BIOFORTIFICATION OF ZINC AT VARIOUS GROWTH STAGES AND PRIMING SOURCES IMPROVE PHENOLOGICAL AND GROWTH CHARACTERISTICS OF DURUM WHEAT

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Abstract- Seed priming is involved in the speedy germination, early growth and various physiological and biochemical processes of plant. Low zinc (Zn) availability in alkaline soil and its binding in soil reduce its uptake by plants which affect all the growth traits. Durum wheat (DW) seed being comparatively hard than common bread wheat sometimes fails to germinate due to hardness. Research was conducted on Phenology and growth of durum wheat as influenced by different priming sources and foliar Zinc application at various growth stages during *rabi* season 2020-2021 and 2021-2022 at the Agronomy Research Farm, The University of Agriculture, Peshawar-Pakistan. Experiments were conducted in RCB design with split-plot arrangement replicated thrice. Priming sources included [no priming (control), Hydro-priming, Halo-priming (priming with NaCl)] and Zn levels included 0 (no Zn application), 2.25, 4.5 and 6.75 kg Zn ha^{-1}) applied at various growth stages i.e. (100% at tillering, 100% at boot and 50 % at tillering+50% boot stages). $ZnSO_4.7H_2O$ was used as a source of Zn. Priming sources and Zn application stages were assigned to main plots and Zn levels to the subplots. DW cv. Pasta-18 was sown in lines 30 cm apart with hand hoe at the seed rate of 120 kg ha^{-1} on 4^{th} Nov 2020 during 1^{st} year and 7^{th} Nov 2021 during 2^{nd} year. There were 10 rows in each subplot and row length was 3 meter recommended doses of NPK i.e. 120:90:60 were used. Irrigation was applied when needed. Weeding was carried with recommended weedicides for narrow and broad leaf weeds. The results revealed significant variation in most of the phonological and physiological attributes of DW during both years. Early emergence (13 days), maximum emergence (120 m^{-2}), less number of days to tillering (34), highest plant height (105.9 cm) were recorded in plots where seeds were hydro-primed. Lower values for all the aforementioned parameters were recorded in non-primed seed plots. Early maturity (175 days) and minimum values for all the above mentioned traits were recorded in plots where foliar Zn was applied 100% at tillering stage. Significantly, higher days taken to anthesis (135.7 days), maturity (174.3 days), maximum plant height (105.3 cm), SPAD value (53.3) of DW were observed in plots where Zn was applied at the rate 4.5 kg ha^{-1} followed by plots where foliar Zn was applied at the rate 6.75 kg ha^{-1} however, minimum values for all the mentioned observation were recorded in control experimental plots. It was concluded from the results that hydro-priming improved germination, enhanced early and uniform emergence of DW stand. Therefore, to maximize the phonological and yielding attributes of durum wheat it is recommended to ensure seed hydro-priming and foliar zinc application @ 2.4 kg ha^{-1} 50% at tillering+50% at boot stage.

Index Terms- Seed primming; Phenology;Zinc application, triticale and Yield and yield components

I. Introduction

Durum wheat (*Triticum turgidum* L.) is separate tetraploid specie of wheat belonging to family poaceae. Common wheat is hexaploid having 42 chromosomes number expressing A, B and D genomes compared with durum wheat having 28 chromosomes number with A and B genomes only. With the increasing human population the need and importance of durum wheat is increasing day by day. It is the most nutritious and economically important crop due to its unique characteristics and products. The seed of durum wheat is hard containing high protein content. A large variety of confectionary items are prepared from durum wheat that include durum bread, *chapattis*, bakery cakes, noodles, breakfast foods, biscuits, cookies and so many (Krishna *et al.,* 2017)**.** It has high protein content in their seed, the strength of seed enable durum to be used for special purposes, and the most popular being pasta which is completely prepared from durum wheat flour (Afridi *et al.,* 2014).

Pandemic lockdowns have altered food consumption patterns around the world. Stockpiling of staples and more home-cooking has given a big boosted to one wheat-based product in particular pasta and to the durum wheat. Leading durum and pasta exporting countries have experienced surging demand. Italy, which exports 60% of its pasta output, saw international sales increase by 30% during the first half of 2020, as reported by the Economist in November 2020, with multinational industry giant Barilla at the forefront. Globally the annual estimated production of pasta was 14.3 million tons with total worth $14.9 billion (USDA, 2015). European Union human consumption demand for durum wheat had increased from 8.2 million tons in 2018-19 to 8.7 million tons to 2019-20 during "the period of lockdown in spring 2020 that was implemented in response to the COVID-19 pandemic. Worldwide durum wheat are produced and consumed in Europe, only Italy grows 4 million tons of durum and imports another 2 million tons, South America and USA (Mckee, 2021). Generally durum wheat contributes about 10% in bread wheat production, inhabiting about 11 m ha in Mediterranean areas of the world (Karimizadeh *et al.*, 2013). The estimated global production of durum wheat is 36 m tons and is considered the important food crop of the world (Chris, 2017). Turkey and America is the leading countries producing 2m ha each (Statistic Canada, 2017). Durum wheat in Pakistan is grown on small area with estimated 0.5 to 0.8 million ha annually (USDA, 2015). Nevertheless due to its strong connection with traditional dishes, this crop is cultivating in the developing world as cash crop to feed the growing world population.

