AGRO METEOROLOGICAL INDICES INFLUENCED BY VARYING SOWING ENVIRONMENT AND VARIETIES OF WHEAT IN WESTERN MAHARASHTRA PLAIN ZONE

ABSTRACT

An agro-meteorological investigation was undertaken during *rabi*, 2016 and 2017 at Farm, Department of Agricultural Meteorology, College of Agriculture, Pune, Maharashtra State (India).The experiment was laid out in split plot design with three replications. The treatment comprised of four varieties *viz.* V_1: NIAW-301 (*Trymbak*) V_2: NIAW-917 (*Tapovan*), V_3: NIAW-1415 (*Netravati*) and V_4:NIAW-1994 (*Phule Samadhan*) as main plot and four sowing windows *viz*., S_1: 43rd MW (22-28 October), S_2: 45th MW (5-11November), S_3: 47th MW (19-25 November) and S_4: 49th MW (3-9 December) as sub plot treatments. The agrometeorological indices indicated more values for 45th MW (5-11November) and 47th MW (19-25 November) sown wheat crops and lowest values in late sown crop. Days to crown root stage, tillering stage, ear emergence stage, 50% flowering stage, milking stage, dough stage and physiology maturity matched closely with observed values for all sowing environments. It revealed that 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 43.43 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 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), 49th MW sowing window (39.04 and 37.07 q ha^{-1}) during 2016 and 2017, respectively.

Keywords: Wheat, Growing Degree Days, Helio Thermal Units, Photo Thermal Units, sowing dates, verities, growth stages and yield

1. INTRODUCTION

Wheat (*Triticum aestivum L*.) is originated in South West Asia. It is one of the most important staple food grain crops throughout the world. India ranks second in the world in respect of wheat production, next only to china that has played a vital role in stabilizing the food production of the country. Area under this crop in India is 31.61 million hectare with a production of 109.52 million tonnes of production and 3464 Kg./hectare productivity. In Maharashtra, this crop is presently being cultivated on 1.31 million hectare with a production of 2.33 million tonnes and productivity of 1782 Kg/hectare [1].

The productivity of any crop is the complex phenomenon governed by a number of factors such as an appropriate sowing time, sowing method, spacing, use of improved varieties, judicious use of water and nutrients, weed, pest and disease management. Apart from agronomic practices weather factors have very significant impact on crop production. Therefore optimum sowing windows for higher yield is necessary. In climate change scenario, weather parameters prevails during crop growing season strongly influence crop growth and development and it accounts for two thirds (67%) of variation in productivity while other factors including soil and nutrient management account for one-third (33%) of the productivity. 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].

Wheat (*Triticum aestivum L.*) is basically a long day crop of the temperate region and requires relatively low temperature for satisfactory growth. Among the climatic factors, temperature plays a key role in determining the sowing time and consequently the duration of different phenophases, which affect the crop productivity [16].

[11] studied November to December and four varieties (DWR-162, DWR-195, DWR-185, and DWR-1013) on the phenological development, growth, and productivity of wheat under Raichur (Karnataka, India) conditions. Maximum GDD (1989) and PTU (14760) were recorded in DWR-1013, followed by DWR-185, DWR-162, and DWR-195. It was concluded that GDD and PTU could also be used as tools for recommending the optimum sowing period for wheat genotypes.

[15] advocated that the normal sowing of wheat crop around 7^{th} November to 20^{th} 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 20^{th} November sown crop followed by 7^{th} November sown crop under the agro-climatic conditions of Udaipur (Rajasthan), India. Similarly, [6] revealed from their study that the highest thermal and radiation regimes of 2095^{o}C a day for GDD, 15515^{o}C day ha-1 for HTU, 31880^{o}C day h for PTU and 2140 mmol m^{-2} for PAR was associated with the maximum yield from crop sown on 20th November. Grant et al.(2011) reported that climate warming may raise wheat (Triticum aestivum L.) yields in cooler climates and lower them in warmer climates.

Wheat has its own definite requirements for temperature and light for emergence, growth and flowering [4]. The optimum temperature required for wheat anthesis and grain filling ranges between 12 and 22°C and exposure to temperature above 30 °C at pre-anthesis or post-anthesis stages reduces the grain filling rate in wheat and thereby decreases the grain yield. Therefore, heat stress imposed on plant due to delayed sowing is considered as the most significant abiotic stress affecting wheat productivity [12]. Hence, it becomes imperative to have knowledge of exact duration of phenological stages in a particular crop-growing environment and their impact on yield of crop. Growing of suitable variety at an appropriate time is essential for ensuring optimum productivity. Being a thermo sensitive crop, choice of suitable variety for different sowing windows further gets prime importance. Therefore, an experiment was planned to study the agro-meteorological indices under different sowing dates to obtain higher grain yield of promising wheat varieties in western Maharashtra plain zone.

