The Pharma Innovation Journal 2021; 10(12): 1138-1146

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(12): 1138-1146

www.thepharmajournal.com
Received: 06-09-2021
Accepted: 18-11-2021

Ram Niwas Choudhary
Assistant Research Scientist, Agricultural Research Station, A. A.U. Dhandhuka, Gujarat, India

Kinjal J Suthar
Assistant Research Scientist, Agricultural Research Station, A. A.U. Dhandhuka, Gujarat, India

KD Mevada
Director of Research, Organic University, Anand, Gujarat, India

Surendra Singh
Dean and Professor, COA, Kotputli, SKNAU, Rajasthan, India

VD Mahariya
SRF, Agricultural Research Station, A. A.U. Dhandhuka, Gujarat, India

Sanjay D Doba
JRF, Agricultural Research Station, A. A.U. Dhandhuka, Gujarat, India

Corresponding Author:
Ram Niwas Choudhary
Assistant Research Scientist, Agricultural Research Station, A. A.U. Dhandhuka, Gujarat, India

Agro-meteorological indices, phenological stages and productivity of durum wheat (*Triticum durum* Desf.) influenced by seed soaking and foliar spray of stress mitigating bio-regulators under conserved moisture condition

Ram Niwas Choudhary, Kinjal J Suthar, KD Mevada, Surendra Singh, VD Mahariya and Sanjay D Doba

DOI: https://doi.org/10.22271/tpi.2021.v10.i12p.9503

Abstract
An experiment was conducted at Agricultural Research Station, Anand Agricultural University, Dhandhuka during the rabi seasons of the years 2017-18 and 2018-19 to determine the response of meteorological indices on seed soaking and foliar sprays of stress mitigating bio-regulators under conserved soil moisture conditions in durum wheat. The experiment comprised of four treatments of seed soaking *viz*; No seed soaking (S_0), Seed soaking with water (S_1), Seed soaking with 100 ppm Salicylic acid (S_2) and Seed soaking with 500 ppm Thiourea (S_3) and four treatments of foliar spray *viz*; No spray(C_0), Water spray (C_1), 100 ppm Salicylic acid spray (C_2) and1000 ppm Thiourea spray (C_3) of stress mitigating bio–regulators on durum wheat var. GADW 3 was conducted in Randomized Block Design (Factorial). The results showed significant response for growing degree days (GDD), Helio thermal units (HTU), Helio thermal use efficiency (HTUE) to attain different phenological stages (emergence, CRI, tillering, flag leaf, heading, milking, dough and maturity). On the pooled basis, significantly higher heat use efficiency of grain yield recorded under seed soaking with salicylic acid (100 ppm) (S_2) and foliar spray of salicylic acid (100 ppm) (C_2) was 1.31 & 1.28 (kg/ha/^{0}C day) respectively, over no seed soaking (S_0) and no foliar spray (C_0). However, it was found at par with seed soaking with 500 ppm thiourea (S_3) as well as 1000 ppm foliar spray of thiourea spray (C_3).

Keywords: Seed soaking, foliar spray, salicylic acid, Thiourea, GDD, HTU, HTUE and HUE

Introduction

Durum wheat (*Triticum durum* Desf.) is the second most important species globally as well as nationally grown after bread wheat (*Triticum aestivum* L.). In fact durum wheat was the predominantly grown in Central India, particularly in the *Malwa* region in Madhya Pradesh, *Bhal* and coastal agro-climatic zone in Gujarat, Southern Rajasthan and *Bundel khand* region of Uttar Pradesh. Total durum wheat production in India is sharing about 4 to 10 percent of total wheat production (Anon., 2017) [5]. Besides moisture stress, heat stress is also a very important factor that affects the agricultural production worldwide due to climate change (Hall, 2011) [9]. A recent simulation study has shown that a rise in temperature by 1^0C can lead to a decline in wheat production by 250 kg/ha in Rajasthan and by 400 kg/ha in Haryana (Kalra *et al.*, 2008) [11]. The duration of each phenol-phases determines the dry matter accumulation and its partitioning into different organs. Anand Kumar *et al.* (2017) [4] reported that the duration of growth stage of any particular species was directly related to temperature and it could be predicted using the sum of daily air temperature. The day and night temperature played vital role for the completion of the primary requirement of degree day. Quite high value of minimum temperature was promoted the higher respiration and ultimately increases the water requirement and lowers the assimilation rate. Changes in climatic variables like rise in temperature and decline in rainfall may be more frequent in future as suggested by the Intergovernmental Panel on Climate Change (IPCC, 2007) [10].

Temperature is an important environmental factor that influences the growth and development, phenology and yield of crops (Bishnoi *et al.*, 1995) [6]. Pre-anthesis and post- anthesis high temperature and heat may have huge impacts upon wheat growth, and the stress reduced the photosynthetic efficiency of crop (Wang *et al.*, 2011) [19].

Soaking of seeds and /or spraying the crop with water and / or some bio-regulators like salicylic acid and thiourea are one of the proven technologies to mitigate the ill-effects of moisture and heat stress on productivity of durum wheat by enhancing proper germination and developing heat stress tolerance in the crop. Bio-regulator is a group of naturally occurring growth promoting phyto-hormones, which regulates several physiological processes like cell division, cell elongation, and synthesis of nucleic acid and proteins (Mandava, 1988) [13]. Such studies are done little for durum wheat; therefore, an experiment was conducted to determine the response of different meteorological parameters to seed soaking and foliar application of bio-regulators in durum wheat.

