Journal of Agrometeorology 17 (1) : 90-97 (June 2015)

Relation between agrometeorological indices, crop phenology and yield of rice genotypes as influenced by real time N management

TAUSEEF A BHAT, LATIEF AHMAD* and R. KOTRU

Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir Shalimar, Srinagar, Jammu and Kashmir 190025

**Corresponding author email: electricdream2003@yahoo.co.in*

ABSTRACT

Field experiment was conducted during 2012 and 2013 to study yield variations in rice genotypes (*Oryza sativa* L.) due to leaf colour chart (LCC) based N application and agrometeorological indices. Treatments included two rice genotypes (Jhelum and SR-2) and eight rates of N application (control, recommended practice (120 kg N ha^{-1}) and LCC d” 3, 4 and 5 @ 20 and 30 kg N ha^{-1}) laid out in randomized block design replicated three. The pooled data showed that SR-2 recorded significantly higher value of yield and growing degree days (GDD), heliothermal units (HTU) and heat use efficiency (HUE), besides took more days to reach different phenophases as compared to Jhelum. LCC d”5 @ 30 and 20 kg N ha^{-1} recorded significantly higher grain yield, GDD, HTU, HUE and took maximum number of days to different phenophases. This indicated that N application based on LCC 5 should be adopted in rice cultivars particularly SR-2 to achieve maximum yield under temperate conditions of Kashmir valley.

Key Words: Growing degree days, heliothermal units, phenothermal index, rice, yield

Rice is the most consumed cereal grain in the world constituting the dietary staple food of more than half of the world population. Apart from food rice is intimately involved in the culture as well as economy of many societies. India stands first in area (36.95 m ha) and second in production (120.6 million tonnes) next only to China. However, the average productivity of rice in India is only 3.26 tonnes per hectare against the global average of 4.37 (FAO 2010). In Jammu and Kashmir, rice is being cultivated in an area of 261.35 thousand hectares with a production of 761.104 thousand tonnes (Economic Survey 2010). Weather and climate greatly influence the agricultural productivity in any region. Agricultural production and productivity of any region is being regulated by the prevailing climate of that area through temperature, rainfall, light intensity, radiation, sunshine duration etc. (Goswami *et al.*, 2006). Temperature is one of the most pivotal environmental factor which effects the growth and development of crop plants particularly phenology and yield (Bishnoi *et al.* 1995). Plants have a definite temperature requirement to attain phenological stages. Among the major plant nutrients nitrogen is the most critical element in crop production including rice (Nachimuthu *et al.* 2007). It is vital for maintaining and improving crop growth and yield. Nitrogen losses from the soil-plant system are large leading to low fertilizer N-use efficiency when N application is not synchronizing with crop demand (Debtanu and Das 2013). Improvement in the synchrony between crop N demand and the N supply from soil or the applied N fertilizer is likely to be the most promising strategy to improve N use efficiency. It can be achieved by following real-time N management using LCC based on periodic assessment of plant N status and delayed application of fertilizer N until the N level goes below a critical level (Peng *et al.* 1996). Therefore, an experiment was conducted to study the effect of LCC based N application on yield and agrometeorological indices in rice genotypes under temperate conditions of Kashmir.

