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Phenological behaviour of *gobhi sarson* (*Brassica napus* L.) and thermal indices as influenced by drip irrigation and fertigation schedules under semi-arid subtropical conditions of Punjab

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ABSTRACT

A field experiment was conducted during *rabi* 2016-17 and 2017-18 at the Research Farm of Department of Agronomy, Punjab Agricultural University, Ludhiana, to study the phenological behaviour of *gobhi sarson* (*Brassica napus* L.) and thermal indices as influenced by drip irrigation (60, 80 and 100% of cumulative pan-evaporation, CPE) and fertigation schedules (60, 80 and 100% recommended dose of fertilizers, RDF) in comparison with conventional flood irrigation and manual application of fertilizers *i.e.* absolute control. The pooled data revealed that *Brassica* irrigated through drip at 100% of CPE took maximum number of days to attain 50% flowering, 50% siliqua formation and physiological maturity, followed by 80 and 60% of CPE. Higher fertigation levels also delayed the number of days taken to attain various phenological stages. Maximum seed yield was observed at 100% of CPE with 100% RDF which was statistically at par with 100% of CPE with 80% RDF and 80% of CPE with 80 or 100% RDF, but significantly higher than absolute control. Maximum accumulation of heat units along with heat use efficiency (1.49 kg grains ha^{-1} °C day $hour^{-1}$) was also obtained at 100% of CPE with 100% RDF.

Key words: *Gobhi sarson*, drip irrigation, fertigation, phenology, thermal indices

Temperature plays a vital role in growth and development of crop plants by regulating their physiological, chemical and biological processes. Each plant requires a certain specific amount of heat units to attain a developmental stage or to move from one developmental stage to another (Kumar *et al.*, 2014). Accumulated heat units or GDD (a thermal time concept) is the amount of heat energy accumulated by crop plants over a period of time and is based on the principle that actual time required by crop plants to attain a particular phenological stage is directly related to temperature ranged between base temperature (below which no growth takes place) and optimum temperature. Heat unit concept was generally applied to correlate phenological development in crops to predict crop maturity dates (Kiran and Chimmad, 2018). Consequently, agro-climatic models based on thermal indices such as growing degree days (GDD) which relate temperature to crop growth and dry matter production can effectively be used for prediction of growth and yield based on weather parameters (Rao *et al.,* 1999).

Gobhi sarson (*Brassica napus* L.), being a temperate crop, grows well under temperature ranging from 15-25°C. The germination is quick at 27°C, but further growth and development needs a cool temperature between 15-20°C and at maturity, a high temperature up to 28-30°C is desired (Joshi, 2015). Unlike other crops, it also requires accumulation of definite amount of heat units to achieve various phonological stages *viz.* flowering, siliqua initiation and crop maturity. Although accumulation of degree days for each development stage is relatively constant and is independent of cultural practices, but irrigation along with fertigation may modify it significantly. Under irrigated conditions, maturity of *Brassica* crop gets exaggerated due to frequent irrigation and fertigation schedules even at lower doses. Besides this, drip irrigation and fertigation reduces the wastage of water and chemical fertilizers, optimizes the nutrient use by applying them at critical stages and at proper place and time, which finally increase water and nutrient use efficiency (Sandal and Kapoor, 2015). Therefore, it becomes imperative to have knowledge of exact duration