Materials and Methods

A field experiment was conducted at Agricultural Research Station, Anand Agricultural University, Dhandhuka, *Bhal* and Coastal Zone of Gujarat in Ahmedabad district during *rabi* season 2017-18 and 2018-19. The climate of this region is semi-arid and sub-tropical. Monsoon commences by the second week of June and retreats by middle of September with an average rainfall of 625.5 mm received entirely from the south-west monsoon currents. The rains are sporadic in this region. The maximum temperature ranged between 27.1 to 42.5 ºC and minimum temperature ranged between 8.0to 22.2 ºC during the crop season of the year of 2017-18, while in the year 2018-19, maximum temperature ranged between 27.9 to 40.8 ºC and minimum temperature ranged between 7.4 to 19.4 ºC. The other parameters *viz*., relative humidity and bright sun shine hours/day were normal during both the years. During both the years of experimentations, there was no rainfall recorded (Fig.1 and 2). In general, weather condition was found congenial during crop season of both the years. Crop was sown under conserved soil moisture condition which is received during rainy season. A total of sixteen treatments comprised of four treatments of seed soaking *viz*; No seed soaking (S_0), Seed soaking with water (S_1), Seed soaking with 100 ppm Salicylic acid (S_2) and Seed soaking with 500 ppm Thiourea (S_3) and four treatments of foliar spray *viz*; No spray(C_0), Water spray (C_1), 100 ppm Salicylic acid spray (C_2) and 1000 ppm Thiourea spray (C_3) of stress mitigating bio–regulators for durum wheat var. GADW 3 were tested in Randomized Block Design (Factorial) with four replications. The line-to-line spacing was kept as 30 cm with a seed rate of 60 kg/ha. Seed were soaked for one hour and then dried in a shadow for 2 to 3 hours before sowing, while foliar spray were applied twice at tillering and ear emergence growth stages. The number of days to attain various phenol-phases was observed from randomly selected five plants in all the plots visually by the number of days taken from the sowing date to attain respective phenol-phases up to maturity. Maximum and minimum temperatures used for study were taken from agro-meteorological observatory that is near from the experimental site. To describe the relationship of meteorological indices on grain yield (y) as a function of the simple effect of seed soaking and foliar spray of bio-regulators on correlation and regression study was under taken. Different meteorological indices were calculated as per formula given below.

Growing degree days (GDD)

The GDD concept assumes that the amount of heat would be more or less same for a crop to reach a particular phenological stage or maturity. The GDD were calculated as the difference between the daily mean temperature and growth base temperature (Nuttonson, 1955) [15].

$$GDD = \frac{(T_{max.} + T_{min})}{2} - T_{base}$$

Base temperature of 5 ^{0}C was considered for wheat crop
Where

T_{max} = Daily maximum temperature (°C), T_{min} = Daily minimum temperature (°C)

T_{base} = Minimum threshold/base temperature (°C)

Helio thermal units (HTU)

Helio thermal units (HTU) were computed by following methods given by Chakavarty and Sastry, 1985. The product of the growing degree days and the maximum bright sunshine hours accumulated over a given period is the helio thermal units (HTU) and expressed as ^{O}C days^{-1} hours.

HTU = GDD x Maximum bright sunshine hours

Helio thermal use efficiency (HTUE)

Helio thermal use efficiency was calculated by dividing the total dry matter recorded at respective days by the accumulated helio thermal units and expressed as g^{O}C days^{-1} hrs^{-1}. Helio thermal use efficiency was calculated as (Chakavarty and Sastry, 1985).

$$HTUE: \frac{\text{Total Dry matter (g)}}{\Sigma\ HTU}$$

Where: Σ HTU = Cumulative helio thermal units

Heat use efficiency (HUE)

Heat use efficiency for grain and biological yields was calculated as (Pandey *et al*., 2010) [16].

$$\text{HUE (kg ha}^{-1}\text{degree-day}^{-1}) = \frac{\text{Grain or biological yield (kg ha}^{-1})}{\text{Accumulated GDD (degree-day)}}$$

Results and Discussion

(A) Effect of Seed soaking

Days to attain different phenological stages

It is clearly evident from data presented in Table 1 that different seed soaking treatments were found to vary in number of days for achieving phenological stages. Treatment S_2 (Salicylic acid @ 100 ppm), being at par with S_3 (Thiourea@500 ppm), found to be superior for days to emergence (6.99), CRI (26.50), tillering (41.10), flag leaf (69.30), heading (74.53), milking (95.71), dough (111.30) and maturity (d 117.00) stages on pooled analysis over no seed soaking (S_0) and seed soaking with water (S_1). On pooled basis, the increase due to seed soaking with salicylic acid @100 ppm in number of days taken to attain emergence stage was to the tune of 0.82 and 0.64 days, for CRI stage 2.41 and 1.97 days, for tillering 2.66 and 2.00 days, for flag leaf 5.11 and 3.25 days, for heading 5.21 and 3.24 days, for milking 6.26 and 3.99 days, for dough 5.71 and 4.43 days, and for maturity 7.75 and 6.26 days, over no spray and water spray, respectively. Amrawat *et al.* (2014) [3] observed that an increase in mean temperature during reproductive phase by 1

^{0}C reduces the reproductive phase by 5 days. The crop duration was drastically increased on account of longer vegetative and reproductive phases. Seed soaking with salicylic acid @ 100 ppm took maximum number of days to attain maturity. This might provide more opportunity time to the crop for more photosynthetic activity, which might in turn ensued higher yield. These results were in close conformity of Solanki and Muhal, 2015 [17].

Growing degree days (GDD) at different phonological stages

The data pertaining to growing degree days (GDD) at different phenological stages (Table 2) indicated that GDD varied to attain various phenological stages with different seed soaking treatments and seed soaking with salicylic acid @ 100 ppm (S_2) treatment observed higher accumulated GDD at emergence (156.69 ^{0}C day), CRI (560.99 ^{0}C day), tillering (840.60 ^{0}C day), flag leaf (1284.64 ^{0}C day), heading (1358.14 ^{0}C day), milking (1680.17 ^{0}C day), dough (1929.28 ^{0}C day) and maturity (2045.81 ^{0}C day) stage which was significantly superior over no seed soaking and seed soaking with water on pooled basis. However, it remained at par with seed soaking with thiourea @ 500 ppm (S_3) at all the stage of GDD.

It is an established fact that crop phenology are largely dependent on genetic and environmental factors *viz.* temperature, relative humidity, sun shine hours, rainfall *etc*. (Venkataraman and Krishnan, 1992) [18]. The heat unit or GDD concept was proposed to explain the relationship between growth duration and temperature. This concept assumes a direct and linear relationship between growth and temperature (Nuttonson. 1955) [15].

Helio thermal units (HTU)

It is clearly evident from data furnished in Table 3 that phenol-phase wise Helio thermal units (HTU) varied significantly under different seed soaking treatments in pooled analysis. On pooled basis, seed soaking with salicylic acid @ 100 ppm(S_2) reported maximum HTU to attain emergence (1253.50^{0}C day-hr), CRI (4487.95^{0}C day-hr), tillering (6724.80^{0}C day-hr), flag leaf (10277.10^{0}C day-hr), heading (9506.96^{0}C day-hr), milking (15121.52^{0}C day-hr), dough (17363.48^{0}C day-hr) and maturity (18413.46^{0}C day-hr) stage which was significantly superior over no seed (S_0) soaking and seed soaking with water (S_1), however it remained at par with seed soaking with thiourea @ 500 ppm (S_3) during all the phenol-phases. The cumulative value of HTU in wheat differed among the salicylic acid. Salicylic acid @ 100 ppm had increased the helio thermal unit's consumption at all the phenol-phases. Application of salicylic acid @ 100 ppm registered significantly increase in heat use efficiency over no spray and spray with water. Amrawat *et al.* (2013) [3] also reported the similar results.