MATERIALS AND METHODS

Field experiment was conducted during *kharif* season of 2012 and 2013 with rice genotypes at Sher-e-Kashmir University of Agricultural sciences and Technology of Kashmir Research Farm at Shalimar (34-08^{1} N latitude and 74-83^{1} East longitude and 1587 m above the mean sea level). The soil of the experimental field was silty clay loam containing 0.92 % organic C, with *p*H 6.6, EC 0.22 dS m^{-1}, available N 308.96 kg ha^{-1}, P 33.38 kg ha^{-1} and ammonium acetate extractable K 169.26 kg ha^{-1}. The meteorological data was recorded daily from sowing until harvest by meteorological observatory located near the experimental field (Table 1). The experimental site falls in a mid to high altitude characterized by hot summers and very cold winters (Temperate climate). Under average climatic conditions, the area receives 690 mm of mean annual rainfall most of which occurs from December to April. Rainfall received during the rice-growing season (June to September) was 298.60 mm. The mean monthly maximum and minimum temperatures during the rice growing seasons varied from 25.0 to 32.2°C and 9.7 to 18.3°C, respectively. The experiment was laid out in randomized block design with three replications. The cumulative sun shine hours during the growing season varied between 4.2 and 9.9 hrs. The treatments included two rice genotypes and eight rates of N application (control, recommended practice and LCC ≤ 3, 4 and 5 @ 20 and 30 kg N ha^{-1}). In the recommended N rate treatment, N was applied in three equal splits (1/2, 1/4 and 1/4 total kg N ha^{-1}) at transplanting (basal), mid-tillering and panicle initiation. Nitrogen was applied in form of urea as per treatment schedule. For leaf colour chart-based N management, LCC readings were taken at 4 days interval starting from 12 days after transplanting (DAT) till 50% flowering. 10 disease free hills were selected at random from the sampling area in each plot. From each hill, top most fully expanded leaf was selected and LCC readings were taken by placing the middle part of the leaf on the chart and the leaf colour was observed by keeping the sun blocked by body as sun light affects leaf colour reading. Whenever the green colour of more than 5 out of 10 leaves were observed equal to or below a set critical limit of LCC score, nitrogen was applied as per the treatments in both the varieties (Table 2). Thirty five days old seedlings of rice genotypes were transplanted manually at 15 × 15 cm in the second week of June. All the treatment plots received uniform dose of 60 kg P ha^{-1}, 30 kg K ha^{-1} and 15 kg zinc sulphate ha^{-1} as basal dose before transplanting. Standard crop production practices were followed for weeding, irrigations and crop protection management to grow the crop.

Observations on number of days taken to various phenological stages *viz.* maximum tillering, panicle initiation, 50% flowering, milk stage, dough stage and maturity were in one metre row length. The flowering duration (FD, days) and grain filling duration (GFD, days) were calculated from the difference between days required for attaining two consecutive phenophases. The readings on various phenophases were recorded once the plants have reached 50% of that particular stage in each replication. Crop was harvested manually in the third week of September when 80% of the grains turned to golden colour. Grain and biological yield were recorded at the harvest. Accumulated heat units (GDD) and heat use efficiency were calculated following Islam and Sikdar (2011) whereas, heliothermal units (HTU) and phenothermal index (PTI) were computed as suggested by Singh *et al.* (2008).Least significant difference at a 0.05 level of probability was used to test the significance of differences among treatment means (Cochran and Cox 1955) usingWINDOSTAT software whereas, correlation analysis was performed using SPSS software.

$$\text{GDD} = \sum \left\{ \frac{\text{Tmax.} + \text{Tmin.}}{2} - \text{Tb} \right\}$$

HTU = GDD × Actual Sunshine hours

$$\text{Phenothermal Index (PTI)} = \frac{\text{Degree days consumed between two phenological stages}}{\text{Number of days between two phenological stages}}$$

$$\text{Heat use efficiency (kg/ha/oC day)} = \frac{\text{Seed yield or biological yild (kg/ha)}}{\textit{Accumulated heat units } (^{\circ}\text{C})}$$

RESULTS AND DISCUSSIONS

Crop phenology

Data pertaining to crop phenology and flowering and grain filling duration is presented in Table 3. The two rice cultivars showed a significant difference in number of days taken to different phenophases. SR-2 took highest number of days as compared to Jhelum for completing different phenophases. This variation might be due to differential genetic makeup of varieties. Similar results were also reported by Dixit *et al.* (2004) and Nazki (2005). Flowering duration (FD) and grain filling duration (GFD) varied significantly among the two rice genotypes and it was found highest in SR-2 (10.96 and 23.38) as compared to Jhelum (9.16 and 22.78). These results are supported by the findings of Shamim *et al.* (2013). LCC ≤ 5 @ 30 and 20 kg N ha^{-1} took highest number of days to maximum tillering, panicle initiation, 50% flowering, milk stage, dough stage and maturation as compared to other LCC treatments and recommended nitrogen level. Similarly, LCC ≤ 4 @ 30 and 20 kg N ha^{-1} took more days to complete different phenophases as compared to LCC ≤ 3 @ 30 and 20 kg N ha^{-1}. This is because higher application of nitrogen had increased the number of calendar days. These results are supported by the findings of Praveen *et al.* (2013). Likewise, among the LCC scores, maximum days to flowering and grain filling were recorded with LCC ≤ 5 @ 30 N ha^{-1}(11.02 and 20.83) followed by LCC ≤ 5 @ 30 and 20 kg N

