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Assessment of Crop Weather Relations in Wheat (*Triticum aestivum*) in Western Maharashtra Plain Zone

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Wheat (*Triticum aestivum L.*) is a thermo-sensitive long-day crop. Temperature is a major determinant of its growth and productivity. Late sown wheat exposes preanthesis phenological events to high temperature that influence grain development and ultimately the yield [1].

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Comprehensive assessments of the influence of climate variability on crop yields at local and regional scales can be highly beneficial. With an aim to assess the weather influences on wheat at local scale this study was taken up. An experiment was conducted at Department of Agricultural Meteorology Farm, College of Agriculture, Pune, Maharashtra State (India) in a split-plot design with three replications and sixteen treatment combinations of four different varieties and four sowing windows. Four varieties used were NIAW-301 (*Trymbak*), NIAW-917 (*Tapovan*), NIAW-1415 (*Netravati*) and NIAW-1994 (*Phule Samadhan*). Four sowings were taken up on 43rd MW (22-28 October), 45th MW (5-11November), 47th MW (19-25 November) and 49th MW (3-9 December). The grain yield of wheat was influenced significantly by wheat varieties. The grain yields were significantly higher in NIAW-1994 (51.07 and 48.52 qha-1) and significantly superior to the rest of the wheat varieties. This was followed by NIAW-917(45.72 and 43.43qha^{-1}), NIAW-301(43.57 and 41.27 q ha^{-1}). The variety NIAW-1415 recorded significantly lower grain yield (40.89 and 38.84 qha-1) during 2016 and 2017, respectively. Correlation analysis with weather parameters e.g. Temperature (Maximum and Minimum), Relative humidity (Morning and Evening), Rainfall and bright sunshine hours and yield showed that from tillering to 50% flowering stage, maximum temperature (-0.962*) was significantly negatively correlated with grain yield (r = -0.980**), (r =-0.950**) during 2016 and 2017, respectively in NIAW-301 (*Trymbak*). The same trend was observed in the remaining varieties also. Regression equations were developed to predict the yield.

Keywords: Correlation; regression; wheat varieties; sowing dates; growth stages and yield.

1. INTRODUCTION

"Wheat (*Triticum aestivum L.*) is a thermo-sensitive long-day crop. Temperature is a major determinant of its growth and productivity. Late sown wheat in rice-wheat system exposes preanthesis phenological events to high temperature that influence grain development and ultimately the yield" [1]. "The various meteorological factors such as temperature influence the physiological and morphological development of plant. During growth and development of a cereal crop several growth stages are distinguishable in which important physiological processes occur" [2].

"Temperature ranging between 20^0 to 25^{0}C is ideal for seed sowing and germination, where as the optimum temperature for vegetative growth ranges from 16^0 to 22^{0}C. During the grain development wheat requires a mean maximum temperature of about 25^{0}C for at least 4-5 weeks. Wheat is grown well in those areas where annual rainfall ranges between 1200 mm to1600 mm. Winter wheat generally completes its life-cycle most rapidly when grown in low temperatures during the early stages of growth but high temperature is required during the later stages of growth" [3]. Similarly, [4] advocated that "the normal sowing of wheat crop around 7th November to 20th November coincided with the mean temperature regimes of 16.8 to 20.0^{o}C, 14.5 to 18.9^{o}C and 18.4 to 21.7^{o}C at tillering to heading, heading to milking and milking to dough stages, respectively. The increase to 6.0^{0}C mean temperature During 90 to 105 days after sowing, it caused a reduction in number of effective tillers m^{-1} row in 105 days after sowing by 15 per cent. The highest grain yield was obtained on 20th November sown crop followed by 7th November sown crop under the agro-climatic conditions of Udaipur (Rajasthan), India". The effect of temperature on the wheat productivity can easily by seen in Central India because of high inter-annual fluctuations in the productivity due to fluctuations in seasonal temperature. The productivity of wheat is largely dependent on the magnitude of temperature change. 1^{0}C increase in temperature throughout the growing season will have no effect or slight increase on productivity in north India. But, an increase of 2^{0}C temperature reduced potential grain yield at most of the places.

