Research Journal of Recent Sciences E-ISSN 2277-2502
Vol. **5(10),** 1-8, October **(2016)** *Res. J. Recent Sci.*

Influence of Weather Parameters on Lentil (*Lens culinaris* M.) at Allahabad, India

Singh Vijay Pratap, Nath Satyendra, Patra Sitanshu Sekhar2*, Rout Sandeep and Sahoo Soham
School of Forestry & Environment, Sam Higginbottom Institute of Agriculture Technology & Sciences, Allahabad-211007 (UP) India
mailsspatra@rediffmail.com

Available online at: www.isca.in, www.isca.me
Received 13th September 2016, revised 28th September 2016, accepted 30th September 2016

Abstract

A field experiment was conducted during the 2014-2015 at the research farm of School of Forestry & Environment, Sam Higginbottom Institute of Agriculture Technology and Sciences, Allahabad, to find out the influence of weather parameters on Lentil (Lens culinaris M.) under Allahabad condition in Randomized block design (factorial) replicated thrice. Induction of hydro priming was obtained by immersing the seeds in distilled water. The GDD accumulation was highest in D_1 (1907.25 day °C) than other sowing dates. The minimum GDD was accumulated in D_3 sowing (1633.15 day °C). The highest PTU was obtained by D_1 (21899.10°day hrs). The hygrothermal unit-I was highest (168544.70°day percent) in the D_1. HgTU-II, photo temperature, nycto temperature, inter diurnal temperature was also highest in D_1.

Keywords: Agrometeorological indices, GDD, Lentil, Temperature.

Introduction

Lentil (*Lens culinaris* M.) is the most ancient cultivated crops among the legumes. World Lentil production has increased four times from 1 million tonnes in 1971 to 4.5 million tons in 2012, and this has been accompanied by increased yields from 611 to 1070 kg/ha, respectively[1]. Lentil production in India has always been important as it is one of the most important rabi crops in the country. India has been producing lentil since 1st century AD and has always been an important producer of the crop. In fact, India was the largest producer of the lentil crop in the world until recently Canada took over the lead leaving India at the second place. Indian production of this crop hovers around 10 lakh metric tons per year that are cultivated on about 14 lakh hectares of land. Uttar Pradesh accounts for the maximum production in the country contributing to around 45% of the country's production as well as for the maximum area under lentil cultivation. In India top three lentil producing states are Uttar Pradesh, Madhya Pradesh and Bihar. Lentil is the oldest food legume that has been known to the mankind. The lentil plant, (*Lens culinaris* M.), is a member of the Leguminoceae family[2].

Lentil is a winter crop usually grown in fall and harvested in summer and some varieties can also be sown in spring. However, late sowing will decrease yield and increase protein content[3]. Poor stand establishment results in less tillers and ultimately reduced grain yield. Seed priming improves the germination rate, speed and uniformity even under less than optimum field condition[4,5] thus enabling the establishment of uniform and good crop stand establishment. Another manifestation of seed priming was the substantial increase in the number of total and fertile tillers. As compared with osmopriming, hydro priming clearly improved speed of emergence, vigour index and seedling dry weight. It has been reported that wheat seed hydro priming for less than 12 h is more effective than other methods[6] so it can increase the rate and extent of emergence, improve seedling vigour, earlier flowering and maturity and increase the yield. Although priming is one of the physiological methods, which improves seed performance and seed faster and synchronized germination[7], it has been shown that the longevity of primed seeds in storage is often reduced[8,9]. Whether the benefits of priming on seed performance could be maintained during dry storage still remains unknown. Seed priming started with Greek farmers who soaked cucumber seeds in milk or honey before sowing to increase germination and emergence[10].

