were dried in an oven at 60 °C. Data on plant height, branches plant⁻¹ and pods plant⁻¹ were recorded at harvest from randomly selected five plants from each plot. Biological yield and grain yield were recorded on per plot basis and then converted into kg ha⁻¹. Grainspod⁻¹ were recorded from 20 pods. The data on 100-grain weight were recorded after taking 100 randomly selected grains. Harvest index was calculated by dividing grain yield by biological yield and multiplied by 100. Gross returns, net returns as well as benefit:cost (B:C) ratio were also estimated using prevailing prices of input and output. Data were subjected to analysis of variance (ANOVA) in a split-plot design as per the standard procedure.

Table 1. Effect of dates of sowing and genotypes on different agroclimatic indices (GDD, HTU, PTU) and heat use efficiency of pigeonpea at 50% flowering and physiological maturity.

Year	Treatment	50% flowering				Physiological maturity					
		DAS	AGDD (°C day)	AHTU (°C day)	APTU (°C day)	DAS	AGDD (°C day)	AHTU (°C day)	APTU (°C day)	HUE (kg ha ⁻¹ °C ⁻¹ day)	
2008	Date of Sowing										
		1 May	111	2222	14854	30723	159	3099	22317	41615	0.47
		15 May	104	2083	13686	28760	153	2942	20826	39225	0.55
		1 June	98	1965	13246	26903	149	2802	19804	36816	0.56
		15 June	90	1769	12639	23986	145	2623	19055	33918	0.44
	Genotype										
		AL 201	103	1981	13607	27085	155	2827	20142	37077	0.44
		AL 1507	98	1881	12609	25812	148	2743	19600	36136	0.55
		AL 1578	100	1932	13133	26460	151	2790	19913	36670	0.53
		AL 1593	102	1962	13412	26841	152	2796	19924	36728	0.53
2009	Date of Sowing										
		15 May	104	2249	18965	31076	153	3108	26027	41529	0.42
		1 June	99	2072	16832	28385	149	2869	23807	37825	0.41
		15 June	91	1834	14672	24892	143	2639	21600	34289	0.31
	Genotype										
		AL 201	100	2078	17026	28449	150	2899	24016	38189	0.32
		AL 1507	96	2010	16488	27590	146	2845	23624	37588	0.39
		AL 1578	97	2039	16752	27952	147	2856	23697	37702	0.39
	AL 1593	100	2081	17026	28480	149	2886	23909	38045	0.41	

RESULTS AND DISCUSSION

Effect of date of sowing: Sowing date had a pronounced effect on days to 50% flowering and maturity of pigeonpea (Table 1). Days to 50% flowering and maturity decreased with delay in sowing.

Accumulated agroclimatic indices i.e. growing degree days, heliothermal units, photothermal units and heat use efficiency computed for different dates of sowing from days after sowing (DAS) to 50% flowering as well as physiological maturity are given in Table 1. Early sowing required higher agroclimatic indices as compared to late sowing. Heat units for different phenological stages decrease with delay in sowing of *kharif* mungbean (Singh *et al.* 2010) and *kharif* urdbean (Singh *et al.* 2012). Higher heat units were accumulated for 50% flowering and physiological maturity during 2009 than in 2008. With delay in sowing, lower agroclimatic indices were required and resulted in lowest heat units accumulation for the 15 June sowing as compared with May sowing. In general earlier sown crop availed more growing degree days and accumulated more dry matter than late sown crop. First and second dates of sowing accumulated more heat units, resulting in more heat use efficiencies as compared to third date of sowing.

The date of sowing did not affect the number of nodules plant⁻¹ and nodule dry weight significantly (Table

2). During both years, plant height was significantly higher for the early sowing (1 May in 2008 and 15 May in 2009) than the other sowing dates, possibly due to longer period of vegetative growth. During 2008, 1 May sowing produced significantly higher branches plant⁻¹ than the other sowing dates. However, during 2009, 1 June sown crop significantly produced higher branches plant⁻¹ than 15 May and 15 June sowing. Kumar *et al.* (2008) also reported reduced plant growth and yield attributes in case of delayed sowing.

