Journal of Crop and Weed, 15(1): 24-28 (2019)

Productivity, phenology and heat unit accumulation of wheat (*Triticum aestivum* L.) as influenced by nitrogen management using green seeker

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Received: 06-04-2018; Revised: 27-01-2019; Accepted: 10-02-2019

ABSTRACT

The field experiment was conducted during Rabi 2014-15 and 2015-16 at the Punjab Agricultural University, Ludhiana, Punjab to study the effect of nitrogen (N) scheduling using GreenSeeker on phenology, heat unit accumulation viz growing degree days (GDD), helio-thermal units (HTU) and photo-thermal unit (PTU) and productivity of wheat. Experiment was laid out in complete randomized block design with 10 treatments [N doses 0, 120, 150 & 180 kg ha^{-1} and combinations of $N_{60}/N_{84}/N_{120\ kg\ ha}{}^{-1}$ + additional N as guided by GreenSeeker at second irrigation and at third irrigation] replicated thrice. The soil of the experimental site was low in organic carbon and nitrogen but medium in available phosphorus and potash. Nitrogen dose of 160/164 kg N ha^{-1} in three splits [i.e. 60 kg N ha^{-1} at sowing and 60 kg N ha^{-1} at first irrigation, and 40/44 kg N ha^{-1} at second irrigation as guided by GreenSeeker] and application of 137/130 kg N ha^{-1} in three splits [with 42 kg N ha^{-1} at sowing and 42 kg N ha^{-1} at first irrigation, and 53/46 kg N ha^{-1} as guided by GreenSeeker] at second irrigation recorded longer phenological stages, higher agrometeorological indices and better wheat yield than application of 120 kg Nha^{-1} but similar to application 150 kg Nha^{-1}. Application of 126/113 kg N ha^{-1} [with schedule of 40 kg N ha^{-1} at sowing and 40 kg N ha^{-1} at first irrigation, 40 kg N ha^{-1} at second irrigation and 6/13 kg N ha^{-1} as guided by Green Seeker] at third irrigation resulted in saving of 9-24 kg N ha^{-1}, longer phenophases, agrometeorological indices, heat use efficiency and higher yield in comparison to 150 kg N ha^{-1}.

Keywords: GDD, green seeker, HTU, Phenology, PTU and wheat

Wheat (*Triticum aestivum* L.) is the predominately grown cereal crop in India, having 93.5 million tonnes production from 30.2 mha area with 30.93 q ha^{-1} productivity (Anon., 2016). Weather and climate greatly influence the agricultural productivity in any region being regulated by the prevailing climatic conditions *viz.*, temperature, rainfall, light intensity, radiation, sunshine duration *etc*. (Goswami *et al.*, 2006). Of all the environmental factors, temperature is most pivotal which effects the growth and development of crop plants especially phenology and yield. The heat unit or growing degree days (GDD) was proposed to explain the relationship between growth duration and temperature. This concept assumes a direct and linear relationship between growth and temperature. Every crop has a definite temperature requirement to attain phenological stages. The photothermal unit concept provides a reliable index for the progress of the crop that can be used to predict the yield of any crop (Pal *et al.*, 2013). Though accumulation of GDD and photo-thermal units (PTU) for each developmental stage is relatively constant (Phadnawis and Saini, 1992) but certain management practices could modify them. Nitrogen is the most important nutritional element required by plants. Applications of nitrogenous fertilizers prolongs phenophases and thus require more heat units in comparison to the crop supplied with less amount of fertilizer. N application at later growth stages has also been reported to extend grain filling period and thus increasing grain yield (Kaur and Pannu, 2008). Optimized nitrogen management through different approaches *viz*. site specific nutrient management using GreenSeeker can be used for increasing yield and improving nutrient use efficiency of wheat. GreenSeeker guided fertilizer N application at 2nd or 3rd irrigation events can lead to improved fertilizer N-use efficiency with no reduction in yield through savings in total fertilizer N application as compared with prevalent blanket recommendations and higher recovery efficiency (Singh *et al.*, 2011). Knowledge gap exists on use of GreenSeeker for scheduling nutrients in wheat and its impact on accumulated heat units. Thus, the present study was conducted to evaluate the effect of different nitrogen schedules using need based N application as guided by GreenSeeker on heat units and their relation with grain yield.