Table 1: Standard weekly meteorological data during the crop growing season (Pooled over 2012 and 2013)

Standard Meteorological Week	Max. temperature ^{0}C	Min. temperature ^{0}C	RH1 (%)	RH2 (%)	Rainfall (mm)	Sunshine Hours
24	25.7	13.1	85.0	56.2	33.1	6.1
25	31.1	15.5	73.7	40.2	0.4	9.9
26	29.0	15.5	79.2	48.7	16.6	9.1
27	31.6	17.6	77.7	45.9	13.9	8.4
28	29.1	16.2	81.7	55.5	21.4	6.7
29	31.2	17.2	78.9	48.0	5.7	8.9
30	32.1	17.0	76.9	44.8	7.1	8.5
31	30.5	18.2	81.2	54.7	25.9	6.3
32	28.9	17.9	82.2	56.3	42.3	5.3
33	27.5	18.2	86.0	65.9	52.4	4.2
34	30.9	17.3	78.5	55.2	1.9	7.4
35	29.7	16.0	80.1	54.7	26.8	6.5
36	26.0	15.0	87.7	64.7	32.1	4.6
37	24.9	13.9	88.3	69.0	19.0	5.2
38	28.2	9.73	85.8	52.7	0.0	8.8

Table 2 : Total quantity of nitrogen applied under different treatments in rice cultivars *viz* Jhelum and SR-2 during 2012 and 2013

Treatments	Number of splits	Total N applied
Absolute control	0	0
Recommended dosage of N	3	120
LCC ≤ 3 at 20 kg N ha^{-1}	4	80
LCC ≤ 3 at 30 kg N ha^{-1}	3	90
LCC ≤ 4 at 20 kg N ha^{-1}	5	100
LCC ≤ 4 at 30 kg N ha^{-1}	4	120
LCC ≤ 5 at 20 kg N ha^{-1}	6	120
LCC ≤ 5at 30 kg N ha^{-1}	5	150

ha^{-1}(10.50 and 20.34), whereas, lowest days to flowering and grain filling were recorded in control treatment (8.84 and 18.09). Increased splits of nitrogen under LCC 5 resulted in application of more nitrogen and hence enhanced duration of flowering and grain filling duration. Similar results were also reported by Praveen *et al*. (2013).

Growing degree days and Heliothermal units

The heat unit or GDD was proposed to explain the relationship between growth duration and temperature. This concept assumes a direct and linear relationship between growth and temperature. Data pertaining to GDD and HTUare presented in Table 4 and 5. It was observed that SR-2 accumulated more heat units and HTU as compared to Jhelum to attain different phonological stages. The differential behaviour of rice cultivars to heat unit requirements and HTU could be ascribed to their genetic makeup. Besides, it was alsodue to longer duration of SR-2 in field to complete its growth as compared to Jhelum. Varietal variation for accumulation of GDD to complete different phenophases has also been reported by Pandey *et al*. (2010). LCC ≤ 5 @ 30 and 20 kg N ha^{-1}accumulated highest number of heat units and HTUat all phenophases as compared to other LCC scores and recommended nitrogen level at all the phonological stages. This is due to the fact that higher application of nitrogen had increased the number of calendar days and thermal time of the crop which inturn increased GDD and HTU. These findings are in confirmatory with the results of Davood *et al*.(2009) and Hafiz *et al*.(2013).

Table 3 : Effect of real time nitrogen management on number of days to different phenological stages in rice genotypes (Pooled data over 2012 and 2013)