The pods plant⁻¹ is an important yield attributing character. The crop sown on 15 May recorded the highest number of pods plant⁻¹ (Table 2). In 2008, the 15 May sown crop recorded significantly higher pods plant⁻¹ than the 1 May and 15 June sown crop, which was statistically at par with 1 June sown crop. In 2009, however, the 15 May sown crop recorded significantly higher pods plant⁻¹ than both June 1 and June 15 sown crops. The highest number of pods plant⁻¹ in May 15 sown crop might be due to a better balance between vegetative and reproductive phases and sufficient time available for setting of pods. These findings are in agreement with those of Rani and Reddy (2010) reported for pigeonpea. The date of sowing did not affect the number of grains pod⁻¹ and the 100-grain weight significantly.

The biological yield was significantly reduced with

Table 2. Effect of sowing dates and genotypes on nodulation, plant characters and yield attributes of pigeonpea.

Treatment	Number of nodules plant ⁻¹		Dry weight of nodules (mg plant ⁻¹)		Plant height (cm)		Branches plant ⁻¹		Pods plant ⁻¹		Grains pod ⁻¹		100-grain weight (g)	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Date of sowing														
1 May	10.0		62.8		222.4		11.6		105.2		3.81		6.98	
15 May	10.6	8.0	65.1	42.0	192.6	178.3	10.3	11.3	116.6	128.3	4.34	4.36	7.13	5.91
1 June	10.6	8.6	63.4	40.8	182.9	167.0	9.3	12.1	112.6	110.6	4.34	4.36	7.11	6.27
15 June	8.4	6.8	57.0	38.1	151.7	155.2	9.4	10.4	100.8	93.1	4.12	4.70	7.03	6.26
CD (p=0.05)	NS	NS	NS	NS	8.0	3.7	1.2	0.7	7.9	10.6	NS	NS	NS	NS
Genotype														
AL 201	11.0	8.4	63.7	43.6	182.2	162.2	9.7	11.6	100.7	97.1	4.16	4.35	6.98	6.25
AL 1507	11.2	8.9	61.9	42.3	192.6	162.8	10.3	10.5	113.4	116.1	4.26	4.45	6.78	6.19
AL 1578	10.8	7.6	68.4	40.0	186.0	175.0	10.2	11.9	112.6	112.2	4.15	4.65	7.36	5.88
AL 1593	6.5	6.3	54.3	35.3	188.8	167.2	10.5	10.9	108.6	117.2	4.24	4.45	7.11	6.25
CD (p=0.05)	0.7	1.4	7.6	NS	6.7	3.9	NS	0.8	5.7	8.6	NS	NS	NS	NS

Table 3. Effect of sowing dates and genotypes on the biological yield, grain yield and harvest index of pigeonpea.

Treatment	Biological yield (kg ha ⁻¹)		Grain yield (kg ha ⁻¹)		Harvest index (%)	
	2008	2009	2008	2009	2008	2009
Date of sowing						
1 May	8210		1484		18.1	
15 May	7160	7467	1609	1294	22.5	17.3
1 June	6384	6659	1555	1164	24.4	17.5
15 June	4450	5842	1148	814	25.8	13.9
CD (p=0.05)	747	680	159	62		
Genotype						
AL 201	6353	6633	1289	926	20.3	14.0
AL 1507	6429	6478	1523	1122	23.7	17.3
AL 1578	6741	6744	1516	1126	22.5	16.7
AL 1593	6683	6767	1469	1189	22.0	17.6
CD (p=0.05)	NS	NS	77	103		

Table 4. Effect of sowing dates and genotypes on economics of pigeonpea.

Treatment	Gross returns (Rs ha ⁻¹)		Net returns (Rs ha ⁻¹)		B:C ratio	
	2008	2009	2008	2009	2008	2009
Date of sowing						
1 May	63812		36242		2.31	
15 May	69187	55642	41617	28072	2.51	2.02
1 June	66865	50052	39295	22482	2.43	1.82
15 June	49364	35002	21794	7432	1.79	1.27
Genotype						
AL 201	55427	39818	27857	12248	2.01	1.44
AL 1507	65489	48246	37919	20676	2.38	1.75
AL 1578	65188	48418	37618	20848	2.36	1.76
AL 1593	63167	51127	35597	23557	2.29	1.85