MATERIALS AND METHODS

Characterization of the experimental site

The experiment was established at Research Farm of the Punjab Agricultural University, Ludhiana (30^0 56′ N latitude and 75^0 52′ E longitude and at an altitude of 247 metres above mean sea) during *Rabi* season of 2014-15 and 2015-16. The soil of the experimental site was loamy sand with normal electrical conductivity, neutral pH, low in organic carbon, and low in available nitrogen, medium in phosphorous and potassium. It has sub-tropical and semi-arid type climate. The meteorological

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data recorded from the Agro-meteorological observatory of the Punjab Agricultural University, Ludhiana revealed that total 213 mm rainfall was received during *Rabi* 2014-15 in 26 days whereas during *rabi* 2015-16 it was 71.4 mm in 17 days. Total sunshine hours recorded during *rabi* seasons of 2014-15 and 2015-16 were 981.6 and 938.3 hours, respectively during the time period of experimentation.

Description of experimental design, treatments and agro-meteorological indices

The experiment was replicated thrice and was laid out in complete randomized block design with 10 treatments [No N control, three blanket fertilizer applications (N_{120}, N_{150}, and N_{180}) in three equal splits, three treatments having fertilizer application in three splits upto 2nd irrigation using GreenSeeker (GS) : N_{60} + GS(second irrigation)$_{2nd\ irri}$ (30:30:61/51 kg ha^{-1}), N_{84} + $GS_{2nd\ irri}$ (42:42:53/46 kg ha^{-1}), N_{120} + $GS_{2nd\ irri}$ (60:60:44/ 41 kg ha^{-1}) and three treatments having fertilizer application in four splits upto 3rd irrigation using GreenSeeker : N_{60} + GS(third irrigation)$_{3rd\ irri}$ (20:20:20:14/20 kg ha^{-1}), N_{84} + $GS_{3rd\ irri}$ (28:28:28:6/20 kg ha^{-1}), N_{120} + $GS_{3rd\ irri}$ (40:40:40:6/13 kg ha^{-1}). Sowing was done on November 11 in 2014 and on November 5 in 2015 at 20 cm row spacing using 100 kg seed ha^{-1}. Fertilizer application was done as per treatments, 62.5 kg P_2O_5 and 30 kg K_2O were applied as basal at the time of sowing. In treatments where fertilizer application was done using GreenSeeker at 2nd or 3rd irrigation, equation developed by Singh *et al.* (2011) was used for calculating the amount of fertilizer required.

Four and five irrigations were applied in 2014-15 and 2015-16 respectively. Harvesting was done on 16 April in 2015 and 11 April 2016. After threshing grains were weighed and presented in quintals per hectare. Data related to occurrences of phenological events (when 75 per cent of plants in the plots had reached the respective stage) was recorded on the basis of visual observations and analysed later. The daily meteorological data and days taken to phenological stages were used to compute the agro-meteorological indices like growing degree days (GDD), helio-thermal units (HTU) and photo-thermal unit (PTU) as suggested by (Monteith, 1984) whereas, phenothermal index (PTI) were computed as suggested by Singh *et al*. (2008) and heat use efficiency were calculated following Islam and Sikdar (2011).

Statistical analysis

Statistical analysis of the data was carried out using PROC GLM in SAS 9.4 software (SAS Institute, 2002). Multiple comparisons were made using ADJUST= TUKEY at p d” 0.05 to determine significant effects. The correlation was studied using PROC CORR and regression study is carried out using PROC REG, significant correlation and regression coefficient are marked.

