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RESPONSE OF PIGEONPEA VARIETIES TO SOWING DATES AT HIGH PLANT DENSITY UNDER DIFFERENT AGROCLIMATIC ZONES OF PUNJAB

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ABSTRACT

A multi-location field experiment was conducted at 10 different locations of Punjab to study the response of pigeonpea varieties (AL 882 and PADT 16) to sowing dates (17 June, 24 June, 1 July and 8 July) at high plant density (33 plants/m^2). Results showed that days to 50% flowering and maturity decreased with delay in sowing at all the locations (Ludhiana, Ballowal Saunkhri, Gurdaspur, Bathinda, Abohar, Jalandhar, Faridkot, Patiala, Dyal Bharang and Sangrur). Plant height and pods/plant also decreased with delay in sowing. On mean basis, 24 June sowing recorded the highest grain yield (1941 kg/ha) followed by 17 June and 1 July sowings, which was 23.1, 17.4 and 16.7% higher over 8 July sowing, respectively. Early sown crop (17 June) accumulated higher heat units as compared to late sowings at all the locations. Variety AL 882 recorded higher plant height, pods/plant, 100-seed weight, biological yield and grain yield than PADT 16 and recorded 16.7% higher grain yield over PADT 16. However, PADT 16 variety was early in days to 50% flowering and maturity and accumulated less heat units than AL 882. Being determinate in nature, higher infestation of insect-pests was recorded in PADT 16 as compared to AL 882. It can be concluded that 24th June is the optimum sowing time of pigeonpea variety AL 882 at high plant density and it also provides high economic returns.

Keywords: Grain yield, Heat units, High plant density, Sowing dates, Variety

Pigeonpea [*Cajanus cajan* (L.) Millsp.], also known as red gram, *arhar* or *tur*, is the most important *kharif* pulse and second most important pulse crop of India after chickpea. In India, pigeonpea was cultivated over an area of 4.54 mha with a production of 3.31 mt and the productivity of 728 kg/ha (FAOSTAT, 2021). In Punjab, among the *kharif* pulses, pigeonpea occupies third place in terms of area (1.8 thousand hectares) and second place in production (2.1 thousand tonnes) but has higher productivity (1163 kg/ha) than greengram (960 kg/ha) and blackgram (614 kg/ha) (Anonymous, 2022). It is a versatile crop used as pulse for human consumption, feed and fodder for livestock and as a fuel wood in rural households. Due to its nitrogen fixing ability, it plays an important role in sustaining intensive agriculture by improving physical, chemical and biological properties of soil (Singh *et al.*, 2005).

Earlier cultivated varieties of pigeonpea were of long-duration (250-280 days) with low yield potential ranging from 0.5 to 1.0 t/ha (Adjei-Nsiah, 2012). Therefore, it was considered as a subsistence crop and cultivated on the marginal lands. On the other hand, short-duration pigeonpea varieties are synchronous in maturity and having high yield potential, which fit well in various cropping systems under irrigated or rainfed conditions. Thus, pigeonpea is an excellent crop for diversification of the rice-wheat cropping system in the state of Punjab. For its acceptability in sequence cropping, it must not only give a higher yield on a sustainable basis but also fit well into double and multiple-cropping systems in different agroclimatic zones of the state. Change in sowing times leads to thermal environmental changes in the crop with respect to different crop growth and development stages.

In Punjab, pigeonpea is sown in the second fortnight of May (in rows 50 cm apart using 15 kg/ha seed rate) which requires one or two irrigations before the onset of monsoon rains. However, new varieties with less duration may be sown with the onset of monsoon rains. Most varieties of pigeonpea are photoperiod-sensitive and, therefore, sowing date has an important influence on the vegetative and reproductive growth phases. Delayed sowings beyond the optimum period result in low grain yields of pigeonpea (Kumar *et al*., 2008; Dhanoji and Patil, 2011; Singh *et* al., 2017). Besides, it is also important to understand the influence of high plant density on the population dynamics of different

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insect-pests infesting pigeonpea. Information on high plant density under late planting (June-July) of short-duration pigeonpea varieties is not available in Punjab. Therefore, research experiments were conducted at 10 locations in different agroclimatic zones of Punjab to study the influence of sowing dates on growth and productivity of pigeonpea varieties under high plant density (sowing in rows 30 cm apart using 30 kg/ha seed rate).

