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Heat and water-use efficiency in summer mungbean (*Vigna radiata* L. Wilczek) under different thermal and moisture regimes

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ABSTRACT

The experiment was conducted during summer seasons of 2007 to 2009 with three sowing dates (20 March, 5 April and 20 April) and four termination of last irrigation (45, 50, 55 and 60 days after sowing) to study the growth and yield of mungbean as influenced by thermal and moisture regimes at Ludhiana. The highest grain yield (1474 kg ha^{-1}) was recorded in April 5 sowing date. The delayed sowing caused early maturity but increased water use. The maximum heat accumulation as well as heat use efficiency was reduced after April 5 sowing. Among the irrigation treatments, the delay in termination of last irrigation had increased crop duration, yield as well as water and heat use efficiencies.

Key words: Agrometeorological indices, irrigation, sowing date, mungbean, water use

Mungbean (*Vigna radiata* L. Wilczek) is an important pulse crop and is grown in an area of 3.42 million ha with production of 1.70 million tonnes in India (Anonymous, 2013). This crop is becoming popular among the farmers of Punjab especially as summer crop and it is grown in an area of about 50,000 hectares (Anonymous 2015). Sowing dates plays an important role for realization of the potential yield of this crop (Panwar and Sharma, 2004; Singh *et al.*, 2010). Very early sowing of summer mungbean can reduce the germination whereas delayed sown crop can be damaged by the monsoon rains during end June. Many studies have been conducted in Indo-Gangetic Plains (IGP) of India and concluded that optimum sowing window of this crop is March 20 to April 20. However the recommended sowing window under Punjab ecology is from 20 March to April 10 (Anonymous, 2015). Irrigation management is an important factor for getting optimum yield under different sowing dates. So termination of last irrigation is an important factor to determine the productivity of this crop which can help for timely maturity of this crop before the start of the rainy season in IGP of India. So, the present investigation was planned to study the effect of sowing time and termination of last irrigation on maturity, water use and productivity of summer mungbean.

MATERIALS AND METHODS

The field experiment was conducted at the Punjab Agricultural University, Ludhiana (36°56' N, 75°52' E and altitude 247 m), India during summer season of 2007, 2008 and 2009. The soil of the experimental field was loamy sand, low in organic carbon (0.25%) and medium in available phosphorus (15.5 kg P_2O_5 ha^{-1}) and potassium (230 kg K_2O ha^{-1}). The rainfall of 77.0 mm, 294.4 mm and 53.4 mm was received during the cropping seasons of 2007, 2008 and 2009, respectively.

The experiment, comprised of twelve treatment combinations with three sowing dates (20 March, 5 April and 20 April) as main plot and four termination of last irrigation (45, 50, 55 and 60 days after sowing) as sub plot, was conducted in split plot design with three replications. Measured quantity of water at 75 mm was applied in each post sowing irrigation. An irrigation of 100 mm was also applied before sowing of the experiment. Five post sowing irrigations were applied in all the sowing dates with termination of last irrigation at 45 and 50 DAS whereas termination of last irrigation at 55 and 60 DAS treatments, received six irrigations. Mungbean cultivar SML 668 was sown as per sowing dates and recommended package of practices was followed for the cultivation of the crop.

The data on plant height and pods per plant were collected from randomly selected five plants per plot at the time of harvest. Twenty pods per plot were selected to record data on grains per pod. From the total produce of each plot, 100-seeds were counted and weighed to express 100-seed weight. The crop was harvested when the pods

Table 1: Plant height, yield attributes, yields, harvest index and days to maturity of summer mungbean as influenced by sowing date and termination of last irrigation (Pooled mean of three years)

Treatment	Plant height (cm)	Branches plant^{-1}	Pods plant^{-1}	100-seed weight (g)	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index (%)	Days to maturity
Sowing date								
20 March	34.2	4.77	21.0	6.32	3452	1371	42.8	64.6
5 April	42.7	5.27	23.2	6.21	4083	1474	38.8	60.4
20 April	43.8	5.14	19.2	6.00	3621	1203	34.0	57.9
C.D. 5%	2.1	0.14	1.9	0.13	225	84	-	1.2
Termination of last irrigation (DAS)								
45	35.8	4.61	17.7	6.07	3226	1127	36.2	57.6
50	39.2	5.03	20.2	6.08	3655	1286	36.6	60.4
55	41.6	5.15	22.6	6.25	3894	1442	39.2	61.9
60	44.4	5.44	23.9	6.31	4100	1542	40.5	64.0
C.D. 5%	3.5	0.30	1.1	0.12	290	75	-	0.8
Interaction	NS	NS	NS	NS	NS	NS	-	1.4

DAS – days after sowing

were matured; the bundles were sun dried for few days and then threshed manually. The data on biological and grain yield were collected at the time of harvest. Water use was calculated by including rainfall and irrigation water.