The heat unit or growing degree-days concept was proposed to explain the relationship between the growth duration and temperature. The method was selected to compute GDD using a base temperature of 10^0C. Heat unit system is a scheme for studying plant growth and temperature relationship by the accumulation of daily mean temperature above a certain threshold temperature during the growing season[11]. We know that all the physiological processes and physical processes are temperature dependent. It is also known fact that the increase in the rate of these processes corresponds with increase in yield. The heat unit system concept assumes that there is a direct and linear relationship between growth of plants and temperature. It starts with the assumption that the growth is dependent on the total amount of heat to which it is subjected during its life time. Weather is a tool for finding answers to problems of growth and development. Solar radiation, temperature, soil moisture and bright sunshine hours are important weather elements that influence the crop life cycle[12].

The sowing time is the most important factor determining the yield of wheat. The nutrient content in grain and straw has been reported to be increased with delay in sowing of wheat whereas, uptake of these nutrients decreased as the sowing of wheat gets delayed. There are many factors responsible for low yield of wheat but poor crop nutrition and use of varieties with low yield potential are the most important[13]. Keeping in view of the importance the study was aimed to investigate influence of weather parameters on Lentil (*Lens culinaris* M.) under Allahabad condition.

Materials and Methods

The investigation was carried out during Rabi season 2014-15 at the Forest nursery and research centre, School of Forestry and Environment, Sam Higginbottom Institute of Agriculture, Technology and Sciences, Allahabad. Allahabad is located in the South-East part of Uttar Pradesh, India. Allahabad comes under agro-climatic zone-IV, which is named as "Middle Gangetic Plains". Soil of this region is sandy loam and slightly alkaline. The site of experiment is located at 25.57^{o} N latitude, 81.51^{0}E longitude and 90 meters above the sea level. This region has Sub-tropical climate with extreme of summer and winter. The temperature falls down to as low as 1-2^{0}C during winter season especially in the month of December and January. The mercury rises up to 46-48^{0}C during summer.

The Allahabad receives the mean annual rainfall ranges 886 mm. More than 70 per cent rains are received during S-W monsoon season, 5–10 per cent rains are received in winter, 10–15 per cent in pre monsoon and 5–10 percent during post monsoon season. Normal rainy days exceed 40 annually. Summer monsoon rainfall comes in down pours while winter rainfall comes in light drizzles and is easily absorbed in soils.

The soil of the experimental plot was sandy loam in texture and slightly alkaline in reaction. A composite soil sample from 0-15 cm depth was collected from the experimental field before commencement of the experiment to record the physio-chemical properties of the soil and found Bulk density: 1.26 gm/cm^{3}, Organic carbon: 0.75%, pH: 7.37. The design laid out for the present investigation was the two factors RBD with three replications. The weather parameters were recorded at Agromet observatory, SHIATS- DU, Allahabad. During 2014-15 crop seasons, the weekly maximum temperature ranged between 23.6 °C at sowing to 39.4°C during Grain development stage. However, weekly minimum temperature ranged between 7.6 °C at sowing to 21.6 °C at Grain development. In 2015, the average weekly sunshine varied between 6.86 to 8.63 at the time of grain maturity and development stage. The morning relative humidity ranged between 82.43% to 94.71%. However, the evening relative humidity varied between 42% to 70.71%.

The plot treatment comprised of three dates of sowing such as (22nd Nov) (D_1), (02nd Dec) (D_2), (12th Dec) (D_3) and four treatments (hydropriming) viz, H_0 (Control), H_1 (8hrs hyropriming), H_2 (12hrs hyropriming), H_3 (16hrs hydropriming). The lentil variety used was Malika First of all; stubbles of the previous crop were removed manually. The field was ploughed once with the help of tractor and harrowed with blade harrow in both the directions. Then, layout of the experiment was carried out. A recommended dose of N: P: K fertilizers @ 25:60:30 kg ha^{-1} was applied in experimental plot and equally distributed to each experimental unit. The graded and healthy seed of lentil crop was selected by using recommended seed rate @ 30-35 kg ha^{-1}. The seeds were then soaked in distilled water for specific times mentioned in four treatments above viz, for H_1; seeds should be soaked for 8hrs. The seeds were sown manually with hand in previously opened furrow in field. The sowings were done according to the treatment. Gap filling was carried out after 15 days of sowing while thinning operation was carried out to facilitate optimum plant population. Intercultural and hand weeding operations were carried out when required for soil aeration and removal of weeds.

