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HEAT UTILIZATION, IRRIGATION EFFICIENCY AND PRODUCTIVITY OF SOYBEAN (*Glycine max* L. Merrill) AS INFLUENCED BY SOWING DATES, SOWING METHODS AND SEEDING RATES

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Abstract

A field experiment was conducted at the experimental farm of Punjab Agricultural University (PAU), Ludhiana (alluvial loamy sand soil) and at PAU seed farm, Naraingarh, Punjab (sandy loam soil) during kharif 2006 and 2007 to study the heat utilization and production of soybean as influenced by three dates of sowing (June 10, June 25 and July 10), three methods of sowing (flat sowing at 45 and 60 cm, bed planting) and two seed rates (50 and 75 kg/ha). June 10 sowing resulted in the highest accumulation of growing degree days (GDD) and helio-thermal units (HTU) thereby resulting in maximum heat utilization over June 25 and July 10 sowing dates which was reflected in higher biological and grain yield of the crop. Earlier sowing resulted in better growth, yield attributes and higher irrigation water applied efficiency at both the locations. Bed planting of soybean resulted in 33% saving of irrigation water applied over flat sowing. June 10 sowing, bed planting and seed rate of 75 kg/ha recorded the highest returns.

Key Words : H*eat utilization, irrigation efficiency, seed rate, sowing dates, sowing methods, soybean.*

Soybean (*Glycine max* L. Merrill) is the most important grain legume crop of the world. The global area and production under soybean in 2010-11 was 102.4 m ha and 261.6 m tonnes, respectively while in India it was grown on an area of 9.33 m ha with total production of 12.74 m tonnes (1). Soybean contains both high quality protein (43%) and oil (20%). Soybean products are being used on account of dietary, industrial, agricultural and medicinal importance. In addition to improving the soil fertility by fixing atmospheric nitrogen, it is a cheap source of protein for direct human consumption. Due to consumer's preference, soybean demand is going to increase in coming years in India. India imports vegetable oil, so soybean production in the country will not only help in meeting vegetable oil requirements but also save foreign exchange (2). To make any crop successful in any area, it must have good crop husbandry practices for realizing good yields. Sowing time, method and seed rate are known to influence the grain yield considerably (3). Three climatic parameters viz. temperature, rainfall and light are most important for optimum crop growth and development thereby exploit the potentiality of the crop. Among these, temperature plays a vital role in almost all the biological processes of the crop plants. The relative equidistant plant distribution leads to increased leaf area development and greater light interception early in the season which increase the crop growth rate, dry matter accumulation and seed yield (3).

Planting dates, method of sowing and seeding rate are vital factors that must be considered while planting soybean for higher productivity. Solar energy being unlimited, inexhaustible and non-pollutant, its efficient utilization for crop production could be major consideration, especially for a crop like soybean (4). Optimum sowing time plays an important role in keeping balance between vegetative and reproductive phase of the crop. If soybean population is too high, plants compete with each other and often lodge. If the population is too low, a producer is wasting growing space and lowering yield. Furrow irrigated raised bed planting can save considerable amount of irrigation water and maximize water productivity and also provide favourable environment for soybean (5). The present investigation therefore was planned and conducted to study heat unit utilization, growth, yield and economics in soybean under different dates of sowing, planting systems and seed rates.

MATERIALS AND METHODS

A field experiment was conducted at the experimental farm of Punjab Agricultural University (PAU), Ludhiana

(30° 56' N, 75° 52' E; 247 m above mean sea level) and at PAU seed farm, Naraingarh (30° 66' N, 76° 30' E; 260 m above mean sea level) during kharif 2006 and 2007. The soil type at Ludhiana was deep alluvial loamy sand, Typic Ustochrept, low in organic carbon (4.2 g C/kg at 0-15 cm), slightly alkaline (pH 8.2), medium in available P (13.8 kg/ha) and available K (170.3 kg/ha). However, at Naraingarh, soil was sandy loam in texture. The experiment comprising 18 treatment combinations viz., three dates of sowing (June 10, June 25 and July 10), three methods of sowing (flat sowing at 45 and 60 cm, bed planting i.e. 2 rows of soybean on the top of 67.5 cm wide bed having 37.5 cm top and 30 cm wide furrow) and two seed rates (50 and 75 kg/ha) was laid out in split plot design replicated four times using cultivar SL 525. The raised beds were formed after conventional tillage. The recommended fertilizer dose of 30 kg N and 60 kg P_2O_5/ha was applied as urea (46% N) and single superphosphate (16% P_2O_5) before sowing.