delay in sowing (Table 3). The grain yield was significantly higher for 15 May sowing than 15 June sowing date. The crop sown on 15 May registered 3.4 and 40.1 per cent higher grain yield in 2008 and 11.1 and 58.9 per cent higher grain yield in 2009 compared to the 1 June and 15 June sowings, respectively. Higher grain yield in early sowing (15 May) might be due to more pods plant⁻¹ (Table 2). Ram *et al.* (2011) also reported that 15 May sown pigeonpea crop produced significantly higher grain yield than 1 June and 15 June sown crop. The increased grain yield due to early sowing is ascribed to the high leaf area index and its persistence, as well as higher photosynthetically active radiation interception and absorption, leading to higher dry matter accumulation before the attainment of the reproductive stage by the pigeonpea crop (Patel *et al.* 2000). Other researchers have also reported sharp decline in the grain yield of pigeonpea with delay in sowing (Kumar *et al.* 2008, Ram *et al.* 2011). In 2008, with delay in sowing harvest index increased whereas in 2009, 15 June sowing recorded the lowest harvest index, which could be due to variation in rainfall during the two years. Date of sowing × genotype interaction, with respect to grain yield, was found to be non-significant.

The crop sown on 15 May gave the highest gross returns, net returns and B:C ratio (Table 4), which was due to higher grain yield. The 15 May sowing gave an additional income of Rs 2322 & Rs 19823 per hectare in 2008 and Rs 5590 & Rs 20640 per hectare in 2009 compared to those sown on 1 June and 15 June respectively. Reddy *et al.* (2012) also reported higher returns with early sowing of pigeonpea.

Performance of genotypes: Among the genotypes, AL 1507 took minimum days whereas AL 201 and AL 1593 took maximum days to 50% flowering and maturity (Table 1). The genotype AL 201 required the highest and AL 1507 required the lowest agroclimatic indices (AGDD, AHTU and APTU) to attain physiological maturity. During first year of study, AL 1507 and during second year, AL 1593 performed best in terms of heat use efficiency for grain yield, although the differences were quite small among genotypes AL 1507, AL 1578 and AL 1593. Genotype AL 201 had

consistently low heat efficiency.

The highest nodule number plant⁻¹ was observed in AL 1507 (Table 2). In 2008, AL 1578 recorded the highest nodule dry weight whereas in 2009, genotypic differences in terms of nodule dry weight were not significant. The genotypes AL 1507 and AL 1578 recorded the maximum plant height in 2008 and 2009, respectively, whereas AL 201 recorded the lowest plant height. The genotypes did not affect the branches plant⁻¹ during 2008. In 2009, AL 1578 recorded significantly higher number of branches plant⁻¹ than AL 1507 and AL 1593. The number of branches in AL 1578 was at par with AL 201.

AL 1507 and AL 1593 recorded the highest pods plant⁻¹ in 2008 and 2009, respectively (Table 2). The genotype AL 1507 recorded significantly higher pods plant⁻¹ than AL 201, which was, however statistically at par with AL 1578 and AL 1593 in 2008. In 2009, AL 1593 produced significantly higher pods plant⁻¹ than AL 201 which was, however, statistically at par with AL 1507 and AL 1578. The grains pod⁻¹ and 100-grain weight were not influenced significantly.

Genotypes did not differ significantly in biological yield during both the years of study (Table 3). In 2008, AL 1507 recorded significantly higher grain yield than AL 201 which was, however, at par with AL 1578 and AL 1593. In 2009, AL 1593 recorded significantly higher grain yield than AL 201 which was, however, at par with AL 1578 and AL 1507. On the basis of mean of two years, pigeonpea genotypes, AL 1507, AL 1578 and AL 1593 registered 19.4, 19.2 and 20.0 percent higher grain yield over AL 201, respectively. Other researchers also reported genotypic variation with respect to growth and yield of pigeonpea (Mligo and Craufurd 2005, Reddy *et al.* 2006, Singh 2006, Egbe and Vange 2008). During both the years, AL 201 recorded the lowest harvest index. The genotype AL 1507 in 2008 and AL 1593 in 2009 gave the maximum gross returns, net returns and B:C ratio (Table 4).

Conclusion

The crop sown on 15 May provided the highest grain yield (1609 and 1294 kg ha⁻¹ in 2008 and 2009, respectively) and net returns (Rs 41617 and 28072 ha⁻¹ in

2008 and 2009, respectively). Genotypes AL 1507, AL 1578 and AL 1593 performed better in terms of grain yield and net returns. On the basis of this study, it can be concluded that under Punjab conditions, 15 May is the optimum time of sowing of pigeonpea and AL 1507, AL 1578 and AL 1593 are the most promising genotypes with respect to grain yield and economics.

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