The rapidly growing population and changing food preference and the unmet demand for pasta, noodles and cookies etc., it's the need of the day to introduce durum wheat market and varieties that ensure the requisite grain quality traits and maximum yield. A huge amount of diversity exists for this crop and this divergence may also extend too much typical way of consuming durum seed (Elias, 1995).

In arid and semi-arid regions seed germination, seedling emergence and finally crop stand are greatly affected due to limited soil moisture content. To solve this issue several pre-sowing seed techniques are practiced to enhance and improve the germination rate and uniform crop emergence in the field that's ultimately maximize yield of the crop (Khan *et al.*, 2008). Seed soaking in water (hydro) or in a salt (halo) solution for a specific period of time for better germination, uniform emergence called seed priming (Desai *et al.*, 1997). Priming techniques can be used successfully to promote vigorous germination, early and prompt emergence of crop in the field (Joudi and Sharifzadeh, 2006). Seed priming encouraging several biochemical and physical processes such as breaking of dormancy, mobilization of growth inhibitors, enzymes activation which ultimately ensuring faster germination rate (Amooaghaie, 2011). Seed priming help in reducing the drought stress and enhance their potential under limited supply of water, reducing insect, pest and pathogen damages and increasing crop yield of all edible crops (Khan *et al.*, 2005). Seed hydro priming in wheat, maize, triticale, alfalfa, rice and chickpea ensure faster seed germination, emergence, crop stand establishment, crop growth, earlier flowering and high yield and yielding elements (Ghassemi-Golezani *et al.*, 2010). Halo priming (salt) and hydro-priming of seed is considered as the most simple and cheap strategy to alleviate stresses and break the hard seed coat in order to ensure faster germination (Shrivastava *et al.*,2010). Naceur (2012) noted minimum percentage of disease infection and increase seedling growth in primed seed as compared to non-primed seeds of durum wheat.

The shortage of micronutrients not only restricting the productivity of main food crops but also reducing their seed nutritional status. The main cause of poor human health in developing countries is the limited availability of Zn fertilizer to the crops, and the deficiency of zinc is mostly common both in plants and human being. Approximately half of the world cultivated land is affected due to low Zn availability by several antagonistic physical and chemical conditions of the soil i.e. high pH, less amount of organic matter and limited soil moisture (Alloway, 2008). Cereal crop significantly responded to the foliar fertilization of Zn with increase grain yield in rice (Cakmak, 2008), beans (Teixeira *et al.*, 2004) maize and wheat (Potarzycki and Grzebisz, 2009). Each crop had a specific nutritional requirement and level but cereal responding very positively to zinc fortification (Motta *et al.*, 2007).

Generally durum wheat is genetically low in Zinc (25–30 mg of zn/kg of grain) and also more than 40% world cultivated soil is low in Zn nutrients which further intensifying the situation for durum wheat (Cakmak, 2008). Zinc content in durum wheat grains was 8-12 mg kg^{-1} under limited Zn fertilizer and 15-25 mg kg^{-1} under higher zinc availability conditions (Erdal *et al.*, 2002). Foliar Zn fertilization significantly increase grain Zn concentration and was found that Zn fertilization has a synergistic impact on grain Zn content (Kutman *et al*., 2010).

The other limiting factor of yield and quality attributes in durum wheat is the critical growth stages. Maximum grain zinc levels was found in zinc foliar fortification later stages of the crop (Habib, 2009).

Highest Zn concentration and iron concentration found in cereal fortified at later developmental stages (Cakmak, 2012). Foliar application of zinc at tillering and boot stages improves the grain quality and yield (Arif *et al.*, 2006; Gomez-Becerra *et al.*, 2010). Foliar application of zinc and other micronutrients at all developmental stages is more helpful in increasing the seed zinc levels. Zinc application at later stage of crop growth enriches the grain zinc contents. Application of Zn micronutrient at boot, heading and early milk stages exhibited better zinc accumulation in grain than zinc foliar application at tillering, stem elongation and boot stages (Abhrajyoti and Duary, 2022). More nutrients concentration in the grain can be achieved when applied at the later stages of seed formation (Ozturk, 2006).

Pakistan's population is urbanizing at fastest pace in the world with an estimated rate of about 1.8% annually. Due to increasing demand of durum wheat products like pasta, macaroni and spaghetti especially among children and women, the introduction of durum wheat enriched with zinc may resolve the problem of food security, food diversity and zinc deficiency. Furthermore, the problem of germination in hard durum wheat seed may be resolved through various priming techniques. Therefore, the present study was designed to improve the growth, yield and quality parameters of durum wheat using priming sources, foliar zinc application at various growth stages.