The data on plant height, pods/plant, 100-seed weight, biological yield and grain yield were recorded at the time of harvest. Observations on plant height and pods/plant were taken from randomly selected five plants per plot. The 100-seed weight was recorded by taking a random sample of the produce from each plot at the time of harvest. Biological yield and grain yield were recorded on whole plot basis. The crop was harvested from October 28 to November 5 at different locations in various years. The crop was harvested when the pods were mature; the bundles were sun dried for few days before threshing.

The growing degree-days (GDD) were computed by considering the base temperature (T_b) of 10 °C. The sum of the degree days from sowing to physiological maturity were obtained by using the following formula :

Accumulated GDD (°C day) = Σ ($T_{mean} - T_b$)

Where T_{mean} is daily mean air temperature in °C = ($T_{max} + T_{min}$)/2

The helio-thermal unit for a given day represents the product of GDD and the actual hours of bright sunshine for that day. The sum of the HTU for the duration of the crop was determined by using the following formula :

Accumulated HTU (°C day) = $\Sigma [(T_{mean} - T_b) \times Di]$,

where Di is the daily bright sunshine hours.

Heat Use Efficiency (HUE) was also computed with the following formula

$$HUE = \frac{\text{Yield (Stover or grain yield)}}{GDD}$$

The economics of all the treatments were calculated by considering the prevailing prices of inputs and produce. The various formulas used were:

Variable costs = Input costs + operations costs

Gross returns = Price of soybean × grain yield.

Net returns = Gross returns – Variable costs,

B:C ratio = Gross returns/ Variable costs

Irrigation water applied efficiency = Grain yield/irrigation water applied

The data were subjected to analysis of variance following the experimental design for split-plot design.

RESULTS AND DISCUSSION

Growth, yield attributes and yield

Plant height, an index of general growth of plant, showed significant and consistent decrease with the delay in sowings from June 10 to July 10 (Table-1). This decrease in the plant height could be attributed to a shorter vegetative period in delayed sowings. Significant reduction in the plant height of soybean with delayed sowings has also been reported earlier (6, 7). Different planting methods did not influence the plant height significantly except at Ludhiana in 2006, where sowing of two rows of crop on raised beds resulted in significantly higher plant height over flat sowing at 45 or 60 cm. At Naraingarh, differences with respect to plant height in different seed rates were non-significant. In 2007, plant height increased significantly at seed rate of 75 kg/ha over 50 kg/ha.

The highest number of pods were found in June 10 sowing which were on par with June 25 sowings except in 2007 at Ludhiana where June 10 sowings produced significantly higher number of pods over both 25 June and 10 July sowings (Table-1). Delayed sowing to 10 July recorded lowest pods/plant. This might be due to the better root growth in early planting of soybean, enabling the crop to explore more soil

Table-1 : Growth and yield attributes of soybean as influenced by different treatments.

Treatment	Plant height (cm)				Pods/plant				100-seed wt. (g)			
	Ludhiana		Naraingarh		Ludhiana		Naraingarh		Ludhiana		Naraingarh	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Sowing date												
10 June	79.9	73.2	101.4	111.8	50.8	53.6	52.0	102.6	10.45	10.22	10.77	10.57
25 June	74.9	57.0	88.1	98.3	48.3	33.4	50.3	96.7	10.24	9.95	10.41	10.19
10 July	43.1	38.3	48.9	80.9	36.7	21.3	37.4	66.1	9.82	9.43	10.09	9.55
CD at 5%	6.9	7.2	1.9	4.7	7.2	3.3	7.3	7.5	0.29	0.34	0.29	0.30
Sowing method												
Flat (45 cm)	65.7	54.9	79.2	98.3	44.1	35.2	44.6	88.0	10.16	9.87	10.43	10.14
Flat (60 cm)	63.9	58.2	78.9	95.9	45.3	38.9	45.5	86.5	10.19	9.90	10.43	10.16
Bed planting	68.3	55.3	80.3	96.8	46.1	34.2	49.6	90.8	10.17	9.82	10.40	10.00
CD at 5%	2.6	NS	NS	NS	NS	NS	3.4	NS	NS	NS	NS	NS
Seed rate (kg/ha)												
50	69.3	54.1	79.5	96.4	46.9	35.8	47.8	87.2	10.20	9.89	10.44	10.14
75	66.7	58.3	79.4	97.6	44.0	36.4	45.3	89.8	10.14	9.84	10.40	10.06
CD at 5%	2.4	2.9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