Helio thermal use efficiency (HTUE)

It is clearly evident from the data presented in Table 4 that seed soaking had marked influence on HTUE. Seed soaking with salicylic acid @ 100 ppm (S_2) recorded significantly maximum value of HTUE (0.0146kg/ha/^{0}C day) as compared to no seed soaking (S_0) and seed soaking with water (S_1) in pooled analysis. However, it remained at par with seed soaking with thiourea @ 500 ppm (S_3).

Heat use efficiency (HUE)

Data presented in Table 5 further shown that seed soaking treatments had noticeable influence on HTU on grain and biological yield basis during both the years and in pooled data. Seed soaking with salicylic acid @ 100 ppm (S_2) recorded significantly maximum value of HUE on grain (1.31 kg/ha/^{0}C day) and biological yield basis (3.19 kg/ha/^{0}C day) as compared to no seed soaking (S_0) and seed soaking with water (S_1) in pooled analysis, though it remained at par with seed soaking with thiourea @ 500 ppm (S_3).

These results were in close conformity of Solanki and Muhal (2015) [17] who reported that the number of days taken to attain physiological maturity was significantly higher under 100 ppm salicylic acid spray compared to water spray and it registered significantly higher GDD and higher HUE which had proportionate impact on seed yield. This could be ascribed to significantly higher grain and biological yields of wheat under salicylic acid @ 100 ppm over no spray and water spray. Similar results in wheat were also reported by Khichar and Niwas (2007) [12].

Yield

Similar trend was observed for grain and straw yield of wheat (Table 6), wherein, seed soaking with salicylic acid @ 100 ppm (S_2), produced significantly higher grain yield (2008 kg/ha) and straw yield (2895 kg/ha) over no seed soaking (S_0) and seed soaking with water (S_1) in pooled analysis, which recorded an increment to the tune of 27.74 and 23.27 per cent for grain and 31.83 and 30.00 percent for straw yield over no seed soaking and seed soaking with water, respectively. Seed soaking with 500 ppm thiourea (S_3) being at par with salicylic acid @ 100 ppm (S_2), also produced significantly higher grain (1936 kg/ha) and straw (2786 kg/ha) yield over no seed soaking (S_0) and seed soaking with water (S_1) on the pooled mean basis. An increment of 23.16 and 18.85 per cent for grain yield and 26.86 and 25.10 per cent for straw yield was recorded with seed soaking with 500 ppm thiourea over no soaking and water soaking, respectively.

On understanding the diverse effect of salicylic acid on crop growth and development, it may be inferred that increase in yield obtained with salicylic acid @ 100 ppm seed soaking was most probably due to increased crop photosynthesis favoured by both improved photosynthetic efficiency and source to sink relationship. This may be attributed due to the proportionate distribution of dry matter at later stage of crop growth (Ahmad *et al.*, 2018). Higher days to attain different phonol stages might improve the GDD, HTU, HTUE and HUE which might in turn improve the photosynthetic activity in the plant. Giauaint (1976) reported that the bio-regulatory effect of salicylic acid was chiefly through mobilization of dry matter and translocation of photosynthates to sink which ultimately significantly improved the grain yield. Thus, it is highly probable that in the present investigation, salicylic acid with its sulphydryl group not only favoured the green photosynthetic surface, but might have also improved the activity of starch synthetase and hence, the effective filling of seeds.

(B) Effect of Foliar spray

Days to attain different phenological stages

A reference to data from Table1 indicated that different sprays of stress mitigating bio-regulators had their significant effect on number of days taken to reach to different phenological stages during both the years and in pooled results. The foliar spray of salicylic acid spray @ 100 ppm (C_2), being at par with thiourea spray @ 1000 ppm (C_3), recorded significantly higher days to emergence (7.08), CRI (27.11), tillering (41.53), flag leaf (69.15), heading (75.06), milking (96.35), dough (111.12) and maturity (118.70) stages in pooled analysis over no spray (C_0) and spray with water (C_1).

On pooled basis, the increase due to foliar spraying with salicylic acid @100 ppm in number of days taken to attain emergence stage was to the tune of 0.82 and 0.63 days, for CRI stage 3.65 and 2.70 days, for tillering 3.80 and 2.79 days, for flag leaf 4.36 and 2.78 days, for heading 6.30 and 5.06 days, for milking 7.79 and 5.10 days, for dough 6.70 and 4.50 days, and for maturity 11.47 and 8.52 days, over no spray and water spray, respectively.

Growing degree days (GDD) at different phonological stages

Similarly Data also exhibited that crop sprayed with salicylic acid @ 100 ppm (C_2) accumulated higher GDD at emergence (156.89 ^{0}C day), CRI (575.59 ^{0}C day), tillering (847.04 ^{0}C day), flag leaf (1281.41 ^{0}C day), heading (1366.60 ^{0}C day), milking (1690.28 ^{0}C day), dough (1929.36 ^{0}C day) and maturity (2061.78 ^{0}C day)stage which was found significantly superior over no crop sprayed (C_0) and water spray (C_1), but remained at par with foliar spray with thiourea @ 1000 ppm (C_3) on pooled basis. Nandini and Sridhara (2019 also recorded significantly higher GDD, to attain different phenological stages *viz*., germination, tillering, 50 per cent panicle initiation, 50% flowering, grain formation and physiological maturity. Solanki and Muhal (2015) [17] reported that the number of days taken to attain physiological maturity was significantly higher under 100 ppm salicylic acid sprays compared to water spray and it registered significantly higher GDD.

Helio thermal units (HTU)

Data further indicated (Table 3) that different foliar sprayed treatments were found to be significantly influenced HTU over no spray and water spray. On pooled basis, foliar spray with salicylic acid @ 100 ppm (C_2) recorded the maximum HTU at emergence (1255.10^{0}C day-hr), CRI (4604.70^{0}C day-hr), tillering (6776.30^{0}C day-hr), flag leaf (10251.25^{0}C day-hr), heading (9566.20^{0}C day-hr), milking (15212.48^{0}C day-hr), dough (17364.26^{0}C day-hr) and maturity (18555.98^{0}C day-hr), which remained at par with foliar spray with thiourea @ 1000 ppm (C_3), but both were significantly higher over no spray (C_0) and water spray (C_1). Similar results in wheat were also reported by Khichar and Niwas (2007) [12] and Amrawat *et al.*, (2013) [3].