MATERIALS AND METHODS

Multi-location experiments were conducted at the Research Farm of the Department of Plant Breeding and Genetics, PAU Ludhiana, PAU Regional Research Stations (Ballowal Saunkhri, Gurdaspur, Bathinda, Abohar, Faridkot and Dyal Bharang), and Krishi Vigyan Kendras [Noormahal (Jalandhar), Kheri (Sangrur) and Rauni (Patiala)] during *kharif* 2019 to study the effect of date of sowing on the productivity of pigeonpea varieties at high plant density.

The experiment comprised of four dates of sowing (17 June, 24 June, 1 July and 8 July) with two pigeonpea varieties (AL 882 and PADT 16) was conducted in a split-plot design with four replications keeping dates of sowing in the main plots and varieties in the sub-plots. The crop was sown using 30 kg seed/ha with row to row spacing of 30 cm. Two hand weedings at 3 and 6 weeks after sowing were done to keep the crop free from weeds. Irrigation was applied as per the need.

Data on days to 50% flowering and maturity were recorded. The different agroclimatic indices were worked out for 50% flowering and maturity stages of pigeonpea crop as under:

Accumulated growing degree days (GDD) or heat units were calculated using a base temperature of 10.0°C (Dash and Shree, 2013):

GDD (^{o}C day) = $T_{mean} - T_t$

Where, T_{mean} = Daily mean temperature (^{o}C) and T_t = base or threshold temperature

Accumulated heliothermal units (HTU) were calculated as follows:

Accumulated HTU (^{o}C day) = $\sum_{i=1}^{n}$ GDD × Bright sunshine hours

Accumulated photothermal units (PTU) were calculated as follows:

Accumulated PTU (^{o}C day) = $\sum_{i=1}^{n}$ GDD × Day length

To compare the relative performance of different varieties under different sowing dates with respect to utilization of heat in terms of growing degree days during the crop growth period, heat use efficiency (HUE) was calculated as follows:

$$\text{HUE (kg/ha/ }^{o}\text{C day)} = \frac{\text{Grain yield kg/ha)}}{\text{Accumulated heat unis (°C day)}}$$

Among the different insect-pests infesting the crop, the population of blister beetle (*Mylabris pustulata*) and the number of flowers damaged by the beetle was recorded on per plant basis from three plants belonging to each replication at the time of flower initiation. Spotted pod borer (*Maruca vitrata*) webs were recorded from three randomly tagged plants at the time of flower initiation. Assessment of pod damage (due to spotted pod borer) was carried out at the time of harvest from 100 pods collected per treatment by counting the damaged pods and converting the damage into percentage. Similarly, the observations on the incidence of pod bug (*Clavigralla gibbosa*) were recorded from the same three tagged plants from each treatment and expressed as number of pod bugs per plant. Assessment of seed damage due to pod bug was also done at the time of harvest from 100 pods collected per treatment and by counting the shrivelled seeds, and converting the damage into percentage. The different insect-pests infesting the crop were managed using the recommended insecticides as and when required.

At maturity, data on plant height was recorded from five randomly selected plants from the ground level. The number of pods from five plants was counted and averaged into number of pods/plant. Grain yield was recorded plot-wise and converted into kg/ha. From the produce of each plot, 100 seeds were taken for 100-seed weight data. Gross returns, net returns as well as benefit:cost (B:C) ratio were worked out. Data were subjected to analysis of variance (ANOVA) in split-plot design as per the standard procedure.

RESULTS AND DISCUSSION

Effect of sowing dates

Days to 50% flowering (Table 1) and maturity (Table 2) were more in early sowing and less in subsequent sowing dates at all the locations. Pigeonpea requires relatively short daylight period (usually 8-10 hours) for flowering. Days to 50% flowering and maturity were more in early sowing which could be due to extended daylength period beyond 12 hours causing a progressive delay in the time to flower initiation in pigeonpea (Carberry *et al*., 2001). After summer solstice (21 June) as daylength reduces progressively and the critical dark period required for flowering is increased so the late sown crop took less number of days to flower as compared to early sown pigeonpea. Carberry *et al.* (2001) and Saxena and Sharma (1990) reported that flowering in short-duration cultivars was delayed by up to 100 days when daylength in the