Data on days to maturity were recorded. The growing degree-days (GDD) were computed by considering the base temperature (T_b) of 10°C. GDD and helio-thermal units (HTU) were calculated using weather data collected from Meteorological Observatory, Punjab Agricultural University, Ludhiana as explained by Ram *et al*. (2012). Heat use efficiency (HUE) and helio-thermal use efficiency (HTUE) were calculated by dividing grain yield with GDD and HTU, respectively.

All the data collected were subjected to analysis of variance (ANOVA) using the CPCS 1 statistical package. The comparison of treatment means was made by critical difference (CD) at $p = 0.05$. Pooled analysis of three years was done for presenting the data.

RESULTS AND DISCUSSION

Yield and yield attributes

Sowing dates : Based on the pooled mean basis, April 20 sowing recorded the tallest plant which was statistically at par with April 5 but significantly higher than March 20 (Table 1). The taller plant in late sowing might be due to higher temperature prevailed during later sowing dates which is considered to be beneficial for this crop. The highest branches per plant were recorded in April 5 sowing date, which was significantly higher than March 20 sowing but were statistically on par with April 20 sowing. The pods per plant recorded in April 5 sowing were significantly higher than that recorded in other sowing dates. However, pods per plant recorded in March 20 and April 20 were statistically at par with each other. The highest pods per plant recorded in April 5 sowing might be due to higher branches per plant. Singh *et al*. (2015) also reported higher pods per plant in March 25 sowing date. The sowing date has considerable effect on the 100-seed weight of mungbean crop. Earlier sowing date of March 20 produced bolder grains which were statistically at par with the April 5 sowing. The higher 100-seed weight recorded in March 20 sowing might be due to more number of days used by the crop to mature and grain filling period was prolonged in earliest sowing date.

The highest biological yield was recorded in April 5 which was significantly higher than March 20 and April 20 sowing dates. The biological yield recorded in March 20 and April 20 sowing dates were statistically similar. April 5 sowing gave significantly higher grain yield than March 20 and April 20 sowing. The grain yield recorded in March 20 was significantly higher than April 20 sowing. There was 15.2 and 7.0% reduction in biological and grain yield respectively recorded by deviation of sowing from April 5 to March 20. Similarly April 20 sowing recorded 12.2% reduced yield than March 20 sowing. Higher grain yield in April 5 sowing might be due to higher pods per plant. So April 5 was found to be the optimum sowing time of summer

Table 2: Water use, water-use efficiency, accumulated GDD, HUE, accumulated HTU and HTUE of summer mungbean as influenced by sowing date and termination of last irrigation(Pooled mean of three years)

Treatment	Water use (mm)	Water-use efficiency (kg grain $ha^{-1}mm^{-1}$)	Accumulated GDD (^{0}C day)	HUE of grain with GDD(kg ha^{-1} ^{o}C^{-1} day^{-1})	Accumulated HTU (^{o}C day)	HTUE grain for production (kg HTU^{-1})
Sowing date						
20 March	511.8	2.68	1129.9	1.21	10836.3	0.127
5 April	562.0	2.62	1172.9	1.26	11077.4	0.133
20 April	587.7	2.05	1213.3	0.99	10764.8	0.112
C.D. 5%	45.6	0.39	35.8	0.17	NS	NS
Termination of last irrigation (DAS)						
45	530.0	2.13	1100.4	1.03	10384.8	0.109
50	549.3	2.34	1160.3	1.11	10721.3	0.120
55	551.2	2.62	1192.3	1.21	11028.7	0.131
60	584.9	2.64	1235.0	1.25	11436.4	0.135
C.D. 5%	28.8	0.17	19.8	0.07	NS	NS
Interaction	NS	NS	NS	NS	NS	NS

DAS – days after sowing

mungbean to get high yield. Singh *et al*. (2015) also reported higher grain yield in end March sowing date. The late sowing of the crop from March 20 to April 5 and April 20, recorded the 4.2 and 6.7 days reduction in the maturity period of the crop, which might be due to higher temperature conditions under delayed conditions. The higher harvest index recorded in March 20 sowing was due to less biological yield and higher grain yield.

Termination of last irrigation : The taller plants were recorded in termination of last irrigation at 60 DAS which was significantly taller than all other termination of last irrigation treatments except 55 DAS (Table 1). The minimum plant height was recorded in termination of last irrigation at 45 DAS which was due to earlier termination of irrigation and less water use. With delayed termination of last irrigation increase in plant height was recorded at each increased level. It might be due to desirable irrigation requirement for summer crop at later stages. Branches per plant were increased with delaying in termination of last irrigation. Termination of last irrigation at 45 DAS was significantly different from termination of last irrigation at 50 DAS. The higher branches per plant with delayed termination of last irrigation might be due to more plant height and more water available at later stages when temperature was higher. Pods per plant played an important role to realize grain yield of summer mungbean crop. The highest pods per plant were recorded in termination of last irrigation at 60 DAS which was significantly higher than all other levels of termination of last irrigation. The higher pods per plant in later termination of last irrigation might be due to higher branches per plant and more water available for their development.