The first common irrigation was applied just after sowing for the establishment of the seedling. In case of hydropriming, the seeds soaked in distilled water germinated more rapidly than the non-treated by avoiding any kind of moisture stress. Subsequently, Irrigation was applied to the crop as per requirement. Thinning were done at 15 days after every sowing. This operation was done for maintaining a proper plant to plant distance and standard plant population. Hand weeding was done to maintain weed free environment during the initial crop growth stages. Since there was no sufficient rainfall during the crop growing season however, irrigation was provided timely. The crop was harvested with the help of sickle, when more than 80% of grains in the pods were fully ripened and free from greenish tint. The harvesting of each plot was done separately and dried well in the sun light and the harvested sheaves from each net plot was carefully bundled, tagged and transported to the threshing floor. After complete sun drying the bundles of harvested produce of each plot were weighed with the help of spring balance and then threshed manually. The grains obtained after winnowing and sun drying were weighed carefully and recorded in (g) plot^{-1}.

The observations were recorded on five randomly selected competitive plants in each replication for all the characters. Agro meteorological indices developed by utilizing various meteorological elements are found in literature to study the crop weather relationships. The indices such as i. Growing degree days (GDD), ii. Photothermal units (PTU), iii. Heliothermal units (HTU), iv. Phenothermal index were employed in the present study. The methods of computation of the indices are as under.

Growing degree days (GDD) in this investigation (remainder index) were calculated by simple accumulation of daily mean air temperature above a given threshold or base temperature.

It can be mathematically expressed as

$$GDD = \sum_{ds}^{dp}[(Tmax. + Tmin.)/2 - Tb]$$

Photothermal unit (PTU): The photothermal unit which takes into account the maximum possible duration of day light (day length factor or maximum possible sunshine hours) were worked out for each day by multiplying the growing degree days for a day with the corresponding day length factor[14]. The response of crop was examined in relation to both photo thermal units and growing degree days. The degree days for each date of sowing and varieties for different phenological stages were calculated in terms of PTU[15].

PTU = GDD x N

Where: N- Maximum possible sunshine hours which varies with latitude and month at a location.

Heliothermal units (HTU): The value of heliothermal unit represents the product of GDD and actual duration of bright sunshine hours (BSS) for a particular day as recorded by the sunshine recorder. This may be termed as actual photothermal unit. The heliothermal units for each planting i.e. date of sowing and varieties for different phenological stages were calculated by following expression.

HTU = GDD x n

Where: n = Actual duration of bright sunshine hours as recorded by sunshine recorder for a particular location.

Phenothermal index: The phenothermal index is expressed as degree day per growth day It can be expressed as under

$$\text{Phenothermal Index} = \frac{\text{Accumulated thermal units during phenophase}}{\text{Duration of the phenophase}}$$

Hygrothermal unit-I and II: The value of hygrothermal unit represents the product of GDD and relative humidity (Morning and afternoon) for a particular day as recorded by the observatory.

HgTU = GDD x RH

Results and Discussion

The result obtained during the present course of investigation was carried out to visualize a significant influence of different date sowing and hydropriming.

Temperature: The average per day maximum temperature remained more or less same for 02nd December and 12th December sowing conditions. However, maximum temperature were higher for D_1 (22nd November) sown conditions. Per day Maximum temperature increased constantly during flowering, milking and Dough stage in different sowing conditions (Table-1). On the other hand, per day minimum temperature was higher in D_3 (12th December) sown conditions and irrespective of duration of maturity period (Table-2). The average per day mean temperature increased constantly from jointing stage to physiological maturity stage in all sowing conditions. Effect of temperature in growth, maturity and grain dough stages, when Decrease temperature so grain yield and straw yield Decreased[16-18].