Table 1. Effect of date of sowing and varieties of pigeonpea on agroclimatic indices in different agroclimatic zones of Punjab at 50% flowering

Location	Treatment		Days to 50% flowering	AGDD (°C day)	APTU (°C day)	AHTU (°C day)
Ludhiana	Date of sowing	17 June	76	1564	21151	9851
		24 June	77	1579	21087	9546
		1 July	77	1550	20438	8845
		8 July	76	1404	18767	8206
	Variety	AL 882	84	1693	22331	10119
		PADT 16	69	1404	18767	8206
Ballowal Saunkhri	Date of sowing	17 June	82	1590	21368	9700
		24 June	77	1484	19804	8710
		1 July	73	1379	18232	7528
		8 July	69	1285	16816	6747
	Variety	AL 882	78	1488	19721	8531
		PADT 16	73	1380	18389	7812
Gurdaspur	Date of sowing	17 June	84	1639	22098	8037
		24 June	81	1581	21128	7245
		1 July	80	1545	20424	6417
		8 July	78	1475	19270	5799
	Variety	AL 882	88	1695	22395	7357
		PADT 16	74	1424	19065	6392
Jalandhar	Date of sowing	17 June	69	1356	18455	4344
		24 June	68	1333	17971	5057
		1 July	66	1277	17016	5668
		8 July	65	1228	16135	5293
	Variety	AL 882	72	1398	18639	5668
		PADT 16	62	1199	16149	4513
Faridkot	Date of sowing	17 June	86	1825	24426	9252
		24 June	81	1716	22815	8550
		1 July	76	1594	21016	7910
		8 July	70	1466	19170	7236
	Variety	AL 882	86	1818	23914	9465
		PADT 16	70	1482	19799	7008

AGDD: Accumulated Growing Degree Days; APTU: Accumulated Photothermal Units; AHTU: Accumulated Heliothermal Units

photoperiod-inductive phase exceeded a critical value. Due to delayed flowering in early sown pigeonpea, days taken for maturity were more in early sowing dates.

Accumulated agroclimatic indices i.e. growing degree days (GDD), photothermal units (PTU), heliothermal units (HTU) and heat use efficiency (HUE) computed for pigeonpea taken from sowing to 50% flowering as well as physiological maturity under different dates of sowing and varieties are given in Tables 1 and 2, respectively. GDD requirement was higher in 17 June sown crop and decreased with delay in sowing at all locations.

The perusal of data revealed that the pigeonpea crop accumulated 2594, 2350, 2604, 2489 and 2864 GDD at Ludhiana, Ballowal Saunkhri, Gurdaspur, Jalandhar and Faridkot, respectively in 17 June sowing for attaining physiological maturity (Table 2). Accumulated GDD of pigeonpea at harvest under different dates of sowing showed that the early sown crop availed more GDD to attain physiological maturity as compared to late sown crop. The highest accumulation of PTU and HTU was recorded in 17 June sowing (33306 & 16445, 30315 & 14888, 33194 & 12299, 32446 & 9919, 36246 & 15092) at Ludhiana, Ballowal Saunkhri, Gurdaspur, Jalandhar

Table 2. Effect of date of sowing and varieties of pigeonpea on agroclimatic indices in different agroclimatic zones of Punjab at physiological maturity

Location	Treatment		Days to maturity	AGDD (°C day)	APTU (°C day)	AHTU (°C day)	HUE (kg/ha/°C day)
Ludhiana	Date of sowing	17 June	137	2594	33306	16445	0.52
		24 June	134	2487	31619	15189	0.58
		1 July	129	2392	30035	13764	0.58
		8 July	124	2202	27450	12551	0.50
	Variety	AL 882	137	2478	31253	14753	0.54
		PADT 16	125	2359	29951	14221	0.55
Ballowal Saunkhri	Date of sowing	17 June	130	2350	30315	14888	0.39
		24 June	134	2335	29660	14258	1.11
		1 July	133	2250	28227	13570	1.36
		8 July	129	2128	26405	12171	1.15
	Variety	AL 882	133	2280	28803	13814	1.14
		PADT 16	130	2251	28501	13630	0.87
Gurdaspur	Date of sowing	17 June	148	2604	33194	12299	0.80
		24 June	145	2505	31615	11442	0.88
		1 July	140	2368	29646	10257	1.01
		8 July	135	2231	27642	9302	0.96
	Variety	AL 882	143	2432	30579	10845	1.03
		PADT 16	141	2422	30469	10805	0.80
Jalandhar	Date of sowing	17 June	141	2489	32446	9919	0.69
		24 June	140	2340	29801	10155	0.74
		1 July	139	2317	28975	10356	0.62
		8 July	138	2201	27183	9522	0.38
	Variety	AL 882	147	2383	29937	10160	0.70
		PADT 16	132	2290	29266	9816	0.51
Faridkot	Date of sowing	17 June	161	2864	36246	15092	0.52
		24 June	158	2714	34148	14037	0.63
		1 July	155	2567	32020	13214	0.60
		8 July	151	2403	29727	12297	0.46
	Variety	AL 882	169	2683	33508	13865	0.57
		PADT 16	144	2591	32562	13455	0.53