mass resulting in better nutrient absorption and better growth of the crop by producing more number of pods/plant (6, 8).

Planting methods did not differ significantly in respect of pods/plant except in 2006 at Naraingarh, where bed planting of soybean produced significantly higher number of pods/plant over flat sowing of 45 and 60 cm spacings. These results are in conformity with the findings of (5). The differences in pods/plant with respect to seed rate of 50 or 75 kg/ha were non-significant at both the locations. The data on 100-seed weight were not influenced by row spacing and seed rate. However, 100-seed weight was decreased significantly with delayed sowing on July 10 as compared to June 10 sowing, while statistically similar 100-seed weight was recorded in June 10 and June 25 sowing at Ludhiana.

Biological yield and grain yield were significantly affected by different dates of sowing (Table-2). Maximum biological yield and grain yield were obtained from early planted crop on June 10, which were statistically on par with June 25 sowing in 2006 and significantly higher than June 25 in 2007 at Ludhiana while, at Naraingarh, June 10 and June 25 gave statistically similar biological and grain yield in both the years. Further delay in sowing to July 10 significantly reduced the biological and grain yield than June 10 and June 25 sowings at both the locations in all years of study. Decline in biological and grain yield with delayed sowing from June 10 to July 10 was due to shortening of the growing season (Figure-1) and

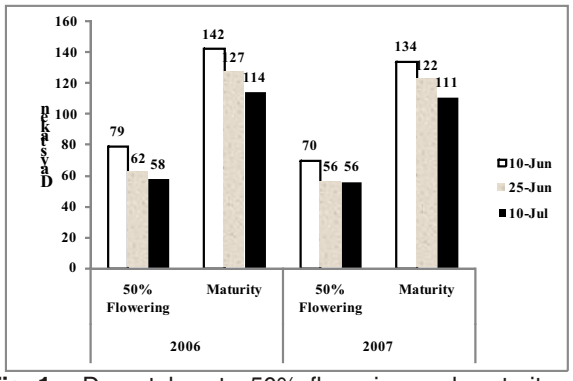

Fig.-1 : Days taken to 50% flowering and maturity of soybean as influenced by different sowing dates.

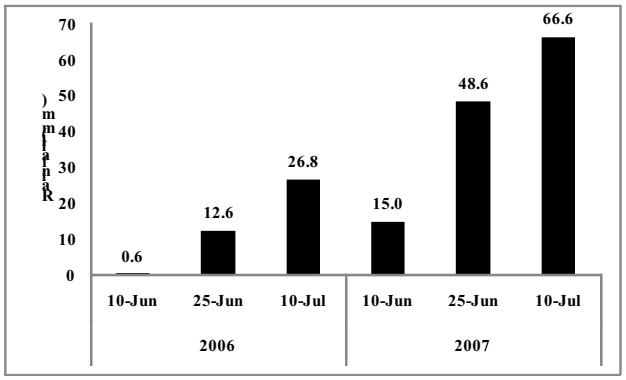

Fig.-2 : Total rainfall received within 5 days of sowing during the crop growing season

Table-2: Biological yield, grain yield, irrigation water applied and irrigation water applied efficiency of soybean as influenced by different treatments at Ludhiana and Naraingarh.