Relative humidity-I and Relative humidity-II: The average per day RH during morning hours increased gradually from sowing to grain development stage in all sowing dates. Among sowing dates, the per day morning relative humidity was found to be higher in D_3 (89.17%) and followed by D_2 (88.59%) sowing conditions. The per day evening relative humidity was observed highest in D_3 sowing conditions (54.06%) however it was observed minimum in D_1 (52.95**%)** (Table-3).

Bright sunshine hours: The average bright sunshine hours for the whole crop season under different sowing conditions remained slightly higher in D_2 (6.96 hours/day) than other sowing dates. Among sowing dates, the bright sunshine hours fluctuated from sowing to maturity stage in D_1 and D_2.

Growing degree days: The data pertaining to accumulated heat units in different treatments are presented in Table-4. Different dates of sowing significant influenced GDD. The GDD accumulation was significantly highest in D_1 (1907.25 day °C) than other sowing dates. The minimum GDD was accumulated in D_3 sowing (1633.15 day °C). The GDD accumulation was highest in D_1 due to longer duration of crop growing period and lowest in D_3 sowing due to forced maturity caused by increase in temperature. The Decrease in GDD may be due to Decrease in the maturity period of the lentil for late sowing[19].

Photothermal unit: The photothermal unit (PTU) under various sowing dates is presented in the Table-5. The highest PTU was obtained by D_1 (17063.41° day hrs) followed by D_2 (18393.99° day hrs). However, lowest PTU was recorded by D_3 (20192.07° day hrs).

Heliothermal units: The accumulated heliothermal unit (HTU) under various sowing dates is presented in the Table-6. Different sowing dates significantly influenced heliothermal unit (HTU). The D_1 accumulated maximum heliothermal units (12785.73°day hrs) to reach maturity stage. The lowest HTU was accumulated in D_3 sowing date that is (10609.45°day hrs).This may be due to cloudiness prevailed during the grain development stage of D_3 sown crop[20].

Hygrothermal Unit-I: The accumulated morning hygrothermal unit-I required by the crop for various phenophases under different dates of sowing are presented in Table-7. The hygrothermal unit-I significantly influenced by sowing dates. The hygrothermal unit-I was highest (136686.1° day percent) in the D_1 followed by D_2 (145007.2°day per cent). The accumulation of HgTU-I was the lowest in D_3 (156024.2° day percent) due to short crop growth period.

Photo temperature (T_{photo}): The photo temperature (T_{photo}) significantly influenced by different sowing dates (Table-8). The photo temperature was the highest in the D_1 (2519.08^{0}C) followed by D_2 sowing condition (2602.08^{0}C). The lowest photo temperature was taken by D_3 sowing condition (2738.78^{0}C).

Nycto temperature (T_{nycto}): The nycto temperature (T_{nycto}) significantly influenced by different sowing dates. The nycto temperature was the highest in D_1 sowing conditions (1726.23^{0}C) followed by D_2 sowing condition (1827.63^{0}C). The lowest nycto temperature was taken by D_3 sowing condition (1971.33^{0}C) (Table-9).

Table 1
Meteorological data recorded during experimental period (*Rabi* 2014-15)