Temperature is considered a one of the most important weather parameter and has profound effect on the yield of *rabi* crops. Changes in temperature affect the grain yield, mainly through phenological development processes. Winter crops are especially vulnerable to high temperature during reproductive stages and differential response of temperature change (rise) to various crops has been noticed under different production environments [5]. "Comprehensive assessments of the influence of climate variability on crop yields at local and regional scales can be highly beneficial" [6]. "Characterizing yield, weather, soil and management factors, from time to time are important sustainable agricultural practices. With an aim to assess the weather influences on wheat at local scale this study was taken up" [6].

2. MATERIALS AND METHODS

2.1 Location of the Experimental Site, Soil and Climatic Condition

The field experiment was conducted for two consecutive years at Department of Agricultural meteorology farm, College of Agriculture, Pune during rabi, 2016 and 2017. The geographical location of the site (Pune) was 18° 32'N, latitude; 73°51E, longitude and 559 m above mean sea level (MSL). The soil is medium black having depth of about 1m. The average annual rainfall of Pune is 675 mm.

2.2 Nature of Season during Experimental Period

Weekly mean meteorological data during the crop growth period (43^{rd} to 13^{th} MW) of rabi 2016 and 2017 recorded in class 'A' observatory situated in the adjoining field. The weekly maximum and minimum temperature during the crop growth period ranged from 35.2 and 9.2 ^{0}C during *rabi* 2016 and 38.6 and 10.3^{0}C during *rabi* 2017. During crop period, the weekly maximum and minimum temperatures varied from 27.0 to 35.2^{0}C and 9.2 to 21.6^{0}C, respectively, during 2016. It was varied from 28.4 to 38.6^{0}C and 10.3 to 21.9^{0}C respectively, during *rabi* 2017. Weekly relative humidity during morning (07.20 hrs LMT) afternoon (14.20 hrs LMT) was 96 and 15 % in 2016, 97 and 16 % in *rabi* 2017, respectively. The range of relative humidity during morning was 67-96 % and 65-97 % during the respective years while during afternoon was in the range of 15-38%, while, it was between 16-58 % during two years of experimentation, respectively. The weekly wind velocity during the crop growth period ranged from 1.1 to 4.8 and 1.6 to 4.4 kmph during 2016 and 2017, respectively. The annual bright sunshine hour's day-1 were 10.4 and 9.8 during 2016 and 2017, respectively. During the crop period, weekly sunshine hour day-1 ranged from 6.1 to 10.4 in 2016 and from 5.0 to 9.8 during 2017. It could be noticed that the sunshine hour's day-1 were minimum in 50th and 46th MW (6.1, 8.0) during 2016, while in 49th MW (5.0) during 2017. The weekly evaporation ranged from 3.4 to 7.9 and 3.2 to 7.9 mm per day in 2016 and 2017, respectively. The weekly photoperiod i.e. maximum possible sunshine hours which were fixed for the particular day in a year ranged from 10.38 to 13.87.

2.3 Experimental Details

The experiment was conducted in a split plot design with three replications & sixteen treatment combinations of four different varieties and four sowing windows. Four varieties used were NIAW-301 (*Trymbak*), NIAW-917 (*Tapovan*), NIAW-1415 (*Netravati*) and NIAW-1994 (*Phule Samadhan*). Four sowings were taken up on 43^{rd} MW (22-28 October), 45^{th} MW (5-11November), 47^{th} MW (19-25 November) and 49^{th} MW (3-9 December) standard meteorological week respectively.

The experiment was laid out in split plot design with three replications. The gross and net plot size was 3.50 x 2.70 m^2 and 2.50 x 1.80 m^2, respectively. The allocation of treatments was done with random method. The wheat seeds were treated with Azatobacter + PSB culture @250gm/ 10kg seed for better nitrogen fixation in the soil. The seeds were sown by line sowing with distance of 22.5 cm between two rows by using seed rate @ 120kg/ha. The required quantity of fertilizer was given in the form of urea, single super phosphate (SSP) and murate of potash (MOP) as basal dose. The half dose of nitrogen (60 kg/ha.) through urea and full dose of P2O5 (60kg/ha.) through SSP and K2O (40kg/ha.) through MOP were applied as basal dose at sowing to all treatments. The remaining half dose of nitrogen (60 kg ha^{-1}) was top dressed through urea at 30 DAS.

2.4 Statistical Analysis

2.4.1 Statistical analysis and interpretation of data

Correlation and regression analysis were done between the growth and yield characters with the weekly mean/total values of rainfall, maximum temperature, minimum temperature, relative humidity and sunshine hours to determine the effect of weather elements on the growth and yield of wheat. Regression equations were worked out from these observations.