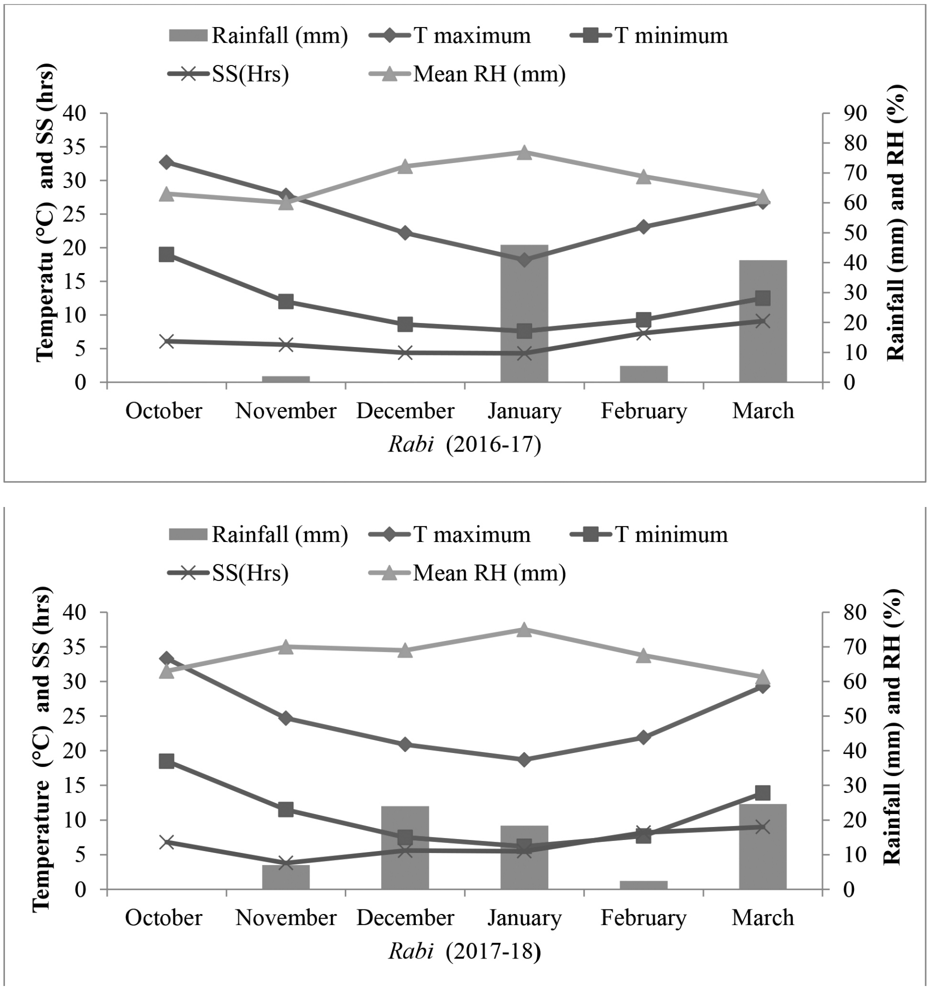

Fig. 1: Meteorological data during crop growing seasons (*Rabi* 2016-17 and 2017-18)

of phenological stages and accumulation of thermal indices under drip irrigation and fertigation and their impact on crop maturity and yield. Keeping this in view, the present investigation was carried out to study the effect of drip irrigation and fertigation schedules on phenology of *gobhi sarson* and thermal indices under semi-arid, sub-tropical climate of Punjab, India.

MATERIAL AND METHODS

The field experiment was conducted at the Research Farm of Department of Agronomy, Punjab Agricultural University, Ludhiana situated at 30°54'N latitude and 75°48'E longitude with an elevation of 247 m above mean sea level during the *rabi* seasons of 2016-17 and 2017-18. This part of Punjab features a semi-arid, sub-tropical climate with cold winters and hot summers. The mean monthly maximum temperature ranged between 18.2-32.7 and 18.7-33.3°C, mean monthly minimum temperature 7.6-19.0 and 6.2-18.5°C, whereas mean relative humidity remained 60.1-76.9 and 61.3-75.0% during 2016-17 and 2017-18, respectively (Fig. 1). A total rainfall of 94.0 and 76.4 mm was received during both the years, respectively.

The soil of the experimental field was loamy sand in texture having 1.58 g cm^{-3} average bulk density of soil profile from 0-30 cm depth. The experiment was conducted in randomized complete block design keeping combination of three irrigation levels at 60, 80 and 100% of cumulative pan evapo-transpiration (CPE) and three fertigation levels with 60, 80 and 100% recommended dose of fertilizers (RDF) comprising of nine treatments under drip irrigation along with one conventional flood irrigation and manual application of fertilizers (absolute control). The gross size of the experimental plot was 5.6 m x 3 m and in each plot, six rows of *gobhi sarson* L.