Std weeks	Dates	Rainfall (mm)	Temperature (^{0}C)		Relative humidity (%)		Eo (mm/day)	BSS hours
			Max.	Min.	I	II		
47	17Nov-23Nov	0.0	29.8	11.97	84	44.86	2.6	7.94
48	24Nov-30Nov	0.0	30.71	11.2	82.43	42.57	2.74	8.19
49	1Dec-7Dec	0.0	30.26	11.86	83.57	44.71	2.8	8.39
50	8Dec-14Dec	0.0	28.8	8.57	86.43	50.71	2.46	7.53
51	15Dec-21Dec	1.2	24.14	9	89.57	57.43	1.89	6.27
52	22Dec-28Dec	0.0	18.06	7.64	94.71	61.57	1.29	5.06
53	29Dec-4Jan	4.71	18.26	11.71	93.14	62.43	1.23	8.17
01	5Jan-11Jan	0.0	22.23	11.11	91	60.29	1.51	5.86
02	12Jan-18Jan	0.0	14.77	7.9	93.71	70.71	1.2	6.24
03	19Jan-25Jan	0.29	18.91	9.96	93.57	67.43	1.31	4.66
04	26Jan-1Feb	4.51	21	12.9	90.71	58.57	1.34	4.26
05	2Feb-8Feb	0.63	27.14	11.89	91.29	54.43	1.29	4.4
06	9Feb-15Feb	0.11	27.03	11.74	87.14	48.71	1.4	5.6
07	16Feb-22Feb	0.0	30.89	12.91	86.14	47.29	1.89	6.86
08	23Feb-1Mar	0.06	30.67	14.94	88.43	54.86	2.11	6.51
09	2Mar-8Mar	9.57	28.69	14.8	92.57	58.71	1.94	6.41
10	9Mar-15Mar	0	31.74	15.91	85.57	44.14	2.66	7.74
11	16Mar-22Mar	1.17	33.26	19.77	88.71	47.14	2.09	7.57
12	23Mar-29Mar	0.0	36.83	20.97	83.71	42	2.29	8.63
13	30Mar-5Apr	0.69	34.29	20.69	85.86	49.71	2.46	7.97
14	6Apr-12Apr	0.03	37.94	21.06	86	45.43	3	7.93
15	13Apr-19Apr	1.6	32.9	20.9	90.75	50.75	1.95	5.65

Source: Agrometeorologial Observatory Unit, School of Forestry and Environment, SHIATS, Allahabad

Table-2
Average temperatures during rabi crop season 2014-2015
A. Maximum Temperature (^{0}C/day)

Sowing Date	Phenophases						Average
	P_1	P_2	P_3	P_4	P_5	P_6	
D_1	11.73	10.65	10	9.98	9.24	13.66	10.87
D_2	13.2	8.47	8.77	10.18	11.79	15.4	11.30
D_3	10.4	8.35	9.94	10.17	11.94	17.79	11.43

B. Minimum temperature (^{0}C/day)

Sowing Date	Phenophases						Average
	P_1	P_2	P_3	P_4	P_5	P_6	
D_1	30.07	30.6	28.03	18.48	18.55	28.01	25.62
D_2	30.45	29.07	22.47	18.55	22.01	30.77	25.55
D_3	27.6	24.2	19.85	17.87	27.67	32.82	25.00

C. Mean temperature (^{0}C/day)

Sowing Date	Phenophases						Average
	P_1	P_2	P_3	P_4	P_5	P_6	
D_1	20.9	20.63	19.01	14.23	13.89	20.84	18.25
D_2	21.83	18.77	15.62	14.37	16.9	23.08	18.43
D_3	19	16.28	14.90	14.02	19.81	25.31	18.22

Table 3
Relative humidity-I and Relative humidity-II
(A) Maximum Relative Humidity (%/day)

Sowing Date	Phenophases						Average
	P_1	P_2	P_3	P_4	P_5	P_6	
D_1	80.67	82.75	86.13	93.8	92.89	88.73	87.50
D_2	83	85.67	90.75	92.65	91.26	87.96	88.55
D_3	87	89	92.87	92.9	87.95	87.27	91.17

(B) Minimum Relative Humidity (%/day)

Sowing Date	Phenophases						Average
	P_1	P_2	P_3	P_4	P_5	P_6	
D_1	44.67	43.25	50	61.33	65.89	51.16	52.72
D_2	44.75	45.33	58.67	64.06	57.47	48.94	53.20
D_3	62.25	55.25	60.70	66.2	45.79	48.83	56.50

(C) Mean Relative Humidity (%/day)