The statistical SPSS software (Statistical Package for the Social Sciences) is used version SPSS 16.0 Copyright 2007 is a data analyzing software through which different types of data may be analyzed on statistical basis, like in MS-Excel. Yield is predicted through a model thus a correlation analysis needs to be described between yield and weather parameters using SPSS software.

3. RESULTS AND DISCUSSION

3.1 Grain Yield

Data with respect to mean grain yield of wheat as influenced by different treatments are presented in Table 1. The mean grain yield of wheat was 45.31 and 43.01 qha^{-1}during 2016 and 2017, respectively.

3.1.1 Effect of varieties

The grain yield of wheat was influenced significantly due to wheat varieties the grain yield was significantly higher in NIAW-1994(51.07 and 48.52 qha^{-1}) and significantly superior rest of the wheat varieties.). This was followed by NIAW-917(45.72 and 43.43 q ha^{-1}), NIAW-301(43.57 and 41.27 q ha^{-1}). The variety NIAW-1415 recorded significantly lower grain yield (40.89 and 38.84 qha^{-1}) during 2016 and 2017, respectively. The differences in grain yield of wheat varieties might be due to inherent genetical potential of wheat variety. Similar results were reported by [7-10].

3.1.2 Effect of sowing windows

The grain yield of wheat was influenced significantly due to extended sowing windows. The grain yield was maximum at 47th MW sowing window (50.40 and 47.88 qha^{-1}), the grain yield of 45th MW (47.94 and 45.42 qha-1) were at par with 47th MW sowing window. This was followed by 43rd MW sowing window (43.88 and 41.68 q ha^{-1}), 49thMW sowing window (39.04 and 37.07 q ha^{-1}) during 2016 and 2017, respectively. The reduction in grain yield caused due to sowing windows was because of difference in temperature. A sowing window of 47th MW was favorable to high grain production because the post anthesis period coincided with relative low temperature. However, later sowing 49th MW were unfavorable to grain yield since low temperature during early sowing might have adversely affected the emergence and ultimately tillers per running meter. In later sowing (49th MW) the period between anthesis and leaf senescence was curtailed by the onset of relatively higher temperature. These results are in agreement with the findings of [7-10].

3.1.3 Interaction effect

The grain yield (q ha^{-1}) was significantly influenced by interaction between varieties and sowing windows during 2016 and 2017. Sowing at 47th MW sowing window (S_3) recorded maximum grain yield (56.08 and 53.29 q ha^{-1}), in variety NIAW-1994 (V_4). This was followed by variety NIAW-917 (V_2) (53.38 and 50.68q ha^{-1}), NIAW-301(V_1) (47.86 and 45.01q ha^{-1}), and NIAW-1415(V_3) (46.51 and 44.20 q ha^{-1}) during 2016 and 2017 respectively. A high temperature particularly during panicle emergence and grain filling stages interfered with normal development of grain cause shriveling of grains. Thus, reduction in grain yield was caused due to smaller size of grains. This results showed that delay in sowing of wheat varieties could not able to assimilate the more biomass resulted in reduced grain yield of wheat. Similar results were reported by [7].

Table 1. Mean Grain yield (q/ha) of wheat as influenced by different treatments

Treatment	Grain yield (q/ha)		
	2016-17	2017-18	Pooled
A) Main plot: Varieties			
V_1:NIAW-301	43.57^c	41.27^c	42.42^c
V_2:NIAW-917	45.72^b	43.43^b	44.57^b
V_3:NIAW-1415	40.89^d	38.84^d	39.86^d
V_4:NIAW-1994	51.07^a	48.52^a	49.79^a
S. Em.±	0.42	0.41	0.41
C.D. at 5%	1.46	1.41	1.44
S_1: 43thMW	43.88^b	41.68^c	42.78^b
S_2: 45thMW	47.94^a	45.42^b	46.68^a
S_3: 47th MW	50.40^a	47.88^a	49.14^a
S_4: 49th MW	39.04^c	37.07^d	38.06^c
S. Em.±	0.87	0.83	0.85
C.D. at 5%	2.54	2.41	2.48