Treatments	Maximum tillering	Panicle initiation	50% Flowering	Dough stage	Maturity	Flowering duration (Days)	Grain filling duration (Days)
Varieties							
Jhelum	30.92	43.46	59.39	89.21	99.29	9.16	22.78
SR-2	34.05	46.96	63.71	94.51	105.42	10.96	23.38
SEm±	0.30	0.38	0.52	0.62	0.52	0.06	0.09
CD (P=0.05)	0.90	1.15	1.57	2.06	1.58	0.20	0.28
Nitrogen Management							
Control	30.42	40.84	58.42	86.14	96.67	8.84	18.09
Recommended	34.83	45.00	62.59	93.01	101.67	9.25	19.25
LCC ≤ 3@ 20 N kg ha^{-1}	32.00	44.00	61.01	89.54	99.00	8.97	18.50
LCC ≤ 3@ 30 N kg ha^{-1}	32.42	44.67	61.75	91.01	99.67	9.17	18.92
LCC ≤ 4 @ 20 N kg ha^{-1}	33.17	46.45	64.31	94.51	103.50	9.27	19.33
LCC ≤ 4 @ 30 N kg ha^{-1}	35.26	47.00	65.34	95.37	104.50	9.42	19.34
LCC ≤ 5 @ 20 N kg ha^{-1}	37.92	48.55	67.54	97.52	105.98	10.50	20.34
LCC ≤ 5 @ 30 N kg ha^{-1}	39.08	50.17	68.51	98.79	107.85	11.02	20.83
SEm±	0.63	0.71	0.96	1.06	0.77	0.14	0.15
CD (P=0.05)	1.89	2.12	2.89	3.18	2.33	0.44	0.47

Table 4 : Effect of real time nitrogen management on number growing degree days in rice genotypes (Pooled data over 2012 and 2013)

Treatments	Maximum tillering	Panicle initiation	50% Flowering	Milk stage	Dough stage	Maturity
Varieties						
Jhelum	440.55	623.34	861.73	1015.33	1294.58	1412.61
SR-2	465.07	641.92	883.98	1035.28	1314.15	1434.26
SEm±	6.30	5.21	6.52	6.73	4.95	4.86
CD (P=0.05)	18.90	15.65	19.57	19.21	14.86	14.58
Nitrogen Management						
Control	395.70	571.03	828.50	954.55	1233.85	1355.35
Recommended	470.55	622.60	864.95	1012.73	1297.40	1405.33
LCC ≤ 3@ 20 N kg ha^{-1}	426.20	604.33	841.63	963.80	1251.78	1374.35
LCC ≤ 3@ 30 N kg ha^{-1}	427.05	607.48	855.35	985.88	1263.88	1387.90
LCC ≤ 4 @ 20 N kg ha^{-1}	447.55	646.18	890.78	1045.73	1326.48	1445.10
LCC ≤ 4 @ 30 N kg ha^{-1}	465.30	652.58	897.15	1062.53	1337.60	1445.40
LCC ≤ 5 @ 20 N kg ha^{-1}	517.93	690.30	941.78	1113.90	1365.23	1465.98
LCC ≤ 5 @ 30 N kg ha^{-1}	546.28	698.65	952.88	1125.10	1381.63	1490.88
SEm±	15.29	14.04	16.23	17.45	14.39	13.11
CD (P=0.05)	45.89	42.12	48.89	52.37	43.18	39.33

Table 5 : Effect of real time nitrogen management on heliothermal units (°day hour) index in rice genotypes (Pooled data over 2012 and 2013)

Treatments	Maximum tillering	Panicle initiation	50% Flowering	Milking	Dough stage	Maturity
Varieties						
Jhelum	3709.30	5192.61	6786.31	7621.62	9230.70	9976.54
SR-2	3789.63	5282.76	6890.12	7696.84	9373.79	10081.87
SEm±	23.71	25.52	29.79	24.22	32.14	30.52
CD (P=0.05)	71.12	76.62	87.38	72.68	96.44	91.57
Nitrogen Management						
Control	3282.60	4667.10	6755.88	7148.80	8975.89	9496.75
Recommended	3857.15	5202.24	6832.11	7617.40	9404.58	10007.48
LCC ≤ 3@ 20 N kg ha^{-1}	3424.92	4968.49	6680.90	7129.72	9092.57	9621.51
LCC ≤ 3@ 30 N kg ha^{-1}	3452.25	5036.07	6812.24	7358.89	9200.16	9840.48
LCC ≤ 4 @ 20 N kg ha^{-1}	3700.73	5398.11	6807.32	7745.81	9391.47	9927.20
LCC ≤ 4 @ 30 N kg ha^{-1}	3833.28	5443.15	6881.68	7935.12	9474.11	9984.44
LCC ≤ 5 @ 20 N kg ha^{-1}	4339.48	5765.28	7208.53	8303.04	9695.07	10497.79
LCC ≤ 5 @ 30 N kg ha^{-1}	4426.68	5781.64	7142.29	8335.99	9786.54	10639.34
SEm±	121.07	130.24	135.44	163.92	148.02	152.29
CD (P=0.05)	363.24	391.64	406.34	491.97	344.03	456.87