II. IDENTIFY, RESEARCH AND COLLECT IDEA

A two year field experiment entitled "Grain quality and yield enhancement of durum wheat using different priming sources and foliar zinc application at various growth stages" was conducted during *Rabi* crop season 2020-2021 and repeated the same experiment in year 2021-2022 at the Agronomy Research Farm, The University of Agriculture Peshawar, Pakistan. The experiments were conducted in randomized complete block design with split plot arrangement having three replication using the three factors i.e. Zinc application stages (ZAS), priming sources (PS) and Zinc (Zn) levels. The Zinc application stages (ZAS1 = 100% at tillering stage, ZAS2 = 100% at booting stage, ZAS3 = 50% at tillering stage + 50% at booting stage) and priming sources (PS0 = Unprimed Seeds, PS1 = Hydro-priming (Water) and PS2 = Halo-priming (NaCl)) were allocated to the main plot and Zn levels (Zn0 = 0 kg ha^{-1}, Zn1 = 2.25 kg ha^{-1}, Zn2 = 4.5 kg ha^{-1} and Zn3 = 6.75 kg ha^{-1}) were the sub plot factor. The crop was sown on well prepared *wattar* seed bed. Seed of durum wheat was collected from Cereal Crops Research Institute, Pirsabak (Nowshera), Pakistan. Recommended seed rate of 120 kg ha^{-1} was sown uniformly in lines manually. Durum wheat seed was primed in a tap water and NaCl solution for 12 hrs in hydroponic system installed at horticulture nursery, The University of Agriculture-Peshawar to soften the hard seed coat of durum wheat and to initiate the process of imbibition of water without hypocotyl and radical emergence. Aeration was ensured through air pumps which inject air into the water through pipes situated inside water tank thereby enhancing the dissolve oxygen level in the water required during seed priming. Seed bed was prepared by tilling the soil initial with primary tillage implement i.e. disc harrow followed by rotavator which is considered as secondary tillage equipment. The seed was planted in a 3x3m size plot. Ten rows of durum wheat were sown in each experimental plot with 0.3x0.3m row to row with 3m row length. Recommended nutrients i.e. NPK were used @ 120:90:60. Foliar Zinc was applied as $ZnSO_4.7H_2O$. Proper and recommended irrigation schedule was followed; however, changes were made according to the weather condition as and when needed. Weeding was carried with recommended weedicides for narrow and broad leaf weeds. During the experiment season, weather data was collected from the regional meteorological center Khyber road Peshawar. During experimental trials all the agronomic operations were kept uniform.

Procedure for data recording

Days to emergence of durum wheat were calculated by counting days from the date of sowing of the crop to the date when 70% seedlings emerged completely in each experimental plot. For emergence (m^{-2}), number of seedlings emerged in central rows of each of sub plot were counted and then converted to m^{-2} by the following formula:

$$\text{Emergence } m^{-2} = \frac{\text{Number of seedlings}}{\text{No.of row } \times \text{ Row}-\text{Row distance} \times \text{R}-\text{length}} \, 1m^2$$

Days till an event i.e. booting, anthesis and maturity stages were recorded by counting days from the date of sowing to the date when 70% of the crop reached to particular stage in each experimental unit. The SPAD value was recorded with the help of SPAD meter (MODEL TYS-A) to know the leaf chlorophyll content. Plant height was recorded by measuring randomly 10 plants in the central rows of the plot before a week of the crop harvest and height was measured through measuring tape from bottom till the tip of the plant including awns and averaged.