Sowing Date	Phenophases						Average
	P_1	P_2	P_3	P_4	P_5	P_6	
D_1	7.8	8.13	7.49	6.75	5.33	5.7	6.87
D_2	8.38	8.27	6.52	6.44	4.66	6.93	6.87
D_3	6.53	7.75	6.1	5.42	4.77	7.27	6.31

Table 4
Growing degree days

Sowing Date	Phenophases						Average
	P_1	P_2	P_3	P_4	P_5	P_6	
D_1	15.9	15.63	14.01	9.23	8.89	15.84	13.25
D_2	16.83	13.77	10.62	9.37	11.9	18.08	13.43
D_3	14	11.28	9.90	9.02	14.81	20.31	13.22

Table 5
Photo thermal unit (PTU)

Sowing Date	Phenophases						Average
	P_1	P_2	P_3	P_4	P_5	P_6	
D_1	149.46	156.72	145.70	103.15	99.95	180.21	139.20
D_2	174.94	142.94	113.42	104.75	131.33	209.54	146.15
D_3	145.11	116.81	110.08	101.51	164.30	238.78	146.1

Table-6
Heliothermal unit (HTU)

Sowing Date	Phenophases						Average
	P_1	P_2	P_3	P_4	P_5	P_6	
D_1	710.23	676.75	692.56	563.48	573.99	799.79	669.47
D_2	752.98	624.17	617.19	578.93	658.86	878.70	685.14
D_3	876.18	622.58	594.41	585.55	679.61	978.88	722.87

Table-7
Hygrothermal Unit-I

Sowing Date	Phenophases						Average
	P_1	P_2	P_3	P_4	P_5	P_6	
D_1	1282.73	1292.93	1200.98	861.77	822.96	1401.59	1143.83
D_2	1396.73	1179.13	954.43	864.59	1080.32	1586.78	1177.00
D_3	1218.2	1003.5	915.37	834.55	1301.17	1763.97	1172.80

Hygrothermal Unit-II

Sowing Date	Phenophases						Average
	P_1	P_2	P_3	P_4	P_5	P_6	
D_1	124.02	126.88	106.83	65.16	47.21	93.09	93.86
D_2	140.86	113.8	71.23	60.57	56.49	128.54	95.25
D_3	91.05	87.32	61.26	49.30	72.87	150.82	85.44

Table-8
Photo temperature (T_{photo})

Sowing Date	Phenophases						Average
	P_1	P_2	P_3	P_4	P_5	P_6	
D_1	25.48	25.61	23.52	16.36	16.22	24.43	21.94
D_2	26.14	23.92	19.04	16.46	19.46	26.92	21.99
D_3	23.3	20.24	17.38	15.94	23.74	29.06	21.61

Table-9
Nycto temperature (T_{nycto})

Sowing Date	Phenophases						Average
	P_1	P_2	P_3	P_4	P_5	P_6	
D_1	16.32	15.64	14.51	12.11	11.57	17.25	14.56
D_2	17.51	13.62	12.19	12.28	14.34	19.24	14.86
D_3	14.7	12.31	12.42	12.09	15.87	21.55	14.82

Table-10
Inter diurnal temperature (T_{IDR})

Sowing Date	Phenophases						Average
	P_1	P_2	P_3	P_4	P_5	P_6	
D_1	18.07	19.2	18.47	9.02	9.57	14.07	14.73
D_2	17.7	20.93	13.90	8.9	9.57	15.18	14.37
D_3	18.15	16.15	10.22	7.35	14.16	14.81	13.47

Inter diurnal temperature (T_{IDR}): The inter diurnal temperature (T_{IDR}) was significantly influenced by different sowing dates. The inter diurnal temperature was highest in the D_1 sowing (1590.3^{0}C) followed by D_2 sowing (1543.3^{0}C). The lowest inter diurnal temperature was taken by D_3 (1499.17^{0}C).