2. MATERIAL AND METHODS

2.1 Location of the Experimental Site, Soil and Climatic Condition

The field experiment was conducted for two consecutive years at Farm, Department of Agricultural meteorology 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 (43rd to 13th 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 hours 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.

2.2 Experimental Details

The experiment was laid out in split plot design with three replications. The treatment comprised of four varieties viz., V_1: NIAW-301 (Trymbak) V_2: NIAW-917 (Tapovan), V_3: NIAW-1415 (Netravati) and V_4:NIAW-1994 (Phule Samadhan) as main plot and four sowing windows viz., S1: 43rd MW (22-28 October), S2: 45th MW (5-11November), S3: 47th MW (19-25 November) and S4: 49th MW (3-9 December) as sub plot treatments.

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 certified seed of all the wheat variety NIAW-1994 (Phule Samadhan), NIAW-301 (Trymbak), NIAW-917 (Tapowan), and NIAW-1415 (Netravati) was procured from the Agricultural Research Station, Niphad, Dist. Nashik, MPKV, Rahuri. 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) was top dressed through urea at 30 DAS.

2.4 Calculation Agro meteorological indices:

2.4.1 Growing Degree Days (GDD):

Temperature is a major environmental factor that determines rate of plant development. The temperature required and range of optimum temperature varies with sowing dates and available soil moisture. Thermal response of sowing dates can be quantified by using the heat unit or thermal time concept. Thermal time or growing degree days is calculated according to the equation,

$$GDD=\sum_{i=1}^{n}\frac{T\ max+T\ min}{2}-T\ base$$

where $\sum_{i=1}^{n}$ =Period in days from sowing date till the last date of harvesting

G.D.D. = Growing degree days

Tmax. = Daily maximum temperature of day i (0C)

Tmin. = Daily minimum temperature of day i (0C)

Tb = Base temperature

In present study, the base temperature of wheat was taken as 4.5 0C.

2.4.2 Photo-Thermal Units (PTU) :

Photo-thermal units were determined by GDD multiplying with maximum possible sunshine hours (N).

Helio thermal units = GDD x N

2.4.2 .1 Determination of maximum possible sunshine hours:

Maximum possible sunshine hours were calculated by using following equation.

N=COS (RADIANS ((COS (RADIANS (((A91-172)*2*180)/365)))*23.5))

2.4.3 Helio Thermal Units (HTU)

Helio thermal units for various growth stages are calculated by the formula given by Ritchie and Nesmith, (1991) [14].

HTU = GDD x Bright sunshine hours

2.4.4 Grain Yield (gha^{-1}):

Grain weight net plot-1was recorded after threshing all plants of each net plot. The final grain yield from each net plot was obtained by adding grain weight of five observations plants of respective net plot. The treatment wise per hectare grain yield was computed by multiplying hectare factor and calculating as grain yield ha^{-1}

3. RESULT AND DISCUSSION

3.1 Agro meteorological indices

3.1.1 Growing Degree Days (GDD):

Heat unit requirement or GDD has been used for characterizing the thermal response in wheat crop and other crops [13]. Bright sunshine hours, maximum and minimum temperature during the growth period were recorded from meteorological observatory. Growing degree days (GDD) were computed by taking a base temperature 4.5^{0}C.

It was evident from the Table 1 that accumulated growing degree days (GDD) for different genotypes under different thermal environments varied considerably from sowing to maturity. Different wheat varieties responded differently in terms of accumulated GDD at the time of maturity. Higher GDD was observed under 47th MW in varieties NIAW-917 (2421.7 and 2457.6) and NIAW-1994 (2340.8 and 2382.7) during 2016 and 2017, respectively. Lower GDD was noticed under 49th MW in case of NIAW-1415(1637.4 and 1675.85) during 2016 and 2017, respectively. The requirement of heat unit was higher for timely sown crop than late sown crop due to longer period for all the phenological stages in the timely sown crop. A progressive delay in sowing decreased the duration of phenophases which caused a decrease in accumulation of GDD during various phenophases and forced the crop to attain maturity. This decline in GDD accumulation was due to prevailing low temperature during vegetative phases and high temperature during reproductive phases of development in late sown crop [7]. These findings are in conformity with [13], [2] and [3] who reported that heat unit requirement decreased with delay in sowing window.