Helio thermal use efficiency (HTUE)

A reference to data (Table 4) indicated that different foliar sprays had their significant impact on HTUE. The crop sprayed with salicylic acid @ 100 ppm (S_2), being at par with foliar spray with thiourea @ 1000 ppm (C_3), recorded significantly higher HTUE (0.0142 kg/ha/^{0}C day) proved superior over no spray (C_0) and water spray (C_1) in pooled mean, respectively.

Heat use efficiency (HUE)

Data (Table 4) indicated that different foliar spray had their significant effect on HUE during both the years and in pooled basis. The crop sprayed with salicylic acid @ 100 ppm (C_2) recorded significantly higher HUE on grain (1.28 kg/ha/^{0}C day) and biological yield basis (3.13 kg/ha/^{0}C day) and being at par with foliar spray with thiourea @ 1000 ppm (C_3) proved superior over no spray (C_0) and water spray (C_1) in pooled analysis.

The phenological studies of wheat revealed that the increase in salicylic acid from control to foliar spray with thiourea @ 1000 ppm had increased significantly the number of day's required for different phenol-phases. Foliar spray with salicylic acid @ 100 ppm, the crop duration was reduced on account of shorter vegetative and reproductive phase. The cumulative value of HTU (4.13) in wheat differed among the salicylic acid. Increase in salicylic acid @ 100 ppm had increased the helio thermal unit's consumption at all the phenol-phases and in both crop seasons. Application of salicylic acid @ 100 ppm registered significantly increase in heat use efficiency over no spray and spray with water. These results were in close conformity of Solanki and Muhal (2015) [17] who reported that the number of days taken to attain physiological maturity was significantly higher under 100 ppm salicylic acid spray compared to water spray and it registered significantly higher GDD and higher HUE which had proportionate impact on seed yield. This could be ascribed to significantly higher grain and biological yields of wheat under salicylic acid @ 100 ppm over no spray and water spray. Similar results in wheat were also reported by Khichar and Niwas (2007) [12] and Amrawat *et al.* (2013) [3].

Yield

A close perusal of the data (Table 5) pointed out that foliar spray with 100 ppm salicylic acid spray (C_2), being at par with foliar spray with 1000 ppm thiourea (C_3), generated considerably higher grain (1984 kg/ha) and straw (2859 kg/ha) yield over no spray (C_0) and water spray (C_1), on pooled basis. The pooled gain for grain yield obtained under salicylic acid spray were recorded to the tune of 23.69 and 20.90 per cent for grain yield and 28.26 and 26.17 per cent for straw yield over no spray (C_0) and water spray (C_1), respectively. While for thiourea spray the increase was recorded to the tune of 28.26 and 26.17 per cent for grain yield and 19.51 and 16.82 per cent for straw yield over no spray (C_0) and water spray (C_1), respectively.

An increase in yield attributes and yield obtained with salicylic acid was most probably due to augmented crop photosynthesis favoured by both enhanced photosynthetic efficiency and source to sink relationship resulting due to higher days to attain different phenol stages and thereby, improving GDD, HTU, HTUE and HUE. Effect of salicylic acid was chiefly through mobilization of dry matter and translocation of photosynthates to sink which ultimately significant improved the seed yield. The straw yield enhancement might be attributed to the higher nutrient uptake throughout the crop growth period due to increase days to attain different phenol stages which in turn increased the plant height, dry matter production and number of tillers /m^2 resulting in higher straw yield (Amin *et al.*, 2008) [2].

Relationship between yields attributes, GDD and HTU (X) and durum wheat seed yield (Y)

Simple correlation coefficients (r) were computedto study the relationship between durum wheat grain yield and straw and biological yield of wheat as well as meteorological indices namely, GDD and HTU. It is obvious from the data that seed yield of durum wheat was significantly and positively correlated with all these yield attributes and meteorological indices (Table 6). As such, the increase or decrease in these characters was found to be associated with a similar increase or decrease in seed yield of wheat. Pooled results showed that every unit increase in straw yield (r=0.998**), biological yield (r=0.999**), GDD at maturity (r=0.964**) and HTU at maturity (r=0.964**) increased the seed yield of wheat by 0.59, 0.37, 2.26 and 0.25 kg/ha, respectively, in pooled analysis. The regression equation also showed that unit change in meteorological indices brought similar changes in seed yield on pooled basis.

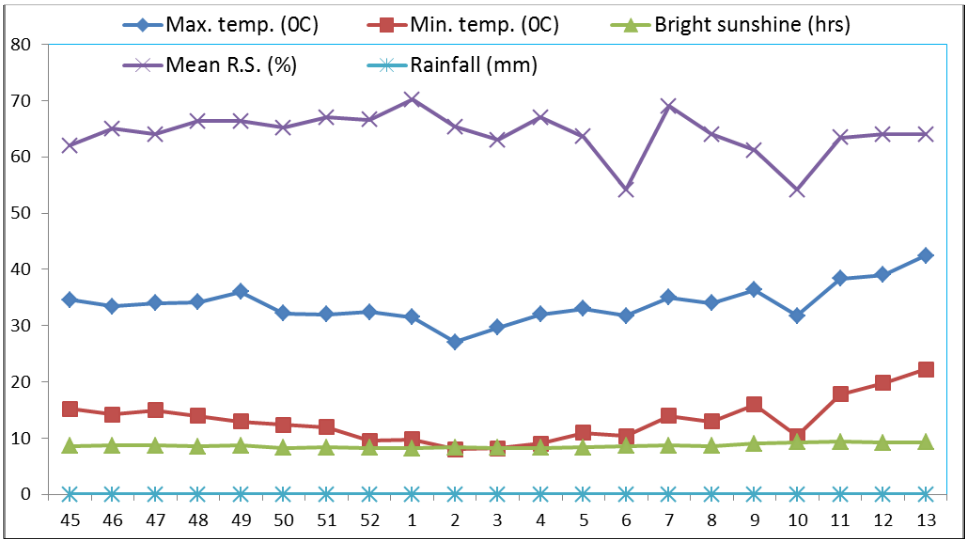

Fig 1: Mean weekly weather parameters recorded during the crop season of 2017-2018