Conclusion

From the above study it is concluded that Agrometeorological parameters i.e. The GDD accumulation was significantly highest in D_1 (1907.25 day °C). Similar trend were also observed in case of heliothermal units (12785.73°day hrs) to reach maturity stage, HgTU-II (98217.9°day percent), photo temperature (2934.18^{o}C), nycto temperature (2120.33^{o}C) in D_1 sowing conditions. So it can be suggests that under the given agro climatic conditions of Allahabad, the Lentil crop sown on 22th November proved to be beneficial as the farmers can keep good harvest.

References

1. FAOSTAT (2013). Production Crops. Food and Agriculture Organization of the United Nations.
2. FAOSTAT (1988). Food and Agriculture Organization (FAO) Traditional. Retrieved from http://ww.fao.org.
3. Sehirali S. (1988). Grain legume crops. *African journal of agronomy*., 314-435.
4. Lee S.S., Kim J.H., Hong S.B., Yun S.H. and Park E.H. (1998). Priming effect of rice seeds on seedling establishment under adverse soil conditions. *Korean Journal Crop Science*., 3, 194-98.
5. Kant S., Pahuja S.S. and Pannu R.K. (2006). Effect of seed priming on growth and phenology of wheat under late-sown conditions. *Tropical Science*, 3, 9-150.
6. Giri G.S. and Schillinger W.F. (2003). Seed priming winter wheat for germination, emergence and yield. *Crop Science*., 3, 2135-2141.
7. Sivritepe H.O. and Dourado A.M. (1995). The effect of priming treatments on the viability and accumulation of chromosomal damage in aged pea seeds. *Annals of Botany*., 75(2), 165-171.
8. Chang S.M. and Sung J.M. (1998). Deteriorative changes in primed sweet corn seeds during storage. *Seed Science Technology*., 26, 613-626.
9. Taylor A.G., Allen P.S., Bennett M.A., Bradford K.J., Burris J.S. and Misra M.K. (1998). Seed enhancements. *Seed Science Research*., 8, 254-256.
10. Parera C.A. and Cantliffe D.J. (1994). Pre-sowing seed priming. *Horticulture Review*., 3, 109-141.
11. Nuttonson M.Y. (1955). Wheat-climatic relationships and the use of phenology in ascertaining the thermal and photo thermal requirements of wheat. *Soil Science.*, 83(2), 163.

12. Reddy T.Y. and Reddy G.H. (2001). Principles of Agronomy. Kalyani Publisher, Ludhiana.78-98.

13. Mehta U.R. and Mathur B.N. (1979). Effect of sowing time and seed rate on yield of wheat in Arid Region of Rajasthan. *Indian Journal of Agronomy*., 1, 17-20.

14. Rajput R.P. (1980). Response of soybean crop to climate and soil environment. Ph. D. Thesis, IARI, New Delhi.

15. Wang J.Y. (1963). Agricultural Meteorology. University of Wisconsin, Medison, Pacemaker Press. 101-135.

16. Ong C.K. (1983). Response to temperature in a stand of pearl millet (Pennisetium typhoides S. & H.). *J. Experimental Botany*, 34(140), 337-348.

17. Fussell L.K., Pearson C.J. and Norman M.J.T. (1980). Effect of temperature during various growth stages on grain development and yield of *Pennisetum americanum*. *Journal of Experimental Botany*., 31, 621-633.

18. Mashingaidze K. and Muchena S. (1982). induction of floret sterility by low temperatures in pearl millet (Pennisetum typhoides (Burm.) Stapf. & Hubbard). *Zimbabwe J. Agric. Res.* 20: 29-37.

19. Singh A.K., Tripathi P. and Adhar S. (2008). Heat unit requirements for phenophases of Wheat genotypes as influenced by sowing dates. *J. Agromet*., 10(2), 209-212.

20. Sastry P.N.S. and Chakarvarty N.V.K. (1982). Energy summation indices for Wheat crop in India. *Agricultural Meteorology*, 27(1-2), 45-48.