3.1.2 Photo Thermal Unit (PTU)

Different wheat varieties responded differently in terms of accumulated PTU at the time of maturity. Highest PTU was observed at 47th MW sowing (S_3) in all the varieties.

Photo thermal units (PTU) for different genotypes under different thermal environment varied considerably at maturity (Table 2). Higher photo thermal units (PTU) observed under 47th MW sowing window in varieties NIAW-917 (21864.3 and 29060.4) and NIAW-1994 (21122.1 and 28089.6) during 2016 and 2017, respectively. These findings are in conformity with [3] the higher PTU value in timely sown crop may be due to fact that crop took longer duration to reach phenological stages.

3.1.3 Helio Thermal Unit (HTU):

Different wheat varieties responded differently in terms of accumulated HTU at the time of maturity. The highest HTU was observed at 47th MW sowing (S_3) in all the varieties.

Helio thermal units (HTU) for different genotypes under different thermal environment varied considerably under maturity period (Table 3). In case of NIAW-917 (21864.33 and 20720.94) the highest HTU was observed under47th MW sowing (S_3). These results are in general agreement with the findings of [9], [10] and [8].

The growing degree day GDD for entire crop growing period decreased with subsequent delay in sowing, whereas HTU and PTU were decreased up to late sowing window condition. These results are in general agreement with the findings of [16].

The occurrence of different phenological events during growing season of any crop and the effect of temperature on plant growth can be inferred using accumulated heat units or growing degree days (GDD). The duration of each growth phase was a result of crop response to external environmental factors. The concept of heat units has been applied to correlate the phenological development of different crops to predict grain yield and physiological maturity [8].

3.2. Grain Yield:

The data presented in (table 4) revealed that variety NIAW-1994 (*Phule Samadhan*) gave significantly highest grain yield (51.07 qha-1 during 2016-17 and 48.52 q ha-1 during 2017-18) as compared to NIAW-301 (Trymbak), NIAW-917 (Tapowan), and NIAW-1415 (Netravati) during both the years. Amongst dates of sowing, 47th MW (19-25 November) sown crop significantly out yielded the subsequent dates of sowing (50.40 q ha-1 during 2016-17 and 47.88 q ha-1 during 2017-18) during both the years.

Table 1.Cumulative growing degree days (heat unit) at critical growth stage as influenced by different sowing windows and varieties in wheat during 2016-17 and 2017-18

Treatments A. Variety	B. Sowing windows :	S_1: 43thMW		S_2: 45th MW		S_3: 47th MW		S_4: 49th MW	
	Growth Stage	16-17	17-18	16-17	17-18	16-17	17-18	16-17	17-18
V1:NIAW-301	CRI	326.2	395.4	379.5	356.3	368.5	393.2	359.7	371.5
	Tillering	607.8	650.6	599.1	641.8	598	619.1	568.3	587.3
	Ear emergence	952.2	952.2	948.7	948.75	931.6	931.6	823.1	823.14
	50% Flow.	1269.6	1327.9	1373.7	1438.8	1330.0	1376.9	1054.4	1091.1
	Milking	1502.4	1513.5	1535.1	1545.1	1541.0	1563.7	1490.0	1489.4
	Dough	1827.3	1637.4	1874.6	1856.1	1885.2	1965.6	1665.7	1623.4
	Maturity	1992.0	2070.1	2197.3	2259.7	2163.5	2204.3	1707.4	1743.7