RESULTS AND DISCUSSION

Phenology

Effect of different treatments on phenology was significant at p d” 0.05 (Table 1). No nitrogen control took minimum number of days to complete all phenological stages and to attain maturity. All treatments took statistically similar number of days to complete maximum tillering and ear emergence except control (Table 1). At later stages the amount of fertilizer applied and number of splits of application had an evident effect on phenological stages. Based on pooled analysis, N_{84} + $GS_{3rd\ irri(6/20)}$ and N_{120} + $GS_{3rd\ irri(6/13)}$ recorded the highest number of days to ear emergence (9 days more than

Table 1: Effect of nitrogen management schedules on grain yield and days taken to different phenological stages in different years

Treatments	Days taken to			
	Maximum tillering	Ear emergence	Anthesis	Maturity
Control	47 b	94 b	101 c	131 b
N_{120}	51 a	99 ab	106 bc	137 ab
N_{150}	51 a	100 a	109 ab	137 ab
N_{180}	53 a	101 a	113 ab	142 a
N_{60} + $GS_{2nd\ irri(61/51)}$	51 a	99 ab	108 abc	137 ab
N_{84} + $GS_{2nd\ irri(53/46)}$	51 a	99 ab	108 abc	137 ab
N_{120} + $GS_{2nd\ irri(44/41)}$	53 a	101 a	110 ab	139 a
N_{60} + $GS_{3rd\ irri(14/20)}$	51 a	101 a	108 abc	138 ab
N_{84} + $GS_{3rd\ irri(6/20)}$	50 a	103 a	110 ab	139 a
N_{120} + $GS_{3rd\ irri(6/13)}$	52 a	103 a	114 a	141 a

*Note: *Means with the same letter are not significantly different*

Table 2: Effect of nitrogen management schedules on heat unit accumulation, phenothermal index (PTI) , heat use efficiency (HUE) and grain yield

Treatment	At Maturity			Phenothermal index (PTI)			Heat use efficiency (kg ha^{-1} °Cday^{-1})	Grain yield (q ha^{-1})
	GDD	HTU	PTU	Ear emergence	Anthesis	Maturity		
Control	1398 b	7896 b	15088 b	7.7b	11.7b	13.6b	2.1c	28.8 e
N_{120}	1496 ab	8777 ab	16281 ab	8.1ab	12.8ab	14.4ab	3.7ab	54.5 abcd
N_{150}	1506 ab	8888 ab	16400 ab	8.2a	13.4a	14.6ab	3.8ab	57.2 abc
N_{180}	1597 a	9624 a	17535 a	8.3a	13.1ab	15.6ab	3.8ab	60.8 a
$N_{60} + GS_{2nd\ irri(61/51)}$	1505 ab	8871 ab	16394 ab	8.1ab	12.6ab	14.4ab	3.5ab	52.9 bcd
$N_{84} + GS_{2nd\ irri(53/46)}$	1509 ab	8894 ab	16436 ab	8.2a	12.5ab	14.6ab	3.8ab	56.4 abcd
$N_{120} + GS_{2nd\ irri(44/41)}$	1540 ab	9115 ab	16822 ab	8.3a	13.2a	14.9ab	3.9a	59.7 ab
$N_{60} + GS_{3rd\ irri(14/20)}$	1531 ab	9113 ab	16708 ab	8.3a	12.4ab	14.7ab	3.3b	49.8 d
$N_{84} + GS_{3rd\ irri(6/20)}$	1537 ab	9133 ab	16784 ab	8.4a	13.2a	14.9ab	3.4ab	52.1 cd
$N_{120} + GS_{3rd\ irri(6/13)}$	1589 a	9567 a	17432 a	8.5a	13.3a	15.6a	3.7ab	58.6 abc