Table 6 : Effect of real time nitrogen management on phenothermal index in rice genotypes (Pooled data over 2012 and 2013)

Treatments	Maximum tillering	Panicle initiation	50% Flowering	Milking	Dough stage	Maturity
Varieties						
Jhelum	14.25	14.34	14.51	14.60	14.51	14.23
SR-2	13.66	13.67	13.88	14.15	13.90	13.61
SEm±	0.05	0.07	0.04	0.08	0.06	0.04
CD (P=0.05)	0.14	0.21	0.13	0.22	0.18	0.14
Nitrogen Management						
Control	13.01	13.98	14.18	14.17	14.32	14.02
Recommended	13.51	13.84	13.82	14.10	13.95	13.82
LCC ≤ 3@ 20 N kg ha^{-1}	13.32	13.73	13.79	13.71	13.98	13.88
LCC ≤ 3@ 30 N kg ha^{-1}	13.17	13.60	13.85	13.88	13.89	13.92
LCC ≤ 4 @ 20 N kg ha^{-1}	13.49	13.91	13.85	14.19	14.00	13.96
LCC ≤ 4 @ 30 N kg ha^{-1}	13.20	13.88	13.73	14.30	14.01	13.83
LCC ≤ 5 @ 20 N kg ha^{-1}	13.66	14.22	13.94	14.31	14.01	13.83
LCC ≤ 5 @ 30 N kg ha^{-1}	13.98	13.93	13.91	14.15	14.04	13.82
SEm±	0.11	0.13	0.09	0.12	0.11	0.08
CD (P=0.05)	0.32	0.39	0.28	0.35	0.31	NS

Table 7: Effect of real time nitrogen management on grain yield, biological yield and heat use efficiency of rice

Treatments	Grain yield (q ha^{-1})	Biological yield (q ha^{-1})	HUE on biological yield basis (kg ha-1 °Cday^{-1})	HUE on grain yield basis (kg ha-1 °Cday^{-1})
Varieties				
Jhelum	65.81	147.92	10.47	4.66
SR-2	73.25	159.55	11.13	5.11
SEm±	0.74	1.44	0.12	0.08
CD (P=0.05)	2.24	4.34	0.36	0.26
Nitrogen Management				
Control	40.65	99.79	7.36	3.00
Recommended	71.47	157.18	11.19	5.09
LCC ≤ 3@ 20 N kg ha^{-1}	67.67	149.16	10.85	4.92
LCC ≤ 3@ 30 N kg ha^{-1}	70.06	154.14	11.11	5.05
LCC ≤ 4 @ 20 N kg ha^{-1}	74.24	162.79	11.27	5.14
LCC ≤ 4 @ 30 N kg ha^{-1}	75.35	165.77	11.47	5.21
LCC ≤ 5 @ 20 N kg ha^{-1}	78.79	171.59	11.70	5.38
LCC ≤ 5 @ 30 N kg ha^{-1}	81.53	177.36	11.90	5.47
SEm±	1.49	2.80	0.07	0.05
CD (P=0.05)	4.49	8.41	0.22	0.15

Table 8 : Correlation coefficients of grain yield with agrometeorological indices, flowering duration (FD), grain filling duration (GFD) and heat use efficiency

Parameters	Grain yield
GDD at PI	0.845**
GDD at FL	0.771*
FD	0.684*
GFD	0.866**
HTU at PI	0.683*
HTU at FL	0.698*
HUE_Bio	0.990**
HUE_Grain	0.990**

(** Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level)

Phenothermal index

The phenothermal index for consecutive phenophases is presented in Table 6. The phenothermal index is expressed as degree-days per growth day. It was observed that PTI increased upto flowering stage being maximum at that stage and thereafter gradually decreased till maturity indicating a decrease in daily heat consumption towards maturity. Highest PTI value was observed in Jhelum as compared to SR-2 at all phenophases. Variation in PTI among different rice genotypes was also observed by Shamim *et al*. (2013). LCC ≤ 5 @ 20 kg N ha^{-1} recorded maximum value of PTI up to panicle initiation and after that highest value of PTI was observed in control treatment but was statistically at par with LCC ≤ 5 @ 30 and 20 kg N ha^{-1}. However, at maturity there was no significant difference in PTI among different treatments. Maximum accumulated heat units in LCC 5 resulted in highest PTI value upto panicle initiation whereas lowest number of days taken to different phenophases in control treatment indicated highest PTI value upto maturity which is due to lowest number of days taken to different pehenological stages.