AGDD: Accumulated Growing Degree Days; APTU: Accumulated Photothermal Units; AHTU: Accumulated Heliothermal Units; HUE: Heat Use Efficiency

and Faridkot, respectively for attaining physiological maturity and reduced with delay in sowing which might be due to reduction in daylength and sunshine hours at different locations. Similar results were reported by Singh *et al*. (2013). The highest HUE (1.36 kg/ha/°C day) was recorded in 1 July sowing and the lowest HUE (0.38 kg/ha/°C day) was recorded in 8 July sowing at Ballowal Saunkhri and Jalandhar, respectively.

The requirement of heat units was higher for early sown crop than late sown crop due to longer period for all the phenological stages in the early sown crop. The late sowing decreased the duration of phenophases which caused a decrease in agroclimatic indices during various phenophases and forced the crop to mature early.

The plant height was affected significantly by sowing dates at Ludhiana, Ballowal Saunkhri, Gurdaspur, Jalandhar, Faridkot, Dyal Bharang and Sangrur (Table 3). In general, plant height decreased with delay in sowing due to early onset of flowering in delayed sowing dates. In early sown crop, vegetative growth continued for a longer period so its plant height was more. Ram *et al.* (2011) and Kumar *et al*. (2008) reported that plant height of pigeonpea decreases in late sowings as compared to early sowing dates.

The number of pods/plant varied significantly due to different sowing dates at all the locations except at Ballowal Saunkhri (Table 4). The highest number of pods/plant was recorded in 24 June sowing at Ludhiana and Faridkot, in 1 July sowing at Ballowal Saunkhri and in 17 June sowing in the remaining locations. In general, the lowest number of pods/plant was recorded in 8 July sowing at all the locations, which might be due to less time available in this sowing date for the translocation of assimilates towards sink (pods). The 100-seed weight was significantly affected by sowing dates at Gurdaspur, Faridkot, Dyal Bharang and Sangrur (Table 4). In general, there was decrease in 100-seed weight at almost all the locations with the delay in sowing. On mean basis, the highest 100-seed weight was recorded in 17 June sowing (8.92 g) and the lowest in 8 July sowing (8.28 g).

The crop sown on 17, 24 June and 1 July recorded higher grain yield than 8 July sowing (Table 5). The highest grain yield of pigeonpea was recorded in 17 June sowing at Bathinda, Abohar, Jalandhar, Patiala and Dyal Bharang, in 24 June sowing at Ludhiana, Faridkot and Sangrur, and in 1 July sowing at Ballowal Saunkhri and Gurdaspur. On mean basis, 24 June sowing recorded the highest grain yield followed by 17 June and 1 July sowings, which was 23.1, 17.4 and 16.7% higher over 8 July sowing, respectively. Delayed sowings result in lower grain yield of pigeonpea (Singh *et al*., 2016). However, at Ballowal Saunkhri the crop sown on 17 June gave significantly low yield due to the high incidence of blister beetle. The growth and yield components were reduced significantly under late sown crop because late planting coupled with early maturity did not allow enough time for vegetative growth and subsequently, there was less pod formation, 100-seed weight and thus reduced grain yield. Other researchers (Kumar *et al*., 2008; Channabasavanna *et al*., 2015; Kithan *et al*., 2020) reported that late sowing of pigeonpea beyond 15 June not only affects seed germination due to higher soil moisture but also yield due to lower temperature during the reproductive and maturity stages.