Note: Means with the same letter are not significantly different

control), these treatments were statistically on par with $N_{120} + GS_{2nd\ irri(44/41)}$, $N_{60} + GS_{3rd\ irri(14/20)}$, N_{180} and N_{150} but significantly higher than other treatments including control. Delayed anthesis recorded in $N_{120} + GS_{3rd\ irri(6/13)}$ which was significantly delayed than N_{120} and control but it was statistically at par with rest of the treatments. Anthesis to maturity is an important period for the grain filling of the crop. Treatments $N_{120} + GS_{3rd\ irri(6/13)}$ again recorded the highest days to maturity which was significantly better and 10 days more than no fertilizer N treatment. When the fertilizer application was carried out in three splits, the treatments with higher dose of fertilizer (N_{180} and N_{120}+$GS_{2nd\ irri}$ ($N_{164-161}$)) had an advantage of increment in number of days for completing life cycle, on the contrary when number of splits were increased to four, even treatment with lower doses [(N_{84}+$GS_{3rd\ irri}$ ($N_{90/104}$) and N_{120}+$GS_{3rd\ irri}$ ($N_{126/133}$)] had recorded statistically at par number of days taken to complete the phenology and all these treatments were significantly better than control. Kaur and Pannu, (2008) also reported significantly extended phenological stages when nitrogen was applied at later stages. Treatments N_{180}, $N_{120} + GS_{2nd\ irri(44/41)}$ and $N_{120} + GS_{3rd\ irri(6/13)}$ had got benefit of 10-14 days to earing and 8-11 days to maturity over no N control, thus increasing grain filling duration in these treatments additionally contributing to grain yield. Higher N doses or more splits keep the chlorophyll in shape so, more photosynthesis will be there, to fill the grains in longer duration (Min, 1980).

Agro-meteorological indices

Indices like GDD, HTU and PTU play an important role in predicting crop productivity. These parameters quantify the thermal heat requirement. GDD is used to express the relationship between period of every phenological stage and temperature degree. Heat unit accumulation (in terms of GDD, PTU, HTU) was significantly higher in fertilized conditions in comparison to unfertilized control which is due to longer period taken for all phenological stages to complete where optimum amount of fertilizer was applied (Table 1& 2). Treatments N_{180} and $N_{120} + GS_{3rd\ irri(6/13)}$ recorded significantly higher GDD, HTU and PTU as compared to control. Whereas the remaining treatments recorded numerically higher GDD, HTU and PTU in comparison to control but were statistically at par with it. This was due to higher application of nitrogen and increased number of splits with optimum nitrogen which had increased the number of calendar days for vegetative growth thus consequently increased time for completion of life cycle and aided in accumulation of higher GDD, HTU and PTU. Ram *et al.* (2012) has also reported higher GDD with longer phenological stages.

Table 3: Correlation and regression studies of grain yield (y) with different agro-meteorological indices(x)

Agro-meteorological indices(x)	Correlation coefficient	Regression coefficient	Adjusted R^2
GDD to maturity	0.85 *	0.142*	0.719
HTU to maturity	0.85 *	0.016*	0.730
PTU to maturity	0.85 *	0.012*	0.716

*p<0.001

The phenothermal index is expressed as degree-days per growth day. Treatment N_{150}, N_{84} + $GS_{2nd\ irri(53/46)}$, N_{84}+ $GS_{3rd\ irri(6/20)}$ and N_{120} + $GS_{3rd\ irri(6/13)}$ recorded significantly higher PTI at ear emergence and anthesis and were better than control. However, at maturity, treatments N_{180} and N_{120} + $GS_{3rd\ irri(6/13)}$ were significantly better than no N control in terms of PTI.