Yield and heat use efficiency

Data on grain yield, biological yield and heat use efficiency (HUE) is presented in Table 7. It was observed that SR-2 recorded significantly higher grain and biological yield than Jhelum. Since rice yield is dependent on the number of panicles m^{-2} and grains $panicle^{-1}$ which were significantly higher in SR-2 and hence the higher grain yield. Bali *et al*. (1995) and Ganajaxi *et al*. (2001) have also reported variation in the grain yield of different rice cultivars. LCC ≤ 5 @ 30 and 20 kg N ha^{-1} recorded significantly higher grain and biological yield than LCC ≤ 4 @ 30 and 20 kg N ha^{-1}, LCC ≤ 3 @ 30 and 20 kg N ha^{-1} and recommended application of nitrogen. Higher yield in LCC ≤ 5 @ 30 and 20 kg N ha^{-1} was due to higher quantity of nitrogen applied in more number of splits which synchronized with the crop demand compared to other levels. These results are also in close conformity with the findings of Kumar *et al*. (1999) and Maiti and Das (2006) who reported higher grain yield with LCC based nitrogen management. Among the two rice cultivars, SR-2 recorded highest heat use efficiency of 11.13 and 5.11 on the basis of biological and grain yield (HUE_Bio and HUE_Grain) as compared to Jhelum which recorded HUE_Bio and HUE_Grain of 10.47 and 4.66 kg ha^{-1} ^{0}C). This was due to significantly higher yield of SR-2 as compared to Jhelum. Variation in rice genotypes with respect to HUE were also observed by Shamim *et al*. (2013). LCC ≤ 5 @ 30 and 20 kg N ha^{-1} (11.90 and 5.47 kg ha^{-1} ^{0}C) observed higher heat use efficiency but was at par with (11.70 and 5.38 kg ha^{-1} ^{0}C) but significantly superior than other LCC scores and recommended nitrogen application. The synchronized and higher application of nitrogen in more number of splits in LCC 5 resulted in higher grain and biological yield which accounted for higher heat use efficiency.

The results obtained from the correlation analysis (Table 8) indicated that growing degree days at panicle initiation and flowering (GDD_{PI} and GDD_{FL}) were highly significant and positively correlated with all the agrometeorological indices except heat use efficiency on biological yield basis (HUE_Bio) at flowering stage. They were significantly and positively correlated with grain yield. Non-significant correlation values were obtained between grain filling duration (GFD) and heat use efficiency (HUE). HTU at panicle initiation and flowering were significantly correlated with the grain yield. This indicated the effect of sunny days on the portioning of the photosynthates into the grain. These results are supported by the findings of Shamim*et al*. (2013). On the basis of these results, SR-2 with N application through LCC 5 stands first in terms of transportation of photosynthates into grain yield as compared to cultivar Jhelum.

CONCLUSIONS

Based on the above findings, it was concluded that higher yield, accumulated heat units, HTU and heat use efficiency was recorded with LCC 5 based N application. Among the varieties, SR-2 recorded higher yield, GDD, HTU and heat use efficiency. This indicated that rice cultivars responded positively to leaf colour chart based N management. Besides, application of agrometeorological indices provides the information related to effect of temperature and solar radiation on the crop phenology, yield and heat energy consumption in rice cultivars.

ACKNOWLEDGMENT

Authors are highly grateful to INSPIRE-DST, New Delhi for funding this research programme to be carried out at Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir.

REFERENCES

Bali, A.S. and H.S.Uppal.(1995). Effect of date of transplanting and water management practices on yield of basmati rice (*Oryzasativa*). *Indian J. Agron.,* 40(2): 186-192.

Bishnoi, O.P., S. Singh, and R. Niwas.(1995). Effect of temperature on phonological development of wheat (*Triticumaestivum*L.) crop in different row orientation. *Indian J. Agric. Sci*., 65:211-214.