Table 1: Effect of drip irrigation and fertigation schedules on phenological stages of *gobhi sarson var*. GSC-7 (pooled data)

Fertigation Schedules (FS)	Irrigation Schedules (IS)				Absolute control
	60% of CPE	80% of CPE	100% of CPE	Mean	
Days taken to emergence					
60% RDF	5.6	5.5	5.7	5.6	5.6
80% RDF	6.0	5.6	5.4	5.7	
100% RDF	6.2	5.8	5.3	5.8	
Mean	5.9	5.6	5.5		
LSD (p=0.05)	IS= NS FS= NS IS x FS= NS IS x FS v/s absolute control=NS				
Days taken to 50% flowering					
60% RDF	81.0	82.5	83.0	82.2	80.7
80% RDF	82.0	84.0	84.9	83.6	
100% RDF	82.5	84.7	85.9	84.4	
Mean	81.8	83.7	84.6		
LSD (p=0.05)	IS= 0.3 FS=0.3 IS x FS=0.5 IS x FS v/s absolute control=0.4				
Days taken to 50% siliqua formation					
60% RDF	94.9	95.9	96.7	95.8	95.2
80% RDF	95.4	97.4	98.5	97.1	
100% RDF	96.0	98.4	99.5	98.0	
Mean	95.4	97.2	98.2		
LSD (p=0.05)	IS=0.5 FS=0.5 IS x FS=0.9 IS x FS v/s absolute control=0.7				
Days taken to physiological maturity					
60% RDF	133.5	137.2	138.4	136.4	133.2
80% RDF	134.2	139.4	141.7	138.4	
100% RDF	135.5	140.2	142.0	139.3	
Mean	134.4	138.9	140.7		
LSD (p=0.05)	IS=0.2 FS=0.2 IS x FS=0.4 IS x FS v/s absolute control=0.3				

(variety GSC-7) were sown at the recommended seed rate of 3.75 kg ha^{-1} with hand drill in rows 45 cm apart. Irrigation schedules were started at one month after sowing and thereafter applied at a fixed interval of six days. The fertigation schedules (150 kg N and 30 kg P_2O_5 ha^{-1}) were started after 15 days of sowing and completed in 10 splits with an interval of 6 days. In flood irrigated plot, half N and full P_2O_5 was applied before sowing and the remaining half N was applied with first irrigation.

Observations on important phenophases *viz*. emergence, 50% flowering, 50% siliqua formation and physiological maturity were recorded. The data on meteorological parameters such as rainfall, relative humidity, maximum and minimum temperature, bright sunshine hours and day length were obtained from Agro-meteorological Observatory, Punjab Agricultural University, Ludhiana (Fig. 1).

Heat use

The growing degree days (GDD) were calculated using the following expressions.

$$GDD = (T_{max} + T_{min})/2 - T_{base}$$

Where, T_{max}= Daily maximum temperature (ºC); T_{min}= Daily minimum temperature (ºC); T_{base}= Base temperature for *gobhi sarson* was taken as 5ºC.

Heat use efficiency (HUE)

HUE (kg grains ha^{-1} ºC day^{-1}) = Grain yield (kg ha^{-1})/ AGDD (ºC day^{-1})

Where, AGDD (ºC day^{-1}) = Accumulated growing degree days

Statistical analysis

Analysis of variance was done to investigate the effect of drip irrigation and fertigation schedules on various recoded parameters of *gobhi sarson* and their interaction. The variance was analyzed using SAS software 9.3, SAS institute Ltd, USA and the difference between means was compared with Fisher's least significant difference (LSD) test at 5% probability level.

RESULTS AND DISCUSSION

Crop phenology

Periodic occurrence of different developmental stages in the life cycle of a crop plant in relation to environmental conditions is known as crop phenology. Effect of drip irrigation and fertigation schedules were found to be significant for all the phenological stages except for number of days taken to emergence as none of the treatment was applied to the field as well as to the seeds at the time of sowing (Table 1). The *Brassica* crop drip irrigated at 100% of CPE took the maximum number of days to attain 50% flowering (85 days), 50% siliqua formation (98 days) and physiological maturity (141 days), which was significantly higher than 80 and 60% of CPE. Higher fertigation levels also delayed the number of days taken to attain various phenological stages. Scheduling at 100% RDF took maximum time to achieve 50% flowering, 50% siliqua formation and physiological maturity which were significantly higher than 80 and 60% RDF. Crop raised at lower irrigation levels along with lower doses of fertigation might have challenged by moisture and nutrient stress, therefore to mitigate the stress led to early flowering, which further facilitated earlier siliqua formation and physiological maturity. Similarly, Kingra *et al.,* (2011) documented higher number of days taken by crop to attain physiological maturity under increased frequency of irrigation in wheat. Moreover, nitrogen favoured late completion of vegetative phase of the plant, therefore, late mobilization of assimilates to the sink, facilitated higher number of days taken to attain physiological maturity with increased nitrogen levels. Likewise, Kaur *et al*., (2017) revealed that higher doses of nitrogen resulted in delayed number of days taken to 50% flowering and maturity in *gobhi sarson.* Nevertheless, delayed maturity was also reported by Ahmad *et al.* (2006) with increasing nitrogen rate progressively.