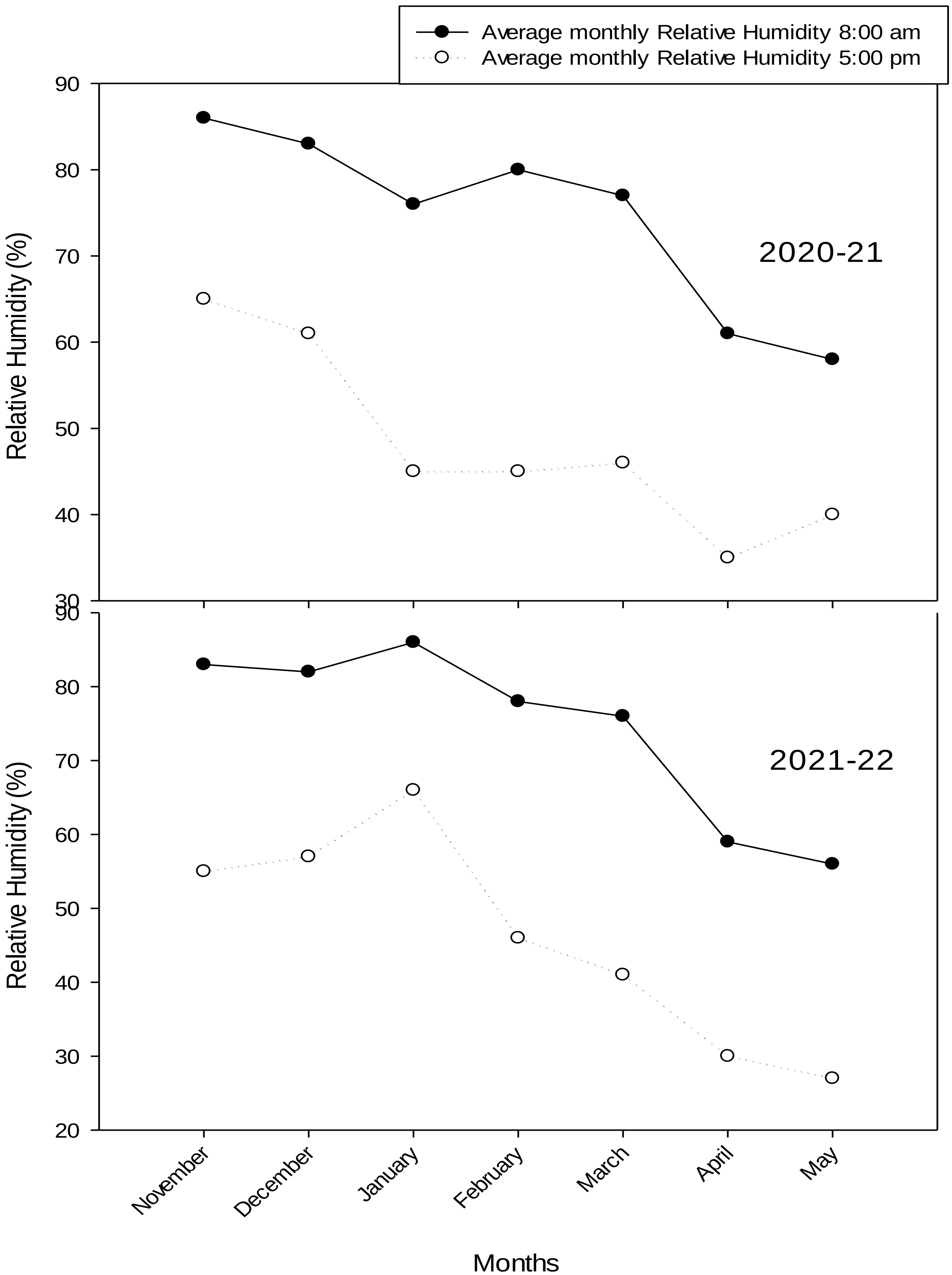

Fig 1.

Monthly average weather data (Relative Humidity) of two years 2020-21 and 2021-2022 for the experimental location for the crop growth season (Pakistan Meteorological Department)

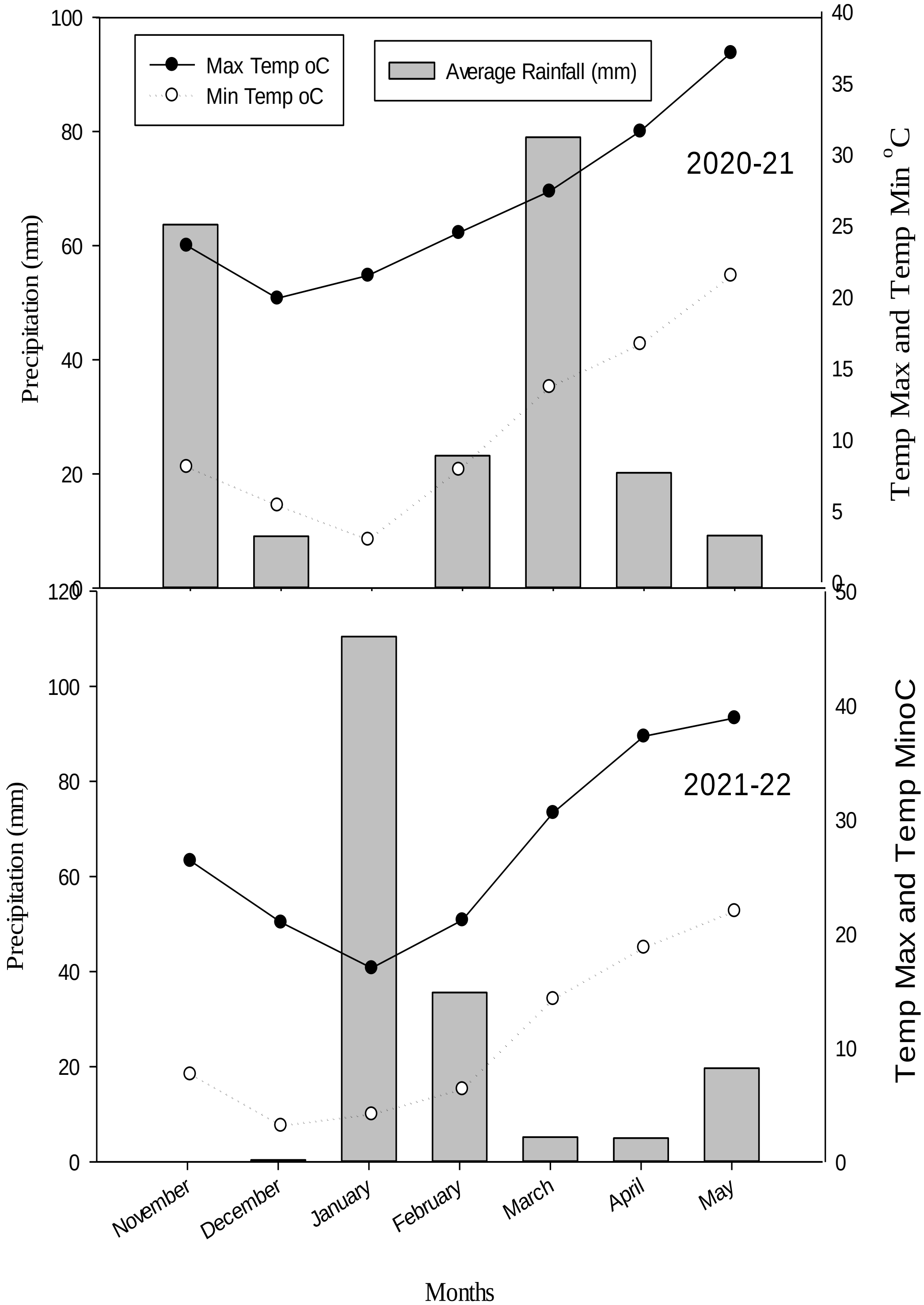

Fig. 2. Monthly average weather data (maximum and minimum temperature) of two year 2020-21 and 2021-2022 for the experimental location for the crop growth season (Pakistan Meteorological Department)