The early sowing (17 June) produced higher grain yield by using accumulated heat units efficiently. As the temperature was favourable throughout normal growing condition, it has utilized more heat units efficiently and increased physiological activities that results in higher grain yield. The timely sown pigeonpea crop performed better in terms of accumulation and utilization of heat units in kandi zone (Ballowal Saunkhri) as compared to south-western zone (Faridkot) of the state as indicated by the meteorological condition attained during the crop season at different locations of the state.

Table 3. Influence of date of sowing and varieties on plant height of pigeonpea

Treatment	Plant height (cm)										Mean
	Ludhiana	Ballowal Saunkhri	Gurdaspur	Bathinda	Abohar	Jalandhar	Faridkot	Patiala	Dyal Bharang	Sangrur	
Date of sowing											
17 June	153.9	209.3	196.8	176.0	163.2	196.0	139.8	157.0	192.7	171.5	175.6
24 June	146.5	200.2	200.7	177.0	158.6	194.0	153.7	161.5	181.7	171.9	174.6
1 July	131.7	187.5	195.5	177.0	157.6	184.0	144.8	149.5	164.1	169.5	166.2
8 July	123.7	177.0	181.6	180.0	-	161.0	140.9	149.0	-	153.7	158.4
CD (p=0.05)	3.6	7.3	5.7	NS	NS	14.0	9.99		12.70	8.4	
Varieties											
AL 882	154.9	217.3	213.4	198.0	181.3	209.0	162.4	165.5	187.5	188.3	187.7
PADT 16	123.0	169.6	173.9	157.0	138.3	158.0	126.9	143.0	171.5	145.0	150.7
CD (p=0.05)	4.3	4.37	4.9	6.0	7.8	10.0	NS		8.87	5.7	

Table 4. Influence of date of sowing and varieties on yield attributes of pigeonpea

Treatment	Ludhiana	Ballowal Saunkhri	Gurdaspur	Bathinda	Abohar	Jalandhar	Faridkot	Dyal Bharang	Patiala	Sangrur	Mean
Pods/plant											
Date of sowing											
17 June	55.3	94.4	72.3	83.4	88.1	48.4	114.4	82.0	64.5	196.8	90.0
24 June	64.9	99.8	70.6	82.2	78.4	44.4	117.8	75.0	61.0	157.0	85.1
1 July	60.3	111.4	60.4	76.0	73.1	41.7	112.5	64.0	56.5	161.3	81.7
8 July	48.6	92.5	57.8	67.9	-	31.0	109.5	-	52.5	130.0	73.7
CD (p=0.05)	5.0	NS	6.1	5.1	10.3	7.3	5.4	12.8		40.9	
Varieties											
AL 882	63.0	121.1	69.8	79.5	87.0	48.2	117.3	75.0	59.8	165.7	88.6
PADT 16	51.5	77.9	60.6	75.3	72.7	34.6	109.9	73.0	57.5	156.8	77.0
CD (p=0.05)	4.9	9.3	2.7	4.0	8.4	5.0	NS	NS		NS	
						100-seed weight (g)					
Date of sowing											
17 June	7.15	8.10	8.75	8.64	9.87	9.36	7.82	10.88	-	9.74	8.92
24 June	7.17	8.20	8.87	8.59	9.72	9.31	7.67	10.38	-	9.63	8.84
1 July	7.15	7.60	9.35	8.68	9.79	9.29	7.49	10.30	-	9.62	8.81
8 July	7.06	7.70	8.53	8.78	-	9.17	6.99	-	-	9.75	8.28
CD (p=0.05)	NS	NS	0.47	NS	NS	NS	0.65	0.4		0.78	
Varieties											
AL 882	7.53	8.60	9.75	10.08	10.93	9.71	8.18	10.78	-	10.50	9.56
PADT 16	6.73	7.20	8.00	7.26	8.65	8.85	6.80	10.25	-	8.87	8.07
CD (p=0.05)	0.17	0.24	0.28	0.30	0.82	0.34	NS	0.30		NS	