Treatment	Grain yield (q/ha)		
	2016-17	2017-18	Pooled
Mean	45.31	43.01	44.16
C) Interaction (A × B)			
V_1S_1	44.23^{c}	42.01^{c}	42.01^{c}
V_1S_2	45.63^{bc}	43.35^{bc}	43.35^{bc}
V_1S_3	47.86^{bc}	45.01^{bc}	45.01^{bc}
V_1S_4	36.56^{d}	34.72^{d}	34.72^{d}
V_2S_1	41.58^{c}	39.52^{cd}	39.52^{cd}
V_2S_2	47.04^{bc}	44.67^{bc}	44.67^{bc}
V_2S_3	53.38^{ab}	50.68^{ab}	50.68^{ab}
V_2S_4	40.90^{cd}	38.84^{cd}	38.84^{cd}
V_3S_1	39.20^{d}	37.22^{cd}	37.22^{cd}
V_3S_2	42.56^{cd}	40.44^{c}	40.44^{c}
V_3S_3	46.51^{bc}	44.20^{bc}	44.20^{bc}
V_3S_4	35.27^{d}	33.49^{d}	33.49^{d}
V_4S_1	50.50^{b}	47.98^{b}	47.98^{b}
V_4S_2	54.28^{ab}	51.56^{ab}	51.56^{ab}
V_4S_3	56.08^{a}	53.29^{a}	53.29^{a}
V_4S_4	43.42^{cd}	41.24^{c}	41.24^{c}
S. Em.±	1.74	1.65	1.70
C.D. at 5%	5.08	4.83	4.95

Note: Observations with same superscript are at par and with different superscript are significantly different

3.2 Crop Weather Relations

The correlations of wheat yield for crop seasons (2016-17 to 2017-18) have been studied for different varieties. Year wise variation in grain yield may be considered more pronounced due to variation in weather variables and their inter-relationship effects rather than factors involved in raising crop for different phonological stages [11].

3.2.1 Correlation between weather parameters and yield for variety NIAW-301

The linear correlation analysis for wheat variety NAIW-301(Table 2) showed that in CRI (crown root initiation) stage on wheat, no weather variable was significantly correlated with grain yield through maximum temperature, minimum temperature, rainfall, relative humidity and bright sunshine hours which were positively correlated with grain yield. In tillering stage on wheat, no weather variable was significantly correlated with yield; however, maximum temperature, rainfall, relative humidity and sunshine are having positive correlation while minimum temperature was negatively correlated. In 50% flowering stage, maximum temperature was significantly correlated with grain yield ($r = -0.980^{**}$), ($r = -0.950^{**}$) during 2016 and 2017, respectively.

In physiological maturity crop growth stage the rainfall, relative humidity and sunshine were having positive correlation and maximum temperature was correlated with grain yield (r = -0.867), (r = -0.874) during 2016 and 2017, respectively.

The results obtained from this analysis indicated that higher maximum temperature during 50% flowering going to cause a reduction in the grain yield of wheat crop. This might be due to effect on physiological mechanism and thermal stress condition which affected the metabolic activities in the plant. Meteorological parameters favorable rainfall was found to have the positive relation as this crop is requiring water requirement at critical stages of CRI, tillering, jointing, heading (50% flowering) and hence rainfall as this stage might have helped to meet its crop water requirements. These results are in agreement with the findings of [12], and [13].

3.2.2 Correlation between weather parameters and yield for variety NIAW-917

The linear correlation analysis for wheat variety NAIW-917(Table 3) showed that in CRI (crown root initiation) stage on wheat, no weather variable was significantly correlated with grain yield through maximum temperature, minimum temperature, rainfall, relative humidity and bright sunshine hours which were positively correlated with grain yield. In tillering stage on wheat, no weather variable was significantly correlated with yield. However, maximum temperature, rainfall, relative humidity and sunshine are having positive correlation while minimum temperature was negatively correlated. In 50% flowering stage, maximum temperature was significantly correlated with grain yield (r = -0.975**), (r =-0.926**) during 2016 and 2017, respectively.

In physiological maturity crop growth stage the rainfall, relative humidity and sunshine were having positive correlation and maximum temperature was correlated with grain yield (r = -0.864), (r = -0.834) during 2016 and 2017, respectively.

The results obtained from this analysis indicated that higher maximum temperature during 50% flowering going to cause a reduction in the grain yield of wheat crop. This might be due to effect on physiological mechanism and thermal stress condition which affected the metabolic activities in the plant. Meteorological parameters favorable rainfall was found to have the positive relation as this crop is requiring water requirement at critical stages of CRI, tillering, jointing, heading (50% flowering) and hence rainfall as this stage might have helped to meet its crop water requirements. These results are in agreement with the findings of [12], and [13].