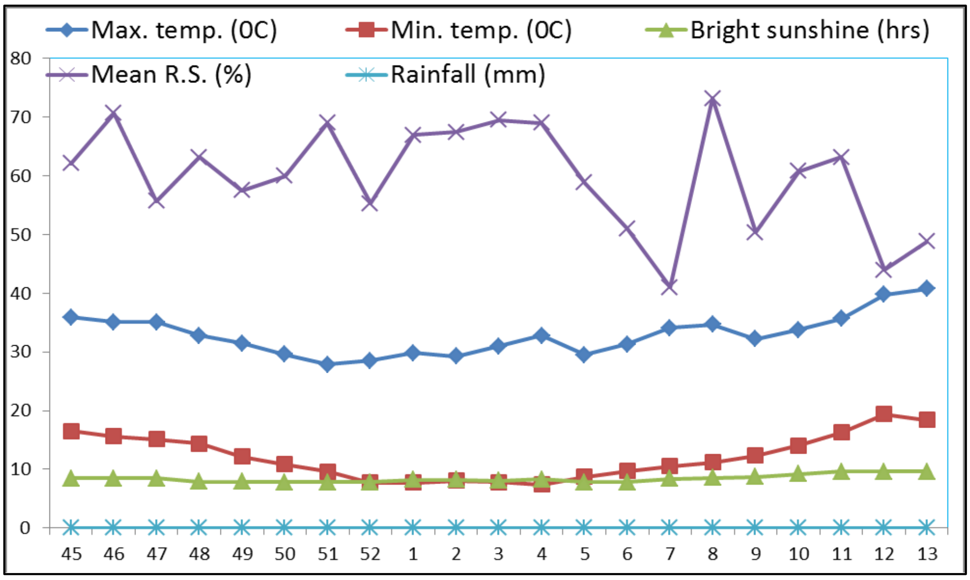

Fig 2: Mean weekly weather parameters recorded during the crop season of 2018-2019

Table 1: Effect of seed soaking and foliar spray of stress mitigating bio-regulators on days to attain different phonological stages of wheat on pooled basis

Treatment	Emergence	CRI	Tillering	Flag leaf	Heading	Milking	Dough	Maturity
Seed soaking								
S_0- Control (No seed soaking)	6.07	24.09	38.44	64.19	69.31	89.45	104.29	109.25
S_1- Seed soaking with water	6.30	24.53	39.10	66.05	70.59	91.72	106.87	110.74
S_2- Seed soaking with Salicylic acid (100 ppm)	6.99	26.50	41.10	69.30	74.53	95.71	111.30	117.00
S_3- Seed soaking with Thiourea (500ppm)	6.82	26.23	40.07	68.89	74.00	95.15	110.32	116.42
S.Em +	0.09	0.30	0.39	0.77	0.87	0.99	1.06	0.96
CD (P = 0.05)	0.25	0.84	1.09	2.17	2.43	2.77	2.97	2.69
Foliar spray								
C_0 -Control (No spray)	6.26	23.46	37.73	64.78	68.76	88.56	104.50	107.23
C_1- Water spray	6.45	24.41	38.73	66.37	70.00	91.25	106.62	110.18
C_2- Salicylic acid spray (100 ppm)	7.08	27.11	41.53	69.15	75.06	96.35	111.12	118.70
C_3- Thiourea spray (1000 ppm)	6.40	26.39	40.72	68.13	74.63	95.88	110.55	117.31
S.Em +	0.09	0.30	0.39	0.77	0.87	0.99	1.06	0.96
CD (P = 0.05)	0.25	0.84	1.09	2.17	2.43	2.77	2.97	2.69
CV (%)	7.83	6.73	5.53	6.53	6.81	6.01	5.55	4.80

Table 2: Effect of seed soaking and foliar spray of stress mitigating bio-regulators on accumulated growing degree days (GDD) at different phonological stages of wheat on pooled basis

	Emergence	CRI	Tillering	Flag leaf	Heading	Milking	Dough	Maturity
Seed soaking								
S_0- Control (No seed soaking)	136.78	516.90	795.38	1212.48	1283.16	1582.21	1814.96	1898.71
S_1- Seed soaking with water	142.28	534.34	804.68	1238.90	1303.46	1617.64	1859.63	1921.74
S_2- Seed soaking with Salicylic acid (100 ppm)	156.69	560.99	840.60	1284.64	1358.14	1680.17	1929.28	2045.81
S_3- Seed soaking with Thiourea (500ppm)	153.68	558.34	820.64	1279.56	1350.99	1672.24	1914.78	2021.27
S.Em +	2.42	5.79	6.90	10.43	13.42	18.02	14.26	20.96
CD (P = 0.05)	6.77	16.23	19.32	29.21	37.59	50.49	39.94	58.72
Foliar spray								
C_0 -Control (No spray)	145.23	514.70	779.81	1220.69	1276.36	1565.79	1818.73	1863.21
C_1- Water spray	145.23	521.88	800.53	1245.44	1293.42	1612.05	1853.81	1913.05
C_2- Salicylic acid spray (100 ppm)	156.89	575.59	847.04	1281.41	1366.60	1690.28	1929.36	2061.78
C_3- Thiourea spray (1000 ppm)	142.08	558.41	833.91	1268.04	1359.38	1684.14	1916.74	2049.49
S.Em +	2.42	5.79	6.90	10.43	13.42	18.02	14.26	20.96
CD (P = 0.05)	6.77	16.23	19.32	29.21	37.59	50.49	39.94	58.72
CV (%)	9.28	6.04	4.78	4.70	5.73	6.22	4.29	6.01