The highest gross returns of pigeonpea were recorded in 17 June sowing at Bathinda, Abohar, Jalandhar, Patiala and Dyal Bharang, in 24 June sowing at Ludhiana, Faridkot and Sangrur and in 1 July sowing at Ballowal Saunkhri and Gurdaspur (Table 6). High gross returns could be due to more grain yield. The highest net returns and B:C ratio of pigeonpea was recorded in 17 June sowing at Bathinda, Abohar, Patiala and Dyal Bharang, in 24 June sowing at Ludhiana, Jalandhar, Faridkot and Sangrur, and in 1 July sowing at Ballowal Saunkhri and Gurdaspur (Table 6). Net returns were higher in 24 June sowing as compared to 17 June sowing, which could be due to less cost of cultivation. In 17 June sowing, more sprays were done to control insect-pests that led to an increase in the cost of cultivation. On a mean basis, 24 June sowing recorded the highest gross returns, net returns and B:C ratio followed by 17 June and 1 July sowings.

Blister beetle prefers to feed on the flowers of pigeonpea. The crop (var. PADT 16) sown on 17 June, 24 June and 1 July flowered relatively earlier as compared to the one sown on 8 July, thus attracting more population of blister beetle (Table 7). Sowing dates of 17 June, 24 June and 1 July recorded 1.25, 1.13 and 0.88 beetles per plant, respectively, whereas no beetles were recorded in the 8 July sown crop owing to late flowering. Likewise, the flower damage due to blister beetle was 4.13 per plant in the 17 June sown crop and decreased progressively in the 24 June sown crop (4.00 per plant) and 1 July sown crop (2.63 per plant). No blister beetle incidence and damage was observed in the 8 July sown crop in both the varieties. The significant reduction in blister beetle infestation in the late planting could be attributed to the lower population of the beetle late in the season. The results are in conformity with the findings of Singh *et al.* (2021) who reported that blister beetle started appearing in pigeonpea in late August under Punjab conditions. Further, its activity increased and reached at its peak in the end of September coinciding with the maximum flowering and thereafter it declined due to the termination of flowers (Singh *et al.* 2021). Therefore, in the present study, pigeonpea planted on 8 July, escaped blister beetle infestation owing to late flowering while the flowering of those planted earlier (in June) coincided with the peak population densities of the beetle.

Since the peak flowering and podding of the crop in both the varieties coincided with the peak incidence of spotted pod borer (*M. vitrata*), the number of webs per plant in all the four sowing dates and the pod damage in the first three sowing dates was statistically similar (Table 7). Likewise, there were non-significant differences in the pod bug population and seed damage due to pod bug in all the four dates of sowing (Table 7).

Table 5. Influence of date of sowing and varieties on grain yield of pigeonpea

Treatment	Grain yield (kg/ha)										Mean
	Ludhiana	Ballowal Saunkhri	Gurdaspur	Bathinda	Abohar	Jalandhar	Faridkot	Patiala	Dyal Bharang	Sangrur	
Date of sowing											
17 June	1335	917	2062	2636	2804	1720	1480	1286	2142	2114	1850
24 June	1428	2597	2210	2518	1623	1715	1705	1130	2055	2428	1941
1 July	1387	3059	2383	2336	1038	1436	1534	1125	1691	2402	1839
8 July	1101	2441	2132	2088	-	838	1095	917	-	1997	1576
CD (p=0.05)	135	217	215.2	223	194	243	67		289	NS	
Varieties											
AL 882	1325	2580	2485	2774	1927	1674	1538	1221	1832	2218	1957
PADT 16	1300	1927	1909	2016	1716	1181	1368	1008	2094	2253	1677
CD (p=0.05)	NS	120	115.4	168	158	172	226		189	NS	