III. WRITE DOWN YOUR STUDIES AND FINDINGS

RESULTS AND DISCUSSION

Days to emergence

Data regarding days to emergence of durum wheat as affected by different priming sources (PS) during *rabi* season 2020-21 and 2021-22 illustrated in table 1. Significant effect of priming sources (P) was observed during both the years for durum wheat; however no differences were noticed for days to emergence of durum wheat during both the growing season. More days to emergence (15.7 days) were noted in a control plots where dried seed was sown followed by halo-primed seed (13.1days) hydro-primed and less number of days to emergence were recorded for hydro-primed treated (12 days) seeds. The interaction between P x Y was found non-significant for days to emergence of durum wheat.

Emergence (m^{-2})

Data regarding emergence m^{-2} of durum wheat as affected by different priming sources (PS) during *rabi* season 2020-21 and 2021-22 shown in table 1. Priming sources (PS) significantly affected emergence m^{-2} during both the years for durum wheat however, no differences were observed for emergence m^{-2} of durum wheat during both the growing season. Maximum emergence m^{-2} (120.4) was recorded in a hydro-primed seeds followed by halo-primed seed (119.3) and the less number of plants emerged in control experimental units. The interaction between P x Y was found non-significant for days to emergence of durum wheat.

Days to tillering

Days to tillering of durum wheat as affected by different priming sources (PS) during *rabi* season 2020-21 and 2021-22 is given in table 2. Statistical analysis of the data showed that priming sources (PS) significantly affected days to tillering of durum wheat during both the years while, no differences were noticed for days to tillering of durum wheat during both the growing season i.e. 2020-21 and 2021-22. Results revealed that more days to tillering (39.7 days) were recorded in a control plots where dried seed was sown followed by hydro-primed (34.8 days) statistically followed by halo-primed treated seeds (34.7 days). The interaction between P x Y was found non-significant for days to tillering of durum wheat.

Days to boot stage

Data regarding days to boot stage of durum wheat as affected by different priming sources (PS) during *rabi* season 2020-21 and 2021-22 reported in table 2. No significant effect of priming sources (PS) was observed during both the years for days to boot stage of durum wheat and also no considerable differences were observed for days to days to boot stage of durum wheat during both the growing season.

Days to anthesis

Data regarding days to anthesis of durum wheat as affected by priming sources and foliar zinc application at various growth stages during year 2020-21 and 2021-22 illustrated in table 3. The statistical analysis shows that foliar zinc application had a significant effect on days to anthesis of durum wheat however; zinc application stages and priming sources were found non-significant for days to anthesis. Averaged over the two year data plots where zinc was applied at the rate 6.75 kg ha^{-1} took maximum numbers of (135.7) days to anthesis statistically followed by plots foliar supplied with 4.5 kg ha^{-1} Zn (135.4) while, minimum days to anthesis in durum wheat were noted in a control experimental plots (132.5).

Days to harvest maturity

Table 3. indicate data regarding days to harvest maturity of durum wheat as affected by priming sources and foliar zinc application at various growth stages during year 2020-21 and 2021-22. Analysis of the data revealed that zinc applied at various growth stages significantly affected maturity of durum wheat. Foliar Zn applied at 50% at tillering+50% at boot stages took maximum days to maturity (175 days) followed by plots fertilized with 100% Zn at boot stage (174 days) however, minimum days to maturity were recorded in a plots where Zn was applied 100% at tillering stage (171.5 days). Foliar Zn application also significantly affected days to maturity of durum wheat. Delayed maturity was noted in a plots fertilized with 2.5 kg ha^{-1} Zn application (174 days) followed by 6.75 (174 days) and 2.25 kg ha^{-1} Zn (174 days) while early maturity (171 days) was observed in control experimental plots. The interaction of Zn x ZAS showed significant effect on days to maturity of durum wheat.

The interaction of Zn x ZAS showed significant effect on days to maturity of durum wheat. Generally plots treated with higher concentration of zinc showed late maturity. Delyaed in maturity was recorded in a plot treated with 6.75 kg ha^{-1} Zn each 50% at tillering+50% at boot stage. However early maturity was observed in a control plots where Zn was not sprayed. In case of growth stages early maturity was noted in plots where zinc was applied 100% at tillering stage.

Plant height (cm)

No significant difference in plant height (cm) of durum wheat was observed between 2020-21 and 2021-22 as depicted in table 4. However, a significant effect of priming sources (PS) and Zn levels (Zn) was observed during both the years while, the effect zinc application at various growth stages (ZAS) was found non-significant for plant height of durum wheat. Priming sources had a considerable impact on plant height. Among priming sources tallest plants (105.8 cm) were noted in plots where hydro-primed seeds were sown followed by halopriming (105.0 cm) and the lowest plant height (98.1cm) was measured in plots where dry seeds were sown. Plant height was also significantly affected by foliar zinc levels. Zn applied at the rate of 4.5 kg ha^{-1} produced taller plants (105.3 cm) followed by plots fertilized with 6.75 kg ha^{-1} Zn (105 cm) however, the smallest plant height (99.7 cm) was observed in control experimental units. All the treatment interactions were found non-significant.