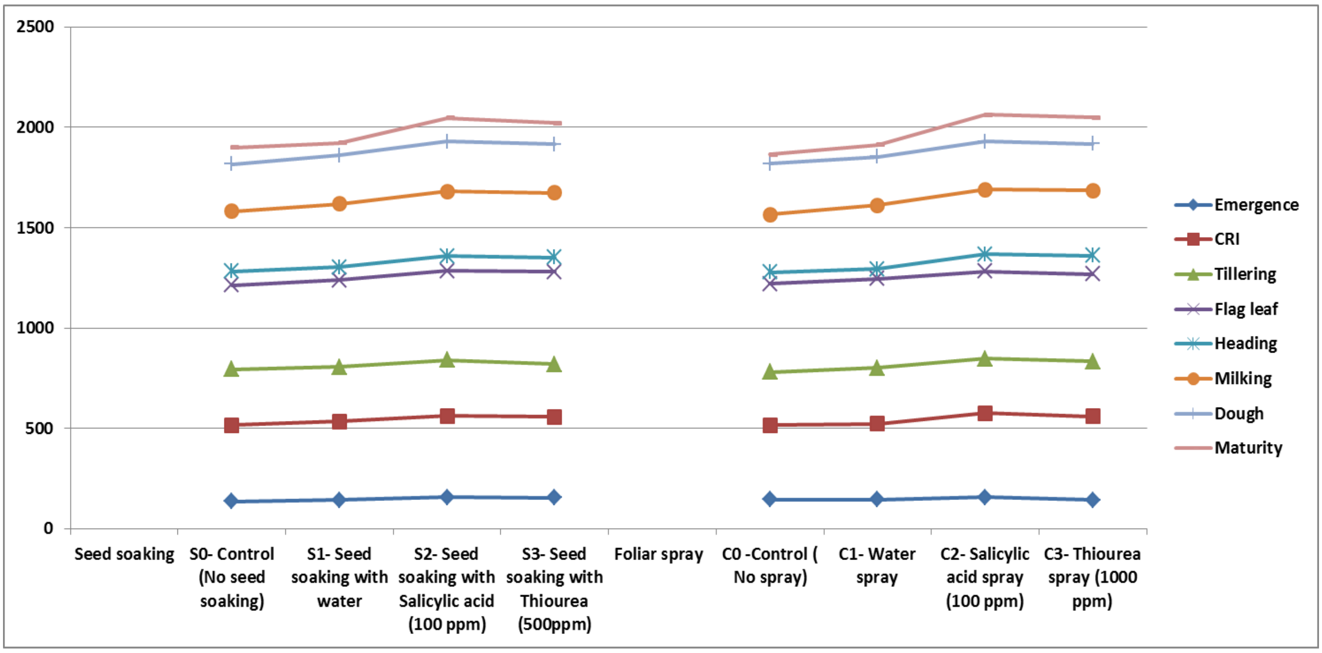

Fig 3: Effect of seed soaking and foliar spray of stress mitigating bio-regulators on accumulated growing degree days (GDD) at different phonological stages of wheat on pooled basis

Table 3: Effect of seed soaking and foliar spray of stress mitigating bio-regulators on accumulated helio thermal units (HTU) at different phonological stages of wheat on pooled basis

	Emergence	CRI	Tillering	Flag leaf	Heading	Milking	Dough	Maturity
Seed soaking								
S_0- Control (No seed soaking)	1094.20	4135.20	6363.00	9699.80	8982.14	14239.86	16334.66	17089.55
S_1- Seed soaking with water	1138.20	4274.70	6437.40	9911.20	9124.24	14558.79	16736.63	17295.64
S_2- Seed soaking with Salicylic acid (100 ppm)	1253.50	4487.95	6724.80	10277.10	9506.96	15121.52	17363.48	18413.46
S_3- Seed soaking with Thiourea (500ppm)	1229.40	4466.75	6565.10	10236.50	9456.91	15050.14	17233.03	18192.59
S.Em +	15.31	61.46	81.83	99.75	96.95	174.99	134.35	201.11
CD (P = 0.05)	42.89	172.15	229.22	279.41	271.57	490.18	376.34	563.35
Foliar spray								
C_0 -Control (No spray)	1161.80	4117.60	6238.50	9765.50	8934.49	14092.09	16368.58	16770.08
C_1- Water spray	1161.80	4175.00	6404.20	9963.50	9053.93	14508.45	16684.31	17219.79
C_2- Salicylic acid spray (100 ppm)	1255.10	4604.70	6776.30	10251.25	9566.20	15212.48	17364.26	18555.98
C_3- Thiourea spray (1000 ppm)	1136.60	4467.30	6671.30	10144.35	9515.63	15157.29	17250.64	18445.39
S.Em +	15.31	61.46	81.83	99.75	96.95	174.99	134.35	201.11
CD (P = 0.05)	42.89	172.15	229.22	279.41	271.57	490.18	376.34	563.35
CV (%)	7.35	8.01	7.10	5.63	5.92	6.71	4.49	6.41

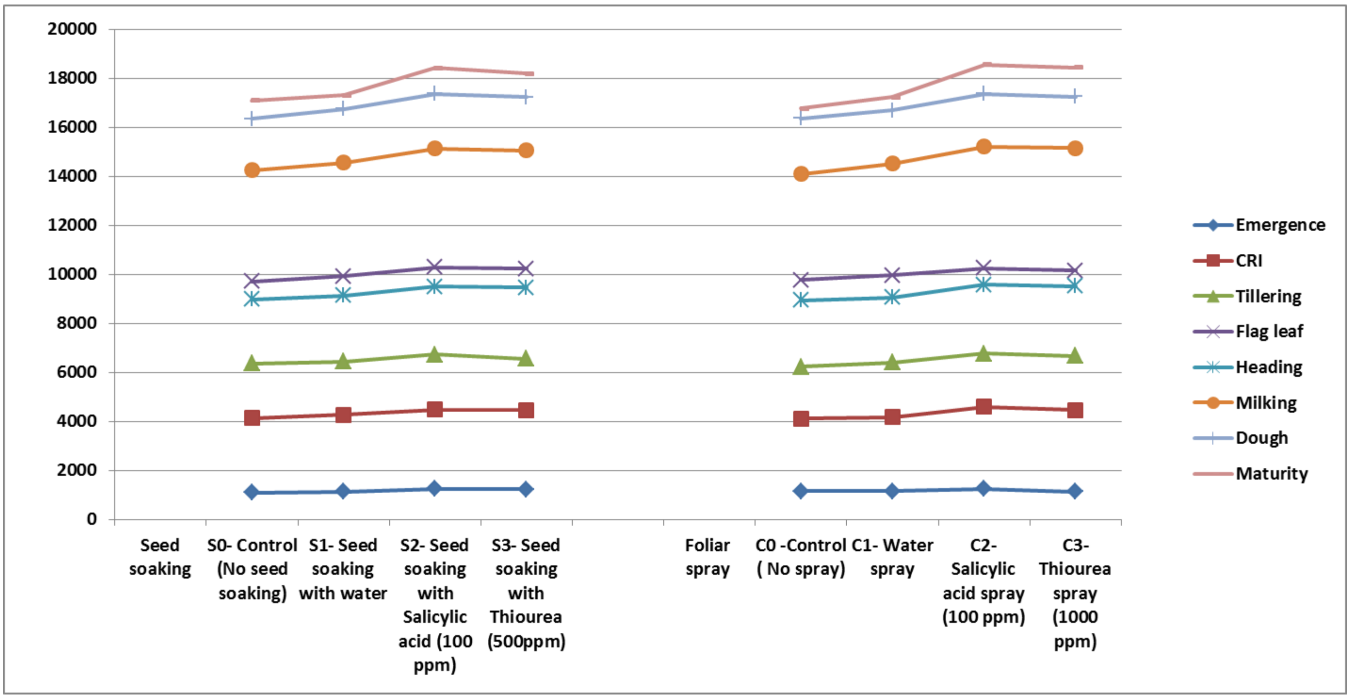

Fig 4: Effect of seed soaking and foliar spray of stress mitigating bio-regulators on accumulated helio thermal units (HTU) at different phonological stages of wheat on pooled basis