Interactions between drip irrigation and fertigation schedules were also found significant for all the phenological stages (Table 1). All treatment combinations acquired significantly more time to attain 50% flowering, 50% siliqua formation and physiological maturity as compared to absolute control except for 60% of CPE with 60% RDF which was statistically at par with absolute control for days taken to 50% flowering and physiological maturity. The crop irrigated with flood method might have undergone moisture stress, as water is available at one growth stage might lead to moisture stress at other stage. Thus, the crop irrigated by flood method resulted in early flowering to mitigate that stress.

Heat use

Drip irrigation and fertigation schedules significantly influenced accumulation of heat units to attain physiological maturity in *Brassica* (Table 2). Drip irrigation at 100% of CPE accumulated significantly higher heat units, (1579°C day) which were statistically more than 80 and 60% of CPE. Thus, decreased levels of drip irrigation from 100 to 60% of CPE resulted in decreased accumulation of thermal indices to attain maturity. Similar results were documented by Dar *et al.,* (2018) in wheat. The reduction in accumulation of heat units was due to reduction in number of days taken to attain physiological maturity under water stress conditions (Brar *et al.,* 2016). Correspondingly, the requirement of heat units was higher for 100% RDF than 80 and 60%, to attain physiological maturity. This could be the fact that higher nitrogen level increased vegetative growth and delays maturity. Interaction between drip irrigation and fertigation schedules was also found to be significant. Among treatment combinations, drip irrigation at 100% of CPE with 100% RDF accumulated significantly higher heat units to attain physiological maturity, which was statistically similar with 100% of CPE and 80% RDF but significantly higher than rest of the treatment combinations. All drip irrigation and fertigation treatments significantly require higher accumulated thermal indices to attain maturity over absolute control except 60% of CPE with 60% RDF, which was statistically similar with absolute control.

Seed yield

Gobhi sarson cv. GSC-7 responded significantly to both irrigation and fertigation treatments. The results pertaining to the seed yield under drip irrigation and fertigation scheduling (Table 2) revealed that drip

Table 2: Effect of drip irrigation and fertigation schedules on heat use efficiency of *gobhi sarson var.* GSC-7 (pooled data)

Fertigation schedules (FS)	Irrigation schedules (IS)				Absolute control
	60% of CPE	80% of CPE	100% of CPE	Mean	
		Heat use (ºC day)			
60% RDF	1450	1504	1537	1497	1443
80% RDF	1465	1555	1595	1538	
100% RDF	1482	1567	1606	1551	
Mean	1466	1542	1579		
LSD (p=0.05)	IS=12.7 FS=12.7 ISxFS=21.9 ISxFS v/s Absolute control=16.4				
		Seed yield (kg ha^{-1})			
60% RDF	1710	1930	2000	1880	1830
80% RDF	1890	2250	2330	2157	
100% RDF	1940	2310	2390	2213	
Mean	1847	2163	2240		
LSD (p=0.05)	IS= 86.9 FS= 86.9 ISxFS=150.5 ISxFS v/s absolute control= 112.1				
		Heat use efficiency (HUE) (kg grains ha^{-1} ºC day^{-1})			
60% RDF	1.18	1.28	1.30	1.25	1.27
80% RDF	1.29	1.45	1.46	1.40	
100% RDF	1.31	1.47	1.49	1.42	
Mean	1.26	1.40	1.42		

Table 3: Correlation and regression coefficients between accumulated growing degree days (AGDD) and seed yield of *gobhi sarson* at different phenological stages