Table 2. Correlation between weather parameters and yield of NIAW-301 during 2016-17 and 2017-18

Weather parameter	Correlation coefficient (r)							
	CRI		Tillering		50% flowering		Flowering – physiological maturity	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Tmax	0.236	0.274	0.118	0.136	-0.980**	-0.950**	-0.867	-0.874
Tmin	0.195	0.125	-0.172	-0.141	-0.229	-0.772	-0.229	-0.746
RH-I	0.210	0.235	0.236	0.278	0.872	0.757	0.872	0.721
RH-II	0.185	0.174	0.145	0.168	0.115	0.498	0.115	0.836
Rainfall	0.263	0.238	0.135	0.174	0.856	0.854	0.856	0.274
BSH	0.168	0.188	0.242	0.268	0.854	0.678	0.854	0.815

r =Correlation coefficient between wheat yield and seasonal average weather variables.
**. Correlation significant at 5 % level (p- 0.05), **. Correlation significant at 1% level (p- 0.01)*

Table 3. Correlation between weather parameters and yield for variety NIAW-917

Weather parameter	Correlation coefficient (r)							
	CRI		Tillering		50% flowering		Flowering –physiological maturity	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Tmax	0.254	0.245	0.123	0.145	-0.975**	-0.926**	-0.864	-0.834
Tmin	0.182	0.136	-0.116	-0.114	-0854.	-0784.	-0.469	-0.442
RH-I	0.274	0.264	0.238	0.239	0.687	0.636	0.323	0.327
RH-II	0.135	0.175	0.165	0.113	0.541	0.548	0.278	0.478
Rainfall	0.251	0.216	0.178	0.198	0..24	0..458	0.371	0.528
BSH	0.143	0.174	0.221	0.248	0.87	0.746	0.412	0.364

r =Correlation coefficient between wheat yield and seasonal average weather variables.
**. Correlation significant at 5 % level (p- 0.05),*
***. Correlation significant at 1% level (p- 0.01)*

Table 4. Correlation between weather parameters and yield for variety NIAW -1415

Weather parameter	Correlation coefficient (r)							
	CRI		Tillering		50% flowering		Flowering –physiological maturity	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Tmax	0.212	0.236	0.143	0.197	-0.948**	-0.962**	-0.832	-0.810
Tmin	0.174	0.194	-0.134	-0.163	-0.832	-0.938	-0.734	-0.734
RH-I	0.265	0.272	0.274	0.274	0.784	0.747	0.678	0.678
RH-II	0.136	0.138	0.139	0.131	0.641	0.541	0.548	0.548
Rainfall	0.215	0.238	0.125	0.178	0.236	0.687	0.269	0.269
BSH	0.145	0.147	0.267	0.239	0.642	0.412	0.428	0.428

r =Correlation coefficient between wheat yield and seasonal average weather variables.
**. Correlation significant at 5 % level (p- 0.05)*
***. Correlation significant at 1% level (p- 0.01)*

Table 5. Correlation between weather parameters and yield for variety NIAW-1994

Weather parameter	Correlation coefficient (r)							
	CRI		Tillering		50% flowering		Flowering –physiological maturity	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Tmax	0.298	0.212	0.247	0.247	-0.983**	-0.952**	-0.832	-0.743
Tmin	0.193	0.135	-0.136	-0.167	-0.823	-0.814	-0.734	-0.689
RH-I	0.245	0.234	0.287	0.236	0.841	0.698	0.678	0.589
RH-II	0.169	0.117	0.138	0.174	0.587	0.478	0.548	0.412
Rainfall	0.287	0.295	0.143	0.112	0.364	0.365	0.269	0.364
BSH	0.139	0.143	0.368	0.398	0.741	0.654	0.428	0.742

r =Correlation coefficient between wheat yield and seasonal average weather variables.
**. Correlation significant at 5 % level (p- 0.05)*

3.2.3 Correlation between weather parameters and yield for variety NIAW-1415

The linear correlation analysis for wheat variety NAIW-1415 (Table 4) showed that in CRI stage on wheat, no weather variable was significantly correlated with grain yield through maximum temperature, minimum temperature, rainfall, relative humidity and bright sunshine hours which were positively correlated with grain yield. In tillering stage on wheat, no weather variable was significantly correlated with yield. However, maximum temperature, rainfall, relative humidity and sunshine are having positive correlation while minimum temperature was negatively correlated. In 50% flowering stage, maximum temperature was significantly correlated with grain yield (r = -0.948**), (r =-0.962**) during 2016 and 2017, respectively.