Table 4: Effect of seed soaking and foliar spray of stress mitigating bio-regulators on helio thermal use efficiency (HTUE) and heat use efficiency (HUE) of wheat on pooled basis

Treatments	HTUE (kg/ha/^{0}Cday)	HUE (kg/ha/^{0}C day)	
		On grain yield basis	On biological yield basis
Seed soaking			
S_0- Control (No seed soaking)	0.0120	1.10	2.64
S_1- Seed soaking with water	0.0125	1.13	2.67
S_2- Seed soaking with Salicylic acid (100 ppm)	0.0146	1.31	3.19
S_3- Seed soaking with Thiourea (500 ppm)	0.0143	1.27	3.11
S.Em +	0.0002	0.02	0.05
CD (P = 0.05)	0.0005	0.05	0.13
Foliar spray			
C_0 -Control (No spray)	0.0126	1.15	2.74
C_1- Water spray	0.0127	1.14	2.72
C_2- Salicylic acid spray (100 ppm)	0.0142	1.28	3.13
C_3- Thiourea spray (1000 ppm)	0.0139	1.24	3.03
S.Em +	0.0002	0.02	0.05
CD (P = 0.05)	0.0005	0.05	0.13
CV (%)	7.58	8.35	9.22

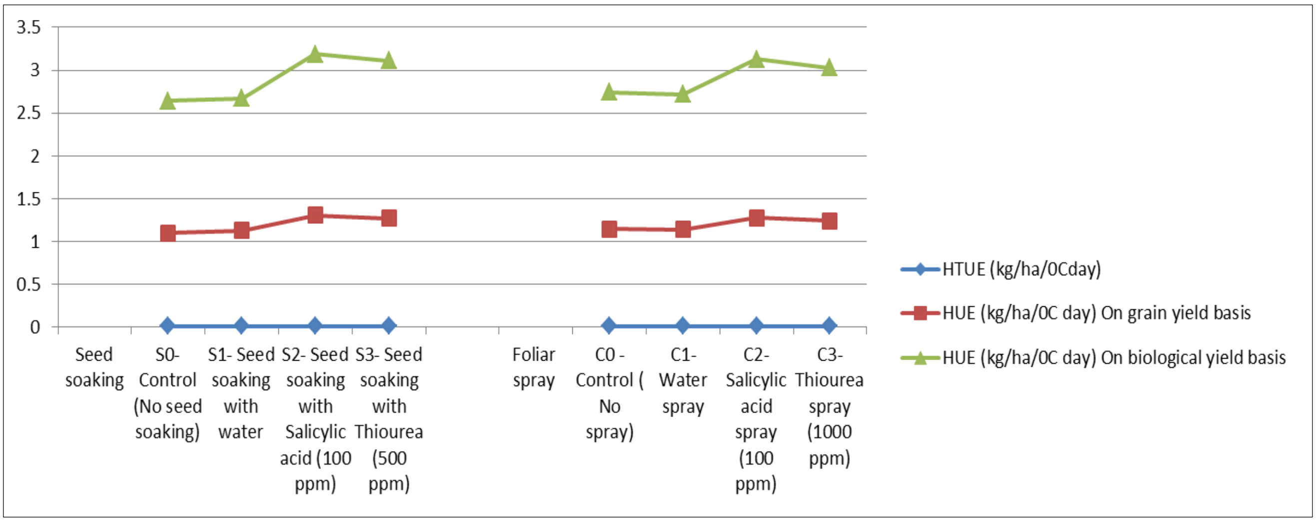

Fig 5: Effect of seed soaking and foliar spray of stress mitigating bio-regulators on helio thermal use efficiency (HTUE) and heat use efficiency (HUE) of wheat on pooled basis

Table 5: Effect of seed soaking and foliar spray of stress mitigating bio-regulators on grain and straw yield of wheat

Treatments	Grain yield (kg/ha)			Straw yield (kg/ha)		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Seed soaking						
S_0- Control (No seed soaking)	1546	1598	1572	2179	2213	2196
S_1- Seed soaking with water	1588	1671	1629	2200	2255	2227
S_2- Seed soaking with Salicylic acid (100 ppm)	1995	2021	2008	2878	2912	2895
S_3- Seed soaking with Thiourea (500ppm)	1933	1939	1936	2763	2808	2786
S.Em+	46	53	35	65	71	48
CD (P = 0.05)	131	150	98	186	203	135
Foliar spray						
C_0 -Control (No spray)	1583	1625	1604	2208	2250	2229
C_1- Water spray	1615	1667	1641	2240	2292	2266
C_2- Salicylic acid spray (100 ppm)	1969	2000	1984	2844	2875	2859
C_3- Thiourea spray (1000 ppm)	1896	1938	1917	2729	2771	2750
S.Em+	46	53	35	65	71	48
CD (P = 0.05)	131	150	98	186	203	135
CV (%)	10.38	11.63	11.04	10.44	11.18	10.82