Treatment	Biological yield (kg/ha)				Grain yield (kg/ha)				Irrigation water applied (cm)				Irrigation water applied efficiency (kg/ha/cm)			
	Ludhiana		Naraingarh		Ludhiana		Naraingarh		Ludhiana		Naraingarh		Ludhiana		Naraingarh	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Sowing date																
10 June	7577	6399	7604	6364	2225	1938	2351	1847	33.3	33.3	20.0	26.7	66.8	58.2	115.8	69.2
25 June	7472	2878	7239	6003	2199	1081	2333	1719	33.3	26.7	20.0	26.7	66.0	40.5	114.9	64.4
10 July	6186	1630	3510	4545	1440	805	1368	1229	26.7	26.7	13.3	20.0	53.9	30.1	102.9	61.5
CD at 5%	721	762	403	613	126	231	276	248	-	-	-	-	6.8	5.9	8.3	6.7
Sowing method																
Flat (45 cm)	6644	3692	5948	5469	1926	1237	1861	1615	35.0	32.5	20.0	27.5	55.0	38.1	91.7	58.7
Flat (60 cm)	7173	3782	5979	5406	1929	1364	1931	1531	35.0	32.5	20.0	27.5	55.1	42.0	95.1	55.7
Bed planting	7116	3467	6427	6038	2009	1257	2261	1649	23.3	21.7	13.3	18.3	86.2	57.9	170.0	90.1
CD at 5%	NS	200	380	513	NS	NS	190	NS	-	-	-	-	7.6	5.6	13.3	8.2
Seed rate (kg/ha)																
50	6935	3521	6003	5190	1944	1211	2009	1463	31.1	28.9	17.8	24.4	62.5	41.9	112.9	60.0
75	7221	3750	6233	6085	1965	1338	2026	1734	31.1	28.9	17.8	24.4	63.2	46.3	113.8	71.1
CD at 5%	NS	NS	NS	404	NS	NS	NS	144	-	-	-	-	NS	4.5	NS	7.2

reduced accumulation of growing degree days (Table-3). Significant reduction in biological yield and grain yield of soybean with progressive delay in sowing from May 2 to August 2 is also been reported (9). The biological and grain yield of soybean in June 25 and July 10 sowing at Ludhiana in 2007 were considerably low as compared to the corresponding values in the year 2006. This may be due to high amount of rainfall received i.e. 48.6 mm and 66.6 mm (Figure-2) within 5 days of sowing done on 25 June and July 10, 2007 respectively, which adversely affected germination, growth and development of the crop in these dates of sowing.

Flat sowing at 45 cm or 60 cm row spacings produced statistically similar biological yield and grain yield at both the locations during both the years. Earlier it has also been reported that line spacing of 30 and 45 cm could not influence biological yield and grain yield significantly (5). As compared to the flat sowing at 45 cm or 60 cm, the bed planting at Naraingarh (on sandy loam soil) produced significantly higher biological yield during both the years and grain yield in 2006 whereas at Ludhiana (on loamy sand soil), it produced significantly lower biological yield in 2007. Use of higher seed rate of 75 kg/ha produced higher biological yield and grain yield over 50 kg/ha but, the differences were non-significant except at Naraingarh in 2007. Similarly, (5) also reported that seed rate of 75 kg/ha produced significantly higher biological yield over 50 kg/ha but, grain yield were statistically on par with each other.

Irrigation water applied and irrigation water efficiency

Irrigation water applied varied with date and method of sowing. The lowest amount of water was applied when crop was sown on 10 July (Table 2). Bed planting of soybean resulted in 33.0% saving of irrigation water applied. Irrigation water applied efficiency decreased with delayed sowing of soybean. Bed planting of soybean recorded significant increase in irrigation water applied efficiency over flat sowing at 45 cm and 60 cm.

Accumulated growing degree days (GDD) and heat use efficiency (HUE)

Table-3 : Heat use efficiency (HUE) and heliothermal use efficiency (HTUE) as influenced by different treatments at Ludhiana

Treatment	Accumulated GDD (°C day)		HUE of grain with GDD (kg/ha/°C day)		HUE of stover with GDD (kg/ha/°C day)		Accumulated HTU (°C day)		HTUE for grain production (kg/HTU)	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Sowing date										
10 June	2712	2696	0.82	0.72	1.97	1.65	19611	19186	0.113	0.101
25 June	2522	2493	0.87	0.43	2.09	0.72	17863	17572	0.123	0.062
10 July	2195	2181	0.66	0.37	2.16	0.38	15500	15601	0.093	0.052
Sowing method										
Flat (45 cm)	2476	2457	0.78	0.50	1.91	1.00	17658	17453	0.109	0.071
Flat (60 cm)	2476	2457	0.78	0.56	2.12	0.98	17658	17453	0.109	0.078
Bed planting	2476	2457	0.81	0.51	2.06	0.90	17658	17453	0.114	0.072
Seed rate (kg/ha)										
50	2476	2457	0.79	0.49	2.02	0.94	17658	17453	0.110	0.069
75	2476	2457	0.79	0.54	2.12	0.98	17658	17453	0.111	0.077