SPAD value

Data pertaining SPAD value of durum wheat as affected by priming sources (PS), zinc levels (Zn) and various zinc application stages (ZAS) during year 2020-21 and 2021-22 are given in table 4. Analysis of the data indicated that zinc application stages (ZAS) and zinc levels significantly affected SPAD value of durum wheat. Maximum SPAD value (51.2) was noted in experimental units where Zn was applied each at 50% at tillering and boot stages followed by 100% Zn applied at 100% boot stage (49.9) while, the lowest SPAD value was noted in plots treated with Zn 100% at tillering stage. Different Zn concentration had a significant effect on SPAD value of durum wheat. Amongst various zinc levels highest SPAD value (54) was observed in a plot treated with 4.5 kg ha^{-1} Zn level followed by 6.75 kg ha^{-1} Zn (51.6) however, the lowest SPAD value for durum wheat was recorded in control experimental plots. The interactions between Zn x ZAS and ZAS x P were found significant for SPAD value of durum wheat.

Table 1. Days to emergence and emergence m^{-2} of durum wheat as affected by priming sources (PS) and foliar zinc application levels (Zn) at various growth stages (ZAS) during the rabi season 2020-21 and 2021-22.

Priming Sources (PS)	Days to emergence		Mean	Emergence m-2		Mean
	2020-21	2021-22		2020-21	2021-22	
Dry Seeds	15.9	15.4	15.7a	112.6	114.9	113.7b
Hydro-priming	12	12	12.0c	117.8	123.1	120.4a
Halo-Priming	13.6	12.6	13.1b	117.4	121.2	119.3a
Mean	13.8	13.4		115.9	119.7	
LSD $_{(0.05)}$ for year (Y)			NS			NS
LSD $_{(0.05)}$ for PS			1.05			2.15

Interaction of PS x Y	NS	NS

Table 2. Days tillering and booting of durum wheat as affected by priming sources (PS) and foliar zinc application levels (Zn) at various growth stages (ZAS) during the rabi season 2020-21 and 2021-22.

Priming Sources (PS)	**Days to tillering**		**Mean**	**Days to booting**		**Mean**
	2020-21	**2021-22**		**2020-21**	**2021-22**	
Dry Seeds	39.9	39.5	39.7a	124	120.7	122.4
Hydro-priming	35.9	33.8	34.8b	121	114.8	117.9
Halo-Priming	34.3	35	34.7b	121.9	137.3	129.6
Mean	39.9	39.5		122.3	124.3	
LSD $_{(0.05)}$ for year (Y)			NS			NS
LSD $_{(0.05)}$ for PS			1.62			NS
Interaction of PS x Y			NS			NS

Table 3. Days to anthesis and harvest maturity of durum wheat as affected by priming sources (PS) and foliar zinc application levels (Zn) at various growth stages (ZAS) during the rabi season 2020-21 and 2021-22.

Zinc App Stages (ZAS)	**Days to anthesis**		**Mean**	**Days to maturity**		**Mean**
	2020-21	**2021-22**		**2020-21**	**2021-22**	
100% Tillering	135.7	131.9	133.8	172.6	170.4	171.5c
100% Boot	135.5	132.9	134.2	173.9	174.1	174.0b
50% at Tillering+50% Boot	135.3	134	134.6	174.8	175.2	175.0a
LSD $_{(0.05)}$			NS			0.95
Priming sources(PS)						
Dry Seed	136	133	134.5	173.2	172.9	173.1
Hydro-Priming	135.4	132.8	134.1	174.1	173.4	173.8
Halo-Priming	135.1	133	134	174	173.4	173.7
LSD $_{(0.05)}$			NS			NS
Zinc Levels (Zn kg ha^{-1})						
0	133.8	131.3	132.5c	172.6	170.4	171.5b
2.25	135	131.6	133.3b	173.9	174	174.0a
4.5	136.7	134.2	135.4a	174.3	174.3	174.3a
6.75	136.6	134.7	135.7a	174.3	174.3	174.3a
LSD $_{(0.05)}$			0.74			0.417
Years						
2020-21			135.5			173.8
2021-22			133			173.2
Significance			NS			NS
Interactions significance						
ZASx P			NS			NS

Y x ZAS	**	*
Y x P	NS	NS
Y x ZAS x P	NS	NS
Zn x ZAS	NS	***
Zn x P	NS	NS
Zn x ZAS x P	NS	NS
Y x Zn	NS	***
Y x Zn x ZAS	*	***
Y x Zn x P	NS	NS
Y x Zn x ZAS x P	NS	NS

Means in the same category of rows or columns followed by different letters were statistically significant using LSD≤0.05 probability level.

Table 4. Plant height (cm) and SPAD value of durum wheat as affected by priming sources (PS) and foliar zinc application levels (Zn) at various growth stages (ZAS) during the rabi season 2020-21 and 2021-22.