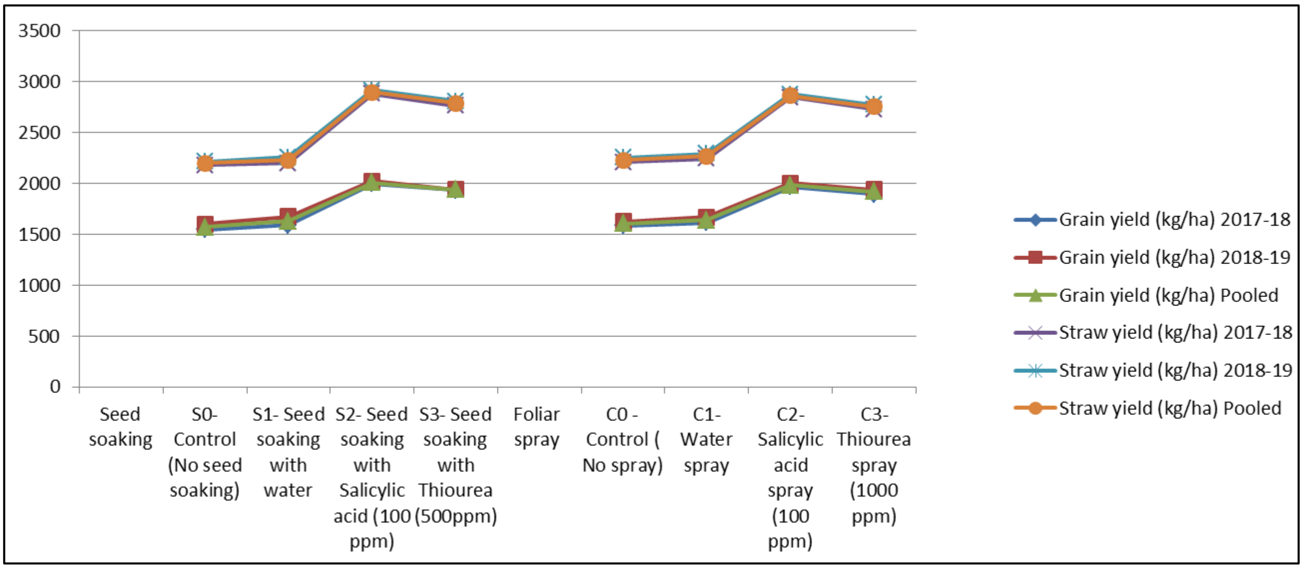

Fig. 6: Effect of seed soaking and foliar spray of stress mitigating bio-regulators on grain and straw yield of wheat

Table 6: Correlation coefficients and their Regression equations for the relationship between grain yield (Y) (kg/ha) and GDD, HTU (X) on pooled basis.

Sr. No.	Treatment	Correlation coefficients (r)	Regression equation $Y = a + b_y \times X$
1.	Straw yield	0.998^{**}	$Y = 293.026+0.591 X_8$
2.	Biological yield	0.999^{**}	$Y = 182.75+0.372 X_9$
3.	GDD at maturity	0.964^{**}	$Y = 2671.22+2.261 X_{10}$
4.	HTU at maturity	0.964^{**}	$Y = 2674.40+0.251 X_{11}$

** Significant at 1 per cent level of significance

Conclusion

From this study it may conclude that seed soaking with salicylic acid @ 100 ppm (S_2) and foliar spray with salicylic acid @ 100 ppm (C_2) stress migrating bio-regulators improved the days to attain different phenological stages which lead to improve GDD, HTU, HTUE and HUE over control and remained at par with seed soaking (S_3) @ 500 ppm and foliar spray of thiourea (C_3) @1000 ppm. These might provide more opportunity time to the crop for its photosynthetic activities and translocation of photosynthates from source to sink which might be subsequently converted to higher yield of durum wheat.

Acknowledgments

The authors grateful acknowledge the Hon'ble Vice Chancellor of Anand Agricultural University and Director of Research, Anand Agricultural University, Anand to provide necessary facility for conducting this research work.

References

1. Ahmad H, Khan I, Liaqat W, Jan MF, Dawood MA. Effect of salicylic acid on yield and yield components of maize under reduced irrigation. International Journal of Environmental Sciences & Natural Resources, 2018, 9(2).
2. Amin AA, Abd El-Kader AA, Abouziena HF, El-Awadi M, Fatma Gharib AE. Effects of Benzoic acid and Thiourea on Growth and Productivity of Wheat (*Triticum aestivum* L.) Plants. International Scientific Researches Journal 2016;72(4):132-149.
3. Amrawat T, Solanki NS, Sharma SK, Jajoria DK, Dotaniya ML. Phenology, growth and yield of wheat in

relation to agro-meteorological indices under different sowing dates. African Journal of Agricultural Research 2013;8:6366-6374.
4. Anand Kumar, Manoj Kumar Tripathi, Virender Pal. Effect of Sowing Time on Growth, Phenology and Yield Attribute of Summer Groundnut (*Arachis hypogaea* L.) in Allahabad 2017;6(4):2357-2365.
5. Anonymous. 2017. https://en.wikipedia.org/wiki/Bhalia_Wheat
6. Bishnoi OP, Singh S, Niwas R. Effect of temperature on phenological development of wheat (*Triticum aestivum* L.) crop in different row orientations, Indian J Agric. Sci 1995;65:211-14.
7. Chakravartty NV, Sastry PN. Some aspects of crop weather interactions in wheat cultivars. Int. J Ecol. Environ. Sci 1985;11:139-144.
8. Giaquinta RT. Evidence of phloem loading from apoplast: Chemical modification of membrane sulphydryl group. Plant physiology 1976;58(5):872-875.
9. Hall AE. Crop Response to Environmental Stress. CRC Press LLC, Boca Ramon, Florida, 2011.
10. IPCC. Parry, M. L., Canziani, O.F., Palutikof, P.J., Van der Linden P. and Hanson, C.E. (Eds.). Climate change: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. Cambridge, UK, 2007, 976.
11. Kalra N, Chakraborty D, Sharma A, Rai HK, Jolly M, Chander S *et al*. Effect of increasing temperature on yield of some wheat crop in North – West India. Curr. Sci 2008;94:82-88.
12. Khichar ML, Niwas R. Thermal effect on growth and yield of wheat under different sowing environments and planting systems. Indian J Agric Res 2007;41:92-96.
13. Mandava NB. Plant growth-promoting brassinosteroids. Annu. Rev. Plant Physiol. Plant Molec. Biol 1988l;39:23-52.
14. Nandini KM, Sridhara S. Heat use efficiency, Helio thermal use efficiency and photo thermal use efficiency of foxtail millet (*Setaria italica* L.) genotypes as influenced by sowing dates under southern transition zone of Karnataka. Journal of Pharmacognosy and Phytochemistry 2019;SP2:284-290.
15. Nuttonson MY. Wheat climate relationship and the use of phenology in ascerting the thermal and photo thermal requirement of wheat. American Institute of crop ecology, Washington DC, USA, 1955, 388.
16. Pandey LB, Pandey RK, Dwivedi DK, Singh RS. Phenology, heat unit requirement of wheat varieties under different crop growing environment. Indian Journal of Agril. Sci 2010;80:136-140.
17. Solanki NS, Muhal S. Effect of seeding dates and salicylic acid foliar spray on growth, yield, phenology and agro-meteorological indices of Brassica species 2015;6(1):289-294.
18. Venkataraman S, Krishnan A. Crops and weather. Publication and information division of ICAR, New Delhi, 1992.
19. Wang X, Cai J, Jiang D, Liu F, Dai T, Cao V. Pre-anthesis high temperature acclimation alleviates damage to the flag leaf caused by post anthesis heat stress in wheat. J. Plant Physiol 2011;168(6):585-593.