The results show that June 10 sowing accumulated highest GDD closely followed by June 25, while, delay in sowing to July 10 resulted in least accumulation of GDD (Table 3). (10) also reported that sowing of soybean on June 16 resulted in higher GDD accumulation over June 26 and July 6 sowing.

During 2006, the grain HUE was similar in June 10 and June 25 sowings and decreased by 29.8% with further delay of sowing from June 25 to July10 whereas, in 2007, the grain HUE was highest in June 10 sowing and decreased by 43.1% and 54.2% in June 25 and July 10 sowing respectively, over June 10 sowing (Table-3). Higher grain HUE on June 26 sowing over July 6 sowing of soybean is also reported by (10). HUE of stover production was almost similar in 2006 under different dates of sowing, sowing methods and seed rates whereas, in 2007, June 10 sowing resulted in maximum HUE of stover production and decreased by 56.4% and 77.0% in June 25 and July 10 sowing respectively. The HUE for grain and stover production worked out for different sowing methods and seed rates (Table-3) show that it was almost similar amongst various sowing methods and seed rates in both the years.

Table-4 : Effect of sowing dates, sowing methods and seeding rate on economics of soybean (mean of two locations and two years)

Treatment	Gross returns (Rs/ha)	Variable costs (Rs/ha)	Net returns (Rs/ha)	B:C ratio
Sowing date				
10 June	30100	14500	15600	2.08
25 June	26395	14500	11895	1.82
10 July	17431	14500	2931	1.20
CD at 5%	5613	-	5613	-
Sowing method				
Flat (45 cm)	23900	14500	9400	1.65
Flat (60 cm)	24318	14500	9818	1.68
Bed planting	25834	14500	11334	1.78
CD at 5%	NS	-	NS	-
Seed rate (kg/ha)				
50	23857	13250	10607	1.80
75	25427	14500	10927	1.75
CD at 5%	NS	-	NS	-

Heliothermal units (HTU) and heliothermal use efficiency (HTUE)

The HTU, also being an important factor of crop growth, calculated from the weather data at Ludhiana are presented in Table-3. The HTU available to the crop from it's sowing to physiological maturity were higher for the crop sown on the June 10 sowing as compared to the June 25 and July 10 sowing. The HTUE decreased progressively with delayed sowing to 10 July in both the years except 25 June sowing in 2006 which gave the highest HTUE. The greater reduction in HTUE under delayed sowing situations may be attributed to the decline in the yield due to decrease in growing season length. Similar results of declining HTUE with delaying sowing of corn from first fortnight of June to first fortnight of July have been reported by (11).

Economics

Among the different sowing dates, the highest gross and net returns were recorded in June 10 sowing which were on par with those obtained in June 25 sowing but significantly higher than July 10 sowing (Table-4). Bed planting recorded the highest gross returns, net returns and B:C ratio however the results were non-significant. Higher net return with ridge sowing of soybean is also reported by (12). As regards seed rates, the gross returns, net returns and B:C ratio were on par in 50 and 75 kg/ha. It has also been reported that seed rates of 50 and 62.5 kg/ha in soybean were on par for economics (5).

CONCLUSION

It is concluded that the crop sown on June 10 accumulated the highest growing degree days and heliothermal units which resulted in higher heat use efficiency for grain and stover production and higher heliothermal unit use efficiency over June 25 and July 10 sowings. Flat sowing of the crop at 45 cm or 60 cm row spacing and bed planting using seed rate of 50 or 75 kg/ha resulted in almost similar heat use efficiency for grain and stover production and heliothermal use efficiency. Early sowing resulted in better growth, yield attributes and higher irrigation water applied efficiency. Raised bed planting of soybean resulted in 33% saving of irrigation water applied over flat sowing. June 10 sowing, bed planting and seed rate of 75 kg/ha recorded the highest returns.

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