The 100-seed weight recorded in termination of last irrigation at 60 days after sowing was significantly better than termination of last irrigation at 45 and 50 DAS treatments but statistically at par with termination of last irrigation treatment of 55 DAS. The minimum 100-seed weight was recorded in termination of last irrigation at 45 DAS. It might be due to grain filling under drought-like conditions due to earlier termination of irrigation. Termination of last irrigation at later stages might have enhanced the mobilization of photosynthates to the developing grains.

The biological yield was recorded to be the highest in termination of last irrigation at 60 DAS, it was statistically at par with termination of last irrigation at 55 DAS but significantly higher than all other treatments. There was significant increase in biological yield with each step in termination of last irrigation from 45 to 60 DAS. The biological yield increase from 45 to 60 DAS was to the tone of 27.1%. The grain yield was found to be the highest in termination of last irrigation at 60 DAS, it was significantly superior to all other termination of last irrigation treatments. The highest grain yield of 1542 kg ha^{-1} was recorded in termination of last irrigation at 60 DAS which was 38.8, 19.9 and 6.9% higher than termination of last irrigation at 45, 50 and 55 DAS respectively. The highest grain yield in termination of last irrigation at 60 DAS might be due to higher irrigation water applied and higher pods per plant and 100-seed weight. The harvest index was the highest in termination of last irrigation at 60 DAS which might be due to higher grain yield in this treatment. With the delayed application of last irrigation at 60 DAS, the maturity was prolonged by 6.4, 3.6 and 2.1 days as compared to termination of last irrigation at 45, 50 and 55 DAS, respectively, which might be due to indeterminate nature of the crop.

Water and heat use efficiency

Sowing dates : The water use was increased with delayed sowing (Table 2). The highest water use (587.7 mm) was recorded in April 20 sowing which was 14.8 and 4.6% higher than March 20 and April 5 sowing respectively. Higher water use in later sowing dates might be due to high temperature and potential evapotranspiration prevailed in the study location. The water use efficiency in March 20 and April 5 sowing was statistically at par with each other. It might be due to low water use in March 20 sowing date and higher grain yield in April 5. April 20 sowing recorded significantly less water use efficiency than other sowing dates due to less grain yield (Table 1.).

The results show that April 20 sowing of crop accumulated the highest GDD which was significantly higher than April 5 and March 20. April 5 recorded higher GDD than March 20 sowing. April 20 sowing accumulated 3.4 and 7.4 per cent higher GDD than April 5 and March 20 sowing, respectively. This may be due to progressive increase in temperature with delayed sowing. The grain HUE was the highest in April 5 sowing which was statistically at par with March 20 but significantly higher than April 20 sowing. It might be due to less grain yield under delayed sowing (Table 1).

The HTU available to the crop and HTUE was the highest in April 5 sown crop whereas lowest HTU and HTUE was recorded in April 20 sown crop. On the pooled mean basis, the HTU recorded in April 5 sowing crop were 2.9 and 2.2% higher than April 20 and March 20 sowing, respectively. Similarly, HTUE in April 5 recorded 4.7 and 18.7% higher than March 20 and April 20 sowing. Higher HTUE in April 5 might be due higher grain yield.

Termination of last irrigation : The water used was increased from 530.0 mm in 45 DAS to 549.3, 551.2 and 584.9 mm in termination of last irrigation at 50, 55 and 60 DAS respectively. Increased water use with delayed termination of last irrigation might be due to more number of irrigations applied to these treatments. Sheoran *et al*. (2001) reported that application of two irrigations, at 20 and 45 days after sowing (DAS), significantly increased the consumptive use and grain yield but decreased water use efficiency as compared to application of one irrigation at 20 or 45 DAS. All the interaction effects were not significant.

Termination of last irrigation also influenced GDD and HUE. The highest GDD and HUE was recorded in termination of last irrigation at 60 DAS (1235 and 1.25). The HUE and GDD at termination of last irrigation at 60 DAS was statistically at par with 55 DAS. However the lowest GDD and HUE were recorded in termination of last irrigation at 45 DAS (1100.4 and 1.03). Similarly, Singh *et al.* (2010) also reported higher GDD and HUE in early sowing of mungbean. The highest HTU was recorded in termination of last irrigation at 60 DAS which was 10.1, 6.7 and 3.7% higher than termination of irrigation at 45, 50 and 55 DAS, respectively. Similarly, HTUE recorded with termination of last irrigation at 60 DAS was 23.8, 12.5 and 3.05% higher than recorded in 45, 50 and 55 DAS respectively. All the interactions were non-significant.

CONCLUSION

It can be concluded that high grain yield can be obtained by sowing summer mungbean between March 20 and April 5. In delayed sowing of mungbean after April 5 its maturity can coincide with early monsoon which generally resulted in lower grain yield. Although termination of last irrigation at 60 DAS increased the grain yield but it also delayed the maturity of the crop by 2.1-6.4 days and increased the water use. So, for April 5 or 20 sown crop, the last irrigation should be terminated around 50-55 days after sowing for timely maturity of the crop.

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