Zinc App Stages (ZAS)	Plant height		Mean	SPAD value		Mean
	2020-21	2021-22		2020-21	2021-22	
100% Tillering	105.1	99.9	102.5	49.3	48.1	48.7b
100% Boot	106.3	101.1	103.7	51.4	49.3	50.3a
50% at Tillering+50% Boot	105.5	100.3	102.9	51.8	50.5	51.1a
LSD (0.05)			NS			0.92
Priming sources(PS)						
Dry Seed	98.7	97.2	97.9b	50.1	49.1	49.6
Hydro-Priming	109.7	102.0	105.9a	51.8	49.1	50.4
Halo-Priming	108.5	102.1	105.3a	50.5	49.7	50.1
LSD (0.05)			1.80			NS
Zinc Levels (Zn kg ha^{-1})						
0	102.7	96.7	99.7c	46.2	45.5	45.9c
2.25	106.0	99.9	103.0b	49.1	47.5	48.3b
4.5	107.3	103.4	105.3a	55.0	51.5	53.3a
6.75	106.4	101.9	104.2ab	52.9	52.6	52.8a
LSD (0.05)			1.20			0.66
Years						
2020-21			105.6			50.8
2021-22			100.5			49.3
Significance			NS			NS
Interactions significance						
ZASx P			NS			***
Y x ZAS			NS			NS
Y x P			**			NS
Y x ZAS x P			NS			NS
Zn x ZAS			NS			**

Zn x P	NS	NS
Zn x ZAS x P	NS	NS
Y x Zn	NS	***
Y x Zn x ZAS	NS	NS
Y x Zn x P	NS	NS
Y x Zn x ZAS x P	NS	*

Means in the same category of rows or columns followed by different letters were statistically significant using LSD≤0.05 probability level.

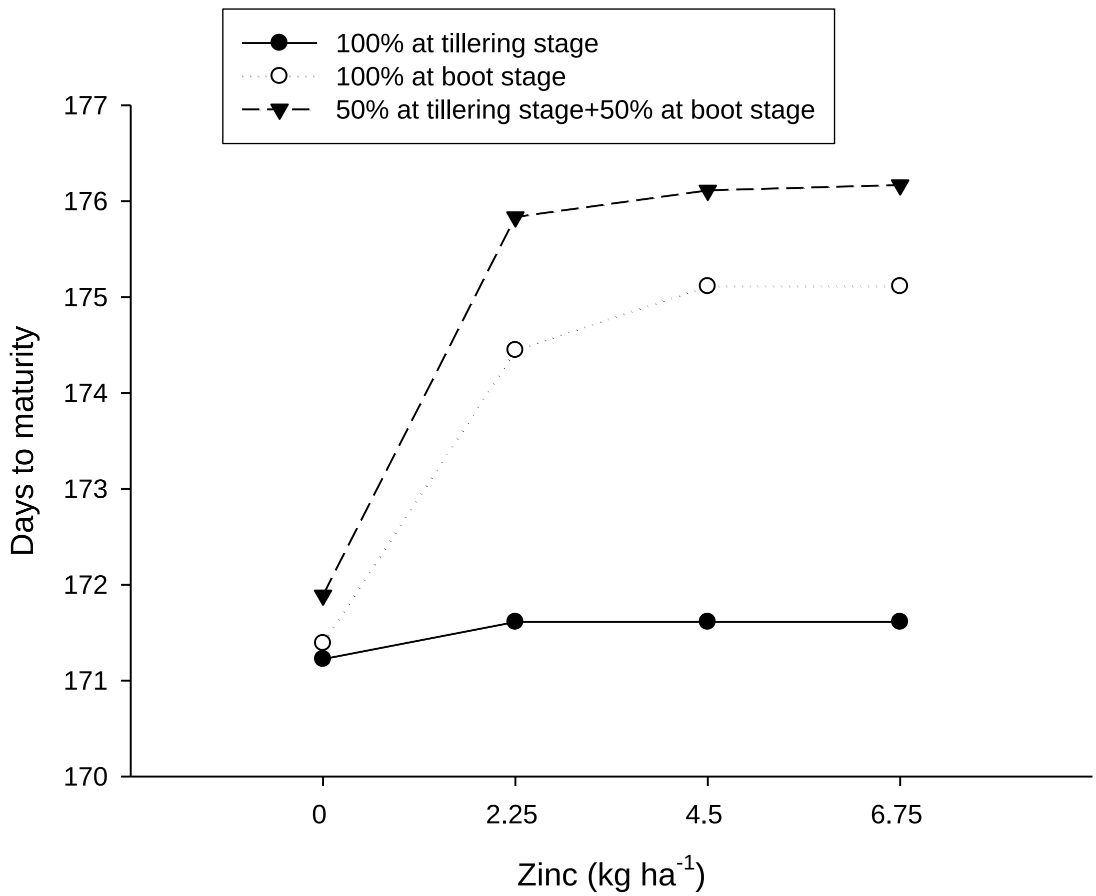

Fig. 3. Interaction of different zinc application stages (ZAS) x Zinc levels (Zn) for days to maturity of durum wheat averaged over two years 2020-21 and 2021-22.