V2:NIAW-917	CRI	326.25	395.45	379.55	356.3	368.5	393.25	359.75	371.5
	Tillering	607.85	650.6	599.15	641.8	598	619.1	568.35	587.35
	Ear emergence	967.2	967.2	974.75	974.75	982.64	982.64	827.14	827.14
	50% Flow.	1209.5	1267.5	1304.3	1370.7	1575.4	1620.3	1200.3	1238.4
	Milking	1513.5	1587.3	1545.1	1754.4	1563.7	1898.7	1489.4	1490.2
	Dough	1637.4	1613.2	1856.1	1834.5	1965.6	1967.4	1623.4	1587.5
	Maturity	1714.25	1793.6	2013.25	2077.5	2421.7	2457.6	1791.65	1826.2
V3:NIAW-1415	CRI	326.25	395.45	379.55	356.3	368.5	393.25	359.75	371.5
	Tillering	607.85	650.6	599.15	641.8	598	619.1	568.35	587.35
	Ear emergence	931.2	931.2	947.75	947.75	951.64	951.64	813.14	813.14
	50% Flow.	1151.2	1203.5	1199.0	1264.9	1347.1	1395.6	1016.7	1055.2
	Milking	1502.4	1502.4	1527.4	1527.4	1537.8	1537.8	1456.1	1456.1
	Dough	1614.7	1614.7	1831.2	1831.2	1864.1	1864.1	1564.3	1564.3
	Maturity	1750.1	1829.7	1933.2	1985.6	2212.6	2253.8	1637.4	1675.8
V4:NIAW-1994	CRI	326.25	395.45	379.55	356.3	368.5	393.25	359.75	371.5
	Tillering	625.21	650.6	599.15	641.8	598	619.1	568.35	587.35
	Ear emergence	979.2	979.2	993.7	993.7	1012.6	1012.6	843.14	843.14
	50% Flow.	1445.3	1525.65	1577.8	1644.15	1671.5	1717.55	1276.8	1313.3
	Milking	1787.3	1502.4	1854.4	1535.1	1898.7	1541.0	1490.2	1490.0
	Dough	1813.2	1827.3	1934.5	1874.6	1967.4	1885.2	1587.5	1665.7
	Maturity	1952.3	2031.2	2137.95	2205.2	2340.8	2382.7	1749.15	1784.65

Table 2. Cumulative Photothermal Unit (PTU) at critical growth stage as influenced by different sowing windows and varieties in wheat during 2016-17 and 2017-18

Treatments A. Variety	**B. Sowing windows :**	**S_1: 43thMW**		**S_2: 45th MW**		**S_3: 47th MW**		**S_4: 49th MW**	
	Growth Stage	**16-17**	**17-18**	**16-17**	**17-18**	**16-17**	**17-18**	**16-17**	**17-18**
V1:NIAW-301	CRI	3298.4	4554.6	2713.2	3915.1	3263.6	4422.0	2998.6	4317.1
	Tillering	5213.7	7294.2	5098.9	7189.8	5067.5	7176.9	4897.2	6820.2
	Ear emergence	8413.1	11912.6	8737.3	12348.3	8827.8	11987.2	6912.1	10452.1
	50% Flow.	10852.4	15235.8	11472.0	16484.4	11362.4	15960.6	8955.6	12653.4
	Milking	13913.4	18742.5	15743.2	19234.5	15933.7	18945.2	12610.5	15984.2
	Dough	15767.2	21369.4	17812.8	22314.6	17963.2	21654.1	13933.7	17942.6
	Maturity	17092.1	23904.2	19396.3	26368.2	19447.5	25962.8	15298.5	20488.8
V2:NIAW-	CRI	3298.4	4554.6	2713.2	3915.6	3263.6	4422.4	2998.6	4317.5

917	Tillering	5213.7	7294.2	5098.9	7189.8	5067.5	7176.4	4897.2	6820.2
	Ear emergence	5467.7	11913.8	8874.2	12487.5	8967.9	13689.1	8347.4	11633.5
	50% Flow.	10283.9	14514.6	10804.3	15651.6	13710.5	18905.4	10227.0	14404.2
	Milking	11913.1	16552.4	13743.7	17864.2	15843.2	21126.3	12672.1	16214.1
	Dough	12742.2	18942.5	15743.8	21475.6	17910.7	23951.6	13987.4	18736.9
	Maturity	14525.5	20571.1	17613.6	24159.9	21864.3	29060.4	16103.0	21499.8
V3:NIAW-1415	CRI	3298.4	4554.6	2713.2	3915.4	3263.6	4422.9	2998.6	4317.4
	Tillering	5213.7	7294.2	5098.9	7189.8	5067.5	7176.4	4897.2	6820.2
	Ear emergence	7536.4	11233.5	7643.8	11467.9	7894.1	11849.2	7310.9	10426.4
	50% Flow.	9769.1	13814.4	9873.5	14388.6	11475.2	16165.8	8602.8	12200.4
	Milking	11733.7	16354.7	11810.4	17894.5	13867.8	19634.2	11467.1	15426.3
	Dough	12914.3	19364.8	13167.2	21457.8	15613.9	22547.2	12995.2	17456.8
	Maturity	14864.3	21001.2	16832.4	23198.4	19916.3	26551.2	14619.8	19648.8
V4:NIAW-1994	CRI	3298.4	4554.6	2713.2	3915.0	3263.6	4422.5	2998.6	4317.7
	Tillering	5213.7	7294.2	5098.9	7189.8	5067.5	7176.2	4897.25	6820.2
	Ear emergence	8932.7	12135.7	9433.4	12854.6	9799.3	12984.5	8212.1	11925.1
	50% Flow.	12058.4	17344.2	13310.5	18933.6	14711.9	20058.6	11003.5	15321.6
	Milking	13913.4	19874.5	15743.2	20147.6	15933.7	21789.5	12610.5	17845.6
	Dough	15767.2	21369.4	17812.8	22647.5	17963.2	23654.1	13933.7	19654.2
	Maturity	16685.1	23427.6	18823.2	25655.4	21122.1	28089.6	15686.7	20989.8