In physiological maturity crop growth stage the rainfall, relative humidity and sunshine were having positive correlation and maximum temperature was correlated with grain yield (r = -0.832), (r = -0.810) during 2016 and 2017, respectively.

The results obtained from this analysis indicated that higher maximum temperature during 50% flowering going to cause a reduction in the grain yield of wheat crop. This might be due to effect on physiological mechanism and thermal stress condition which affected the metabolic activities in the plant. Meteorological parameters favorable rainfall was found to have the positive relation as this crop is requiring water requirement at critical stages of CRI, tillering, jointing, heading (50% flowering) and hence rainfall as this stage might have helped to meet its crop water requirements. These results are in agreement with the findings of [12], and [13].

Table 6. Regression equation developed for wheat varieties

Sr. No.	Variety	Year	Equation	R^2 value
1	NIAW-301	2016	Yield= 0.646 – 0.422 (T max)	0.80
2	NIAW-301	2017	Yield = 1669.85 – 64.358(T max)	0.87
3	NIAW-917	2016	Yield = 0.868 – 0.30.430 (Tmax)	0.86
4	NIAW-917	2017	Yield = 59.225 – 3.268(Tmax)	0.90
5	NIAW-1415	2016	Yield = 4.570– 0.405 (Tmax)	0.89
6	NIAW-1415	2017	Yield = 180.942– 16.215 (Tmax)	0.92
7	NIAW-1994	2016	Yield = 1.276– 0.438 (Tmax)	0.98
8	NIAW-1994	2017	Yield = 833– 28.940 (Tmax)	0.87

**T max = Maximum temperature during flowering (°C)*

3.2.4 Correlation between weather parameters and yield for variety NIAW-1994

The linear correlation analysis for wheat variety NAIW-1994 (Table 5) showed that in CRI stage on wheat, no weather variable was significantly correlated with grain yield through maximum temperature, minimum temperature, rainfall, relative humidity and bright sunshine hours which were positively correlated with grain yield. In tillering stage on wheat, no weather variable was significantly correlated with yield, however, maximum temperature, rainfall, relative humidity and sunshine are having positive correlation while minimum temperature was negatively correlated. In 50% flowering stage, maximum temperature was significantly correlated with grain yield ($r = -0.983^{**}$), ($r = -0.952^{**}$) during 2016 and 2017, respectively.

In physiological maturity crop growth stage the rainfall, relative humidity and sunshine were having positive correlation and maximum temperature was correlated with grain yield (r = -0.832), (r = -0.743) during 2016 and 2017, respectively.

The results obtained from this analysis indicated that higher maximum temperature during 50% flowering going to cause a reduction in the grain yield of wheat crop. This might be due to effect on physiological mechanism and thermal stress condition which affected the metabolic activities in the plant. Meteorological parameters favorable rainfall was found to have the positive relation as this crop is requiring water requirement at critical stages of CRI, tillering, jointing, heading (50% flowering) and hence rainfall as this stage might have helped to meet its crop water requirements. These results are in agreement with the findings of [8], and [11].

3.3 Development of Regression Equations Developed

Stepwise regression analysis was carried out to select the critical variables, which contributed to yield, morphological characters and phenological variables during 2016 and 2017, respectively.

Among all the weather parameters maximum temperature has greatest influence in determining the yield and yield attributes in different varieties. Regression equations were developed based on maximum temperature for estimation of grain yield.

4. CONCLUSIONS

The crop sown during the 47th MW sowing window (S_3) could take maximum calendar days, hence higher growing degree days, photo thermal units, and helio-thermal units for all the stages, which were considerably reduced with subsequent delays in sowing. Thus, the wheat crop sown during the 47th MW sowing window (S_3) recorded the highest grain yield, closely followed by the 45th MW and 47th MW sowing window (S_2) crops. Among the varieties, the timely sown wheat varieties V_2: NIAW-917 (*Tapovan*) and V_4: NIAW-1994 (*Phule Samadhan*) acquired maximum thermal units and produced maximum yield because of their longer duration. NIAW-917 and NIAW-1994 have the potential to efficiently convert the heat units into economic yield and biomass.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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