Table 6. Influence of date of sowing and varieties on economics of pigeonpea

Treatment	Ludhiana	Ballowal Saunkhri	Gurdaspur	Bathinda	Abohar	Jalandhar	Faridkot	Patiala	Dyal Bharang	Sangrur	Mean
Date of sowing						Gross returns (Rs/ha)					
17 June	77430	53186	119596	152888	162632	99760	85840	74588	124236	122612	107277
24 June	82824	150626	128180	146044	94134	99470	98890	65540	119190	140824	112572
1 July	80446	177422	138214	135488	60204	83288	88972	65250	98078	139316	106668
8 July	63858	141578	123656	121104	-	48604	63510	53186	-	115826	91415
Varieties											
AL 882	76850	149640	144130	160892	111766	97092	89204	70818	106256	128644	113529
PADT 16	75400	111766	110722	116928	99528	68498	79344	58464	121452	130674	97278
Date of sowing						Net returns (Rs/ha)					
17 June	38087	13843	80253	113545	123289	60417	46497	35245	84893	83269	67934
24 June	45081	112883	90437	108301	56391	61727	61147	27797	81447	103081	74829
1 July	42703	139679	100471	97745	22461	45545	51229	27507	60335	101573	68925
8 July	27890	105610	87688	85136	-	12636	27542	17218	-	79858	55447
Varieties											
AL 882	41282	114072	108562	125324	76198	61524	53636	35250	70688	93076	77961
PADT 16	35569	71935	70891	77097	59697	28667	39513	18633	81621	90843	57447
Date of sowing						B:C ratio					
17 June	1.97	1.35	3.04	3.89	4.13	2.54	2.18	1.90	3.16	3.12	2.73
24 June	2.19	3.99	3.40	3.87	2.49	2.64	2.62	1.74	3.16	3.73	2.98
1 July	2.13	4.70	3.66	3.59	1.60	2.21	2.36	1.73	2.60	3.69	2.83
8 July	1.78	3.94	3.44	3.37	-	1.35	1.77	1.48	-	3.22	2.54
Varieties											
AL 882	2.16	4.21	4.05	4.52	3.14	2.73	2.51	1.99	2.99	3.62	3.19
PADT 16	1.89	2.81	2.78	2.94	2.50	1.72	1.99	1.47	3.05	3.28	2.44

Table 7. Effect of date of sowing and varieties on blister beetle population & damage to flowers, *Maruca vitrata* webs & damage to pods, and pod bugs & seed damage in pigeonpea at PAU Ludhiana

Date of sowing	Blister beetle population/plant			Flowers damaged due to Blister beetle/plant			*Maruca vitrata* webs/plant		
	AL 882	PADT 16	Mean	AL 882	PADT 16	Mean	AL 882	PADT 16	Mean
17 June	0.00	2.50	1.25	0.00	8.25	4.13	2.00	6.75	4.38
24 June	0.00	2.25	1.13	0.00	8.00	4.00	1.75	6.25	4.00
1 July	0.00	1.75	0.88	0.00	5.25	2.63	1.75	6.00	3.88
8 July	0.00	0.00	0.00	0.00	0.00	0.00	1.50	5.25	3.38
Mean	0.00	1.62		0.00	5.37		1.75	6.06	
CD (p=0.05)	Date of sowing	Variety	Interaction	Date of sowing	Variety	Interaction	Date of sowing	Variety	Interaction
	0.40	0.33	0.66	0.61	0.43	0.86	NS	0.69	NS
	Pod damage (%) due to *Maruca vitrata*			Pod bugs/plant			Seed damage (%) due to pod bug		
	AL 882	PADT 16	Mean	AL 882	PADT 16	Mean	AL 882	PADT 16	Mean
17 June	4.43	9.53	6.98	4.25	4.50	4.38	3.52	3.74	3.63
24 June	3.66	9.37	6.52	4.50	4.75	4.63	3.83	3.95	3.89
1 July	3.44	9.30	6.37	4.25	4.75	4.50	3.80	3.82	3.81
8 July	2.88	7.21	5.05	4.50	4.25	4.38	3.63	3.76	3.70
Mean	3.60	8.85		4.38	4.56		3.70	3.82	
CD (p=0.05)	Date of sowing	Variety	Interaction	Date of sowing	Variety	Interaction	Date of sowing	Variety	Interaction
	0.62	0.66	NS	NS	NS	NS	NS	NS	NS

A possible reason for this might be the fact that the pod bug appears late in the season and during that time, the crop in all the four dates of sowing was at podding and grain filling stage, and therefore, the crop attracted the bug equally.

Performance of varieties

Pigeonpea varieties showed marked variation in the number of days taken for 50% flowering at all the locations under study (Table 1). On mean basis, variety PADT 16 took 13 days less than AL 882 for 50% flowering. Consequently, PADT 16 matured 11 days earlier than AL 882. The number of days taken for maturity by PADT 16 ranged from 125 days at Ludhiana to 144 days at Faridkot (Table 2), while in AL 882, it ranged from 133 days at Ballowal Saunkhri to 169 days at Faridkot.