Table 3. Cumulative Helio thermal Unit (HTU) at critical growth stage as influenced by different sowing windows and varieties in wheat during 2016-17 and 2017-18

Treatments A. Variety	B. Sowing windows:	S_1: 43thMW		S_2: 45th MW		S_3: 47th MW		S_4: 49th MW	
	Growth Stage	16-17	17-18	16-17	17-18	16-17	17-18	16-17	17-18
V1:NIAW-301	CRI	3198.45	3370.28	2713.2	2536.24	3263.62	2704.06	2998.69	2771.61
	Tillering	5213.70	5076.35	5098.90	4389.01	5067.50	4396.95	4897.25	4357.09
	Ear emergence	8672.4	8672.4	8714.7	8714.7	8767.3	8767.3	8373.2	8373.2
	50% Flow.	10852.4	9803.09	11472.0	10199.1	11362.4	10243.9	8955.6	8270.89
	Milking	13813.6	11710.4	14121.7	12634.8	14234.1	15710.1	12933.3	11663.2
	Dough	15617.4	12821.7	17213.5	15611.4	17427.9	17916.7	14617.1	13433.6
	Maturity	17092.1	15861.4	19396.3	18129.9	19447.5	18340.5	15298.5	14618.6
V2:NIAW-917	CRI	3298.45	3370.28	2713.2	2536.24	3263.62	2704.06	2998.69	2771.61
	Tillering	5345.21	5076.35	5167.3	4389.01	5183.5	4396.95	4967.25	4357.09
	Ear emergence	8672.4	8672.4	8714.7	8714.7	8767.3	8767.3	8373.2	8373.2
	50% Flow.	10283.9	9387.34	10804.3	9736.4	13710.5	12544.8	10227.0	9546.62
	Milking	11710.4	11710.4	12634.8	12634.8	15710.1	15710.1	11663.2	11663.2
	Dough	12821.7	12821.7	15611.4	15611.4	17916.7	17916.7	14433.6	14433.6
	Maturity	14525.5	13319.7	17613.6	16331.3	21864.3	20720.9	16103.0	15410.2
V3:NIAW-1415	CRI	3298.45	3370.28	2713.2	2536.24	3263.62	2704.06	2998.69	2771.61
	Tillering	5213.70	5076.35	5098.90	4389.01	5067.50	4396.95	4897.25	4357.09
	Ear emergence	8534.4	7534.4	8612.1	7612.1	8667.4	8667.4	8418.7	8418.7
	50% Flow.	9769.13	8944.22	9873.94	8999.41	11475.2	10414.1	8602.84	7932.08
	Milking	11810.7	11810.7	12743.6	12743.6	14713.4	14713.4	11910.1	11910.1
	Dough	12716.8	12716.8	14367.4	14367.4	16793.3	16793.3	13136.7	12136.7
	Maturity	14864.3	13657.7	16832.4	15456.4	19916.3	18763.7	14619.8	13967.9
V4:NIAW-1994	CRI	3298.45	3370.28	2713.2	2536.24	3263.62	2704.06	2998.69	2771.61
	Tillering	5362.23	5076.35	5387.9	4389.01	5394.05	4396.95	5097.25	4357.09
	Ear emergence	8687.4	8672.4	8733.6	8714.7	8793.1	8767.3	8413.2	8373.2
	50% Flow.	12058.4	11248.8	13310.5	12099.0	14711.9	13566.2	11003.5	10301.7
	Milking	13763.4	11710.4	14916.3	12634.8	16737.8	15710.1	12736.4	11663.2
	Dough	14816.8	12821.7	16343.2	15611.4	18687.4	17916.7	13946.2	14433.6
	Maturity	16685.15	15458.16	18823.26	17600.69	21122.12	19999.03	15686.78	15023.81

Table 4: Effect of sowing dates and varieties on yield of wheat during 2016-17 and 2017-18.

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

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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