Phenological stages	Correlation (r)	Regression (b)	Coefficient of determination (r^2)
50% flowering	0.95*	13.25*	0.90
50% siliqua formation	0.95*	15.79*	0.91
Physiological maturity	0.96*	3.85*	0.92

*Significant at 5% level

irrigation at 100% of CPE recorded maximum seed yield (2240 kg ha^{-1}), which was statistically at par with 80% of CPE (2163 kg ha^{-1}) but 21.3% higher than 60% of CPE (1847 kg ha^{-1}) in pooled data. The crop irrigated through drip at 100% of CPE meant that the crop was exposed to greater availability of moisture at all the growth stages, whereas 60% of CPE might have caused moisture stress. Therefore, there is drastic reduction in seed yield at 60% of CPE as compared to irrigation at 100 and 80% of CPE. In case of fertigation, 100% RDF resulted in maximum seed yield of 2213.3 kg ha^{-1}, which was statistically similar with 80% RDF (2157 kg ha^{-1}) but 17.7% higher than 60% RDF (1880 kg ha^{-1}). The increase in seed yield with increase in fertilizer doses has also been reported by Rathod *et al.,* (2014). Among treatment combinations, maximum yield was produced under irrigation at 100% of CPE with fertigation at 100% RDF which was 30.6% higher than absolute control. All treatment combinations recorded significantly higher seed yield as compared to absolute control except 60% of CPE and 60% RDF. The results were also endorsed by the findings of Sinha *et al.,* (2017) and Sahoo *et al.,* (2018).

Heat use efficiency (HUE)

Heat use efficiency is an indicator of number of grains produced per unit accumulated heat unit. Maximum HUE was recorded when crop was drip irrigated at 100% of CPE (1.42 kg grains ha^{-1} °C day^{-1}), followed by 80% (1.40 kg grains ha^{-1} °C day^{-1}) and 60% (1.26 kg grains ha^{-1} °C day^{-1}). Among fertigation schedules, maximum HUE was observed at 100% RDF (1.42 kg grains ha^{-1} °C day^{-1}) and minimum at 60% (1.25 kg grains ha^{-1} °C day^{-1}). In case of drip-fertigation levels, maximum HUE (1.49 kg grains ha^{-1} °C day^{-1}), was obtained at 100% of CPE with 100% RDF and minimum at 60% of CPE with 60% RDF followed by absolute control. This could be the fact that lower levels of nitrogen and irrigation schedules facilitates early maturity and minimum accumulation of heat units as compared to higher levels. Dar *et al.,* (2018) also reported decreased HUE with increased moisture deficit from FC15 to FC45 (depletion from field capacity) in wheat. The reduction in HUE with increase in moisture stress may be attributed to the reduction in yield under water stress conditions (Table 2).

Correlation and regression analysis

Simple correlation (r), regression (b) and coefficient of determination (r^2) among various parameters of *Brassica* revealed significant positive correlation of AGDD at 50% flowering stage with seed yield indicating the influence of temperature on *Brassica* yield (Table 3). Data further indicated that with each unit increased in AGDD at 50% flowering stage, seed yield increased by 13.25 units. AGDD at 50% flowering accounted for more than 90.0% variation in seed yield. Likewise, AGDD at 50% siliqua formation and physiological maturity accounted for 90.5 and 92.0% variation in seed yield, respectively. The accumulation of GDD during 50% siliqua formation and physiological maturity was found to be significantly and positively correlated with seed yield showing an increase of 15.79 and 3.85 units of seed yield with each unit increase in AGDD during both the stages, respectively.

CONCLUSION

To conclude this study, it has been observed that *gobhi sarson* cv. GSC-7 irrigated through drip at 100% of CPE with 100% RDF had taken maximum number of days to attain 50% flowering, 50% siliqua formation and physiological maturity. Higher levels of drip irrigation and fertigation schedule also increased the duration and amount of accumulated heat units, seed yield and heat use efficiency in all the treatments as compared to absolute control (flood irrigation and manual application of fertilizers) except 60% of CPE with 60% RDF. Further, it can be determined that treatment combination 80% of CPE with 80% RDF was found most efficient in terms of early maturity and statistically similar seed yield in contrast to 100% of CPE with 100% RDF.

Conflict of Interest Statement: The author(s) declare(s) that there is no conflict of interest.

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