The plant height of variety AL 882 was significantly more than PADT 16 at all the locations (Table 3). Singh *et al*. (2018) also reported that late maturing or long duration varieties are generally tall, because of their prolonged vegetative phase, while the short duration or early maturing varieties are comparatively short statured due to their short vegetative growth phase.

From emergence to 50% flowering stage, pigeonpea varieties PADT 16 and AL 882 accumulated 1404 & 1693, 1380 & 1488, 1424 & 1695, 1199 & 1398 and 1482 & 1818 GDD at Ludhiana, Ballowal Saunkhri, Gurdaspur, Jalandhar and Faridkot, respectively (Table 1). The GDD decreased at all locations in both the varieties with delay in sowing from June 17 to July 8 (data not presented). Similarly, the PTUs and HTUs also followed a similar trend as GDD. As variety AL 882 took more number of days to 50% flowering and maturity, therefore, AL 882 acquired more heat units as compared to PADT 16 at all the locations (Table 2).

AL 882 performed better at most of the locations from emergence to physiological maturity by giving more HUE as compared to PADT 16, which might be due to favourable change in temperature. Kour *et al.* (2010) reported that the heat use efficiency increased with the advancement of the crop age up to the milking stage and decreased later due to leaf senescence under the temperate climate of Kashmir in wheat crop.

AL 882 recorded significantly higher number of pods/plant and 100-seed weight (Table 4) than PADT 16 variety at all the locations. The higher yield attributes in variety AL 882 contributed to significantly higher grain yield than PADT 16 at all the locations except at Dyal Bharang (Table 5). Based on the mean of 10 locations, pigeonpea variety AL 882 recorded 16.7% higher grain yield over PADT 16. The highest yield of AL 882 (2580 kg/ha) and PADT 16 (2253 kg/ha) was recorded at Ballowal Saunkhri and Sangrur, respectively, while the lowest yield of AL 882 and PADT 16 was obtained at Patiala (1221 kg/ha and 1008 kg/ha, respectively). The pigeonpea variety AL 882 recorded higher gross returns, net returns and B:C ratio (Table 6) than PADT 16 (except at Dyal Bharang and gross returns at Sangrur) due to its higher grain yield.

Pigeonpea variety PADT 16, being determinate in nature, was early to flower in the first three dates of sowing (17 June, 24 June and 1 July) as compared to AL 882 and, therefore, incidence of blister beetle as well as the flower damage was observed to be higher in these dates and on variety PADT 16 (Table 7). However, PADT 16 sown on the fourth date (8 July) and AL 882 (sown on all the four dates) evaded the attack of blister beetle owing to late flowering. Since peak flowering of both varieties and all dates coincided with the peak incidence of spotted pod borer (*M. vitrata*) the infestation of the pod borer (in the form of webs per plant) was uniform in all four dates. Being a determinate variety, the infestation of *M. vitrata,* in terms of the number of webs as well as the per cent pod damage was higher in PADT 16. The results are in conformity with the studies of several workers who concluded that the determinate varieties of pigeonpea suffered more flower and pod damage by *M. vitrata* (Saxena *et al.,* 1996; Mahalle and Taggar, 2017; Mahalle and Taggar, 2018). In the determinate varieties of pigeonpea, the pods are clustered together at the top of the plant and, therefore, are more vulnerable to the damage by *M. vitrata* as compared to the indeterminate ones (Saxena *et al.,*1996). There were, however, non-significant differences in the pod bug population and seed damage due to pod bug in both varieties.

It can be concluded that 17-24 June is the optimum sowing time of pigeonpea variety AL 882 at high plant density to get high productivity of the crop and provide high economic returns under Punjab conditions. Moreover, early sowing helps to vacate field early for the timely sowing of succeeding *rabi* crops. Therefore, the sowing of pigeonpea at high plant density can play an important role in the diversification of rice-wheat cropping system.

Authors' contribution

Conceptualization of research work and designing of experiments (GS, HKV); Execution of field experiments (GS, HKV, AK, CK, HSB, KS, MS, KK, MS, MS, GK, JS); data collection (GS, HKV, AK, CK, HSB, KS, MS, KK, MS, MS, GK, JS, GKT, RS); Analysis of data and interpretation (HKV, GKT, KKG); Preparation of manuscript (AK, GS, HKV, GKT, KKG)

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