Grain yield and heat use efficiency

Wheat is exposed to a different weather conditions during its different phenological stages of growth that results in variable growth rate and yield. Agro-meteorological indices provide a reliable index for the progress of the crop to predict the yield of any crop. All the treatments comprising of fertilizer application were significantly better than control (Table 2). Comparing different nitrogen levels, treatment N_{180} recorded the highest grain yield which was statistically similar to N_{150} and N_{120}. Among the combinations of fixed N doses and N application with GreenSeeker at 2nd irrigation, the highest grain yield was recorded in N_{120}+$GS_{2nd\ irri}$ ($N_{120+44/41}$) which was statistically at par with N_{60}+$GS_{2nd\ irri}$ ($N_{60+61/51}$) and N_{84}+$GS_{2nd\ irri}$ ($N_{84+53/46}$). If the N application with fixed N doses and GreenSeeker were delayed to 3rd irrigation, treatment N_{120}+$GS_{3rd\ irri}$ ($N_{120+6/13}$) treatment recorded significantly better grain yield than both N_{60}+$GS_{3rd\ irri}$ ($N_{60+14/20}$) and N_{84}+$GS_{3rd\ irri}$ ($N_{84+6/20}$) treatments. Overall highest grain yield was recorded in N_{180} which was statistically similar to N_{120}, N_{150}, N_{60} or N_{84} $GS_{2nd\ irri}$, N_{120}+$GS_{2nd\ irri}$ ($N_{164/161}$) and N_{120}+$GS_{3rd\ irri}$ ($N_{126/133}$) but significantly better than rest of the treatments.

The higher grain yields recorded in these treatments might be due to application of higher dose of N and this higher dose of N led to elongation of different phenophases and higher GDD, HTU and PTU which ultimately gave more time to crop for photosynthesis and translocation thus higher yield.

Based on study of two years, the nitrogen application should be completed upto second irrigation. Grahmann *et al.*, (2014) also reported that N requirement for biomass and yield production has to be satisfied before applying N at later stages with purpose of increasing grain N content. Perusal of the data regarding grain yield only considering the amount of fertilizer used, treatments N_{84}+$GS_{2nd\ irri}$ ($N_{137/130}$) or N_{120}+$GS_{3rd\ irri}$ ($N_{126/133}$) are preferable over N_{180} as without significant reduction in yield, these treatments were saving upto 54 kg N fertilizer per hectare. Heat use efficiency was maximum in N_{120} + $GS_{2nd\ irri(44/41)}$ which was statistically at par with all other treatments except N_{60} + $GS_{3rd\ irri(14/20)}$ and no N control (Table 4). The possible reason could be lower yield in N_{60} + $GS_{3rd\ irri(14/20)}$ and no N control, thus has lower heat use efficiency.

Correlation and regression study

Grain yield is not an independent character, it is associated with different environmental factors like solar radiations, temperature, which are of immense importance. Their interactions with the growing environment of plant influence grain yield ,therefore, correlation and regression studies of yield with agro-meteorological indices are carried out.

It has been observed that grain yield holds a significant positive correlation with all indices. The coefficient of determination (r^2) indicated that 71.9 % of total variability in grain yield was due to its association with GDD accumulated upto maturity; while regression coefficient suggested that one unit increase in GDD will cause an increase of 0.142 q/ha increase in grain yield (Table 3). Kaur *et al.* (2016) had also observed a linear positive relation of agro-meteorological indices and grain yield with variable nitrogen application. This concept of regression studies of grain yield and heat units could be helpful in estimating the grain yield

Application of ($N_{160/164}$) with 60 kg N ha^{-1} at sowing and 60 kg N ha^{-1} at 1st irrigation, and 40/44 kg N ha^{-1} at 2nd irrigation with GreenSeeker guidance at 2nd irrigation or application of $N_{137/130}$ (42 kg N ha^{-1} at sowing and 42 kg N ha^{-1} at 1st irrigation, and 53/46 kg N ha^{-1} with GreenSeeker at 2nd irrigation recorded longer phenological stages and better wheat yield than blanket application of 120 kg N/ha but similar to blanket application 150 kg N/ha. Application of $N_{126/133}$[40 kg N ha^{-1} at sowing and 40 kg N ha^{-1} at 1st irrigation, 40 kg N ha^{-1} at 2nd irrigation and 6/13 kg N ha^{-1} as guided by GreenSeeker at 3rd irrigation] resulted in saving of 9-24 kg N ha^{-1}, longer phenophases, agrometeorological indices and higher yield in comparison to 150 kg Nha^{-1}. Longer duration of phenological stages was also observed with application of N137/130 [42 kg N ha^{-1} at sowing and 42 kg N ha^{-1} at 1st irrigation, 53/46 kg N ha^{-1} with GreenSeeker at 2nd irrigation] or delayed application of $N_{126/133}$[40 kg N ha^{-1} basal, 40 kg N ha^{-1} at 1^{st} irrigation, 40 kg N ha^{-1} at 2^{nd} irrigation and 6/13 kg N ha^{-1} with GreenSeeker guided N at 3^{rd} irrigation].