Cohran, W.G. and G.M.Cox.(1955). *Experimental Design*. John Willey & Sons, New York.

Davood, B.T., A. P.Hemmat, and N.Morteza.(2009). Investigation some Agro meteorological traits of rice under different transplanting dates, planting spaces and nitrogen fertilization levels in North of Iran. *World Applied Sci. J.,* 6(8): 1021-1027.

Debtanu, M. and D.K.Das. (2013). Management of nitrogen through the use of Leaf Colour Chart (LCC) and Soil Plant Analysis Development (SPAD) in wheat under irrigated ecosystem. *Archives Agron. Soil Sci.,* 52:1: 105-112.

Dixit, A.J., V.V.Gaikwad, M.G. Jadhav, and S.T. Thorat.(2004). Effect of sowing time on the phenology and growth of hybrid rice parents. *J. Agrometeorol.,* 6: 72-76.

Economic Survey.(2010). Directorate of Economics and Statistics, Jammu and Kashmir Govt. Srinager.

FAO STAT. (2010). Production Statistics, Food and Agriculture Organisation, Rome.pp. 567.

Ganajaxi, M.H.D., Y. Hedge, and V.V Angadi.(2001). Effect of planting dates and nitrogen levels on the grain yield of aromatic rice genotypes under rainfed conditions. *Karnataka J. Agric. Sci.,*14(3): 758-759.

Goswami B., G.S.Mahi, and U.S.Saikia.(2006). Effect of few important climatic factors on phenology, growth and yield of rice and wheat. *J. Agrometeorol.,* 27: 223-228.

Hafiz, M.H., A.Ashfaq, F.Wajid, A.Farhat, Q. Khaliqa, and

S.Shafqat.(2013). Nitrogen stimulates phonological traits, growth and GDD of maize. *Pakistan J. Agric. Sci.,* 50(3): 337-343.

Islam, R. and Sikdar, S.(2011). Phenology and degree days of rice cultivars under organic culture. *Bangladesh J. Botany,* 40 (2): 149-153.

Kumar, R.M., K. Padmaja, and S.V. Subbaiah.(1999). Tools for plant-based N management in different rice varieties grown in southern India. *Intern. Rice Res. Notes,* 24(3): 23-24.

Maiti, D. and D.K.Das.(2006). Management of nitrogen through the use of leaf colour chart (LCC) and soil plant analysis development (SPAD) in wheat under irrigated ecosystem. *Archives Agron. Soil Sci.,* 52(1): 105-112.

Nachimuthu, G.,V.Velu, P.Malarvizhi, S.Ramasamy, and L.Gurusamy.(2007). Standardisation of Leaf Colour Chart based nitrogen management in direct wet seeded rice (*Oryzasativa* L.). *J. Agron.,* 6(2): 338-343.

Nazki, G.A.(2005). Response of rice cultivars to fertilizer nitrogen and organics under transplanted culture, M.Sc. Thesis, SKUAST-K, J&K, India.

Pandey, I.B., R.K.Pandey, D.K. Dwivedi, and R.S. Singh.(2010). Phenology, heat unit requirement and yield of wheat varieties under different crop-growing environment. *Indian J. Agric. Sci.,* 80:136-140.

Peng, S.,F.V. Garcia, R.C. Laza, A.L. Samico, R.M. Visperas, and K.G.Cassman.(1996). Increased N use efficiency using chlorophyll meter on high yielding irrigated rice. *Field Crop Res.,* 47: 243-252.

Praveen, K.V., S.R. Patel, J.L. Choudhary, and S.Bhelawe,(2013). Heat Unit Requirement of Different Rice Varieties under Chhattisgarh Plain Zones of India. *Earth Sci. Climatic Change,* 5(1): 1-4.

Shamim, M., S.Devendra, K.K. Gangwar, and K.Vipin,(2013). Agro meteorological indices in relation to phenology, biomass accumulation and yield of rice genotypes under Western Plain zone of Uttar Pradesh. *J. Agrometeorol.* 15(2): 50-57.

Singh, A.K., P.Tripathi, and S.Adhar.(2008)b. Heat unit requirement for phenophases of wheat. *J. Agrometeorol.,* 10(2): 209-212.

Received : November 2014 ; Accepted : March 2015