REFERENCES

Anonymous 2016. *Progress report* All India Co-ordinated Wheat and Barley Improvement Project 2015-16. Director report . Ed G P Singh, ICAR-Indian Institute of Wheat and Barley Research, Karnal, India, pp.96.

Goswami, B., Mahi, G.S. and Saikia,U.S. 2006. Effect of few important climatic factors on phenology, growth and yield of rice and wheat. *J. Agromet.*, **27:** 223-28.

Grahmann, K., Verhulst, N., Peòa, R. J., Buerkert, A., Rojas, L. V. and Govaerts, B. 2014. Durum wheat (*Triticum durum* L.) quality and yield as affected by tillage-straw management and nitrogen fertilization practice under furrow-irrigated conditions, *Field Crops Res.*, **164:** 166-77.

Islam, R. and Sikdar, S. 2011. Phenology and degree days of rice cultivars under organic culture. *Bangladesh J. Bot.*, **40:** 149-53.

Kaur, A. and Pannu, R. K. 2008. Effect of sowing time and nitrogen schedules on phenology, yield and thermal use efficiency of wheat (*Triticum aestivum*). *Indian J. Agric. Sci.*, **78:** 366-69.

Kaur, S., Singh, S. and Kingra, P.K .2016. Relationship of wheat yield with agroclimatic indices under varying thermal regimes, nitrogen levels and stress management strategies. *Int. J. Bio-resour. Stress Mgmt.*, **7:** 870-76

Min, Hwang Kee .1980. Association between length of grain filling period and grain yield in two wheat populations (*Triticum aestivum* L. *em Thell.) M.Sc. thesis*, Oregon State University, in Corvallis, Oregon, United States.

Monteith, J.L.1984. Consistency and convenience n the choice of units for agricultural science. *Exp. Agric.*, **20:** 105-17.

Pal, R.K., Rao, M.N.N. and Murty, N. S. 2013. Agro-meteorological Indices to Predict Plant Stages and Yield of Wheat for Foot Hills of Western Himalayas. *Int. J. Agric. Food Sci.Tech.*, **4:** 909-14.

Phadnawis, N. B. and Saini, A. D. 1992. Yield models in wheat based on sowing time and phonological development. *Ann. Pl. Physiol.,* **6:** 52-59.

Ram, H., Singh, G, Mavi, G. S. and Sohu, V. S. 2012. Accumulated heat requirement and yield of irrigated wheat (*Triticum aestivum* L.) varieties under different crop growing environment in central Punjab. *J. Agromet.*, **14:** 147-53.

Singh, A.K., Tripathi, P. and Adhar, S. 2008. Heat unit requirement for phenophases of wheat. *J. Agromet.*, **10:** 209-12.

Singh, B., Sharma, R K., Kaur, J., Jat, M. L., Martin, K. L., Singh, Y., Singh, V., Chandna, P., Choudhary, O. P., Gupta, R. K., Thind, H. S., Singh, J., Uppal, H. S., Khurana, H. S., Kumar, A., Uppal, R. K., Vashistha, M., Raun, W. and Gupta, R. 2011. Assessment of the nitrogen management strategy using an optical sensor for irrigated wheat. *Agron. Sust. Dev.*, **31**: 589-603.