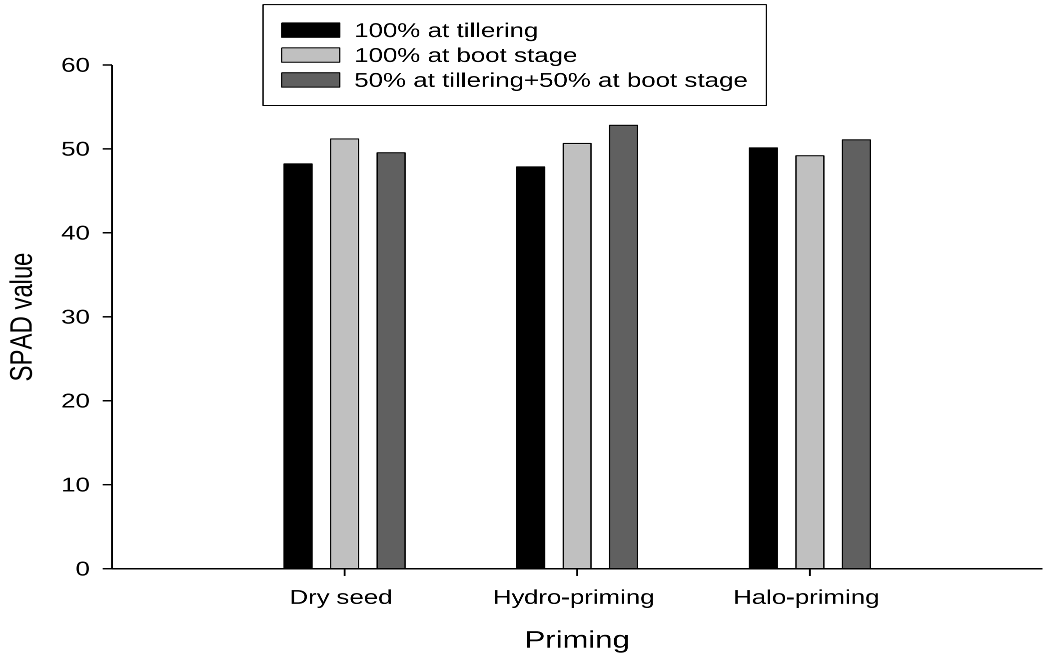

Fig. 4. Interaction of different zinc application stages (ZAS) x priming sources (PS) for SPAD value of durum wheat averaged over two years 2020-21 and 2021-22.

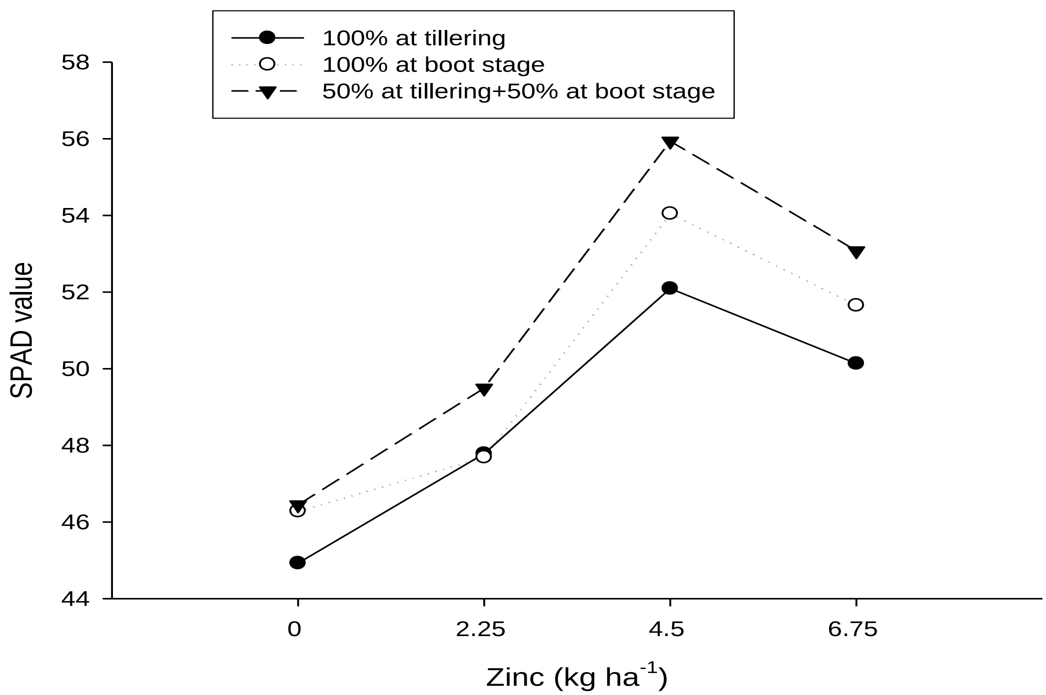

Fig. 5. Interaction of different zinc application stages (ZAS) x Zinc levels (Zn) for SPAD value of durum wheat averaged over two years 2020-21 and 2021-22.

Discussion

Early emergence of durum wheat was recorded for hydro-primed treated seeds followed by halo-primed seeds however; less crop emergence was noted in plots where dried seed was sown. Hameed et al. (2008) and

Musa and Lawal, (2015) reported that with increasing salinity levels germination time and germination was improved with halo-priming in Amaranth seed. It has been proved that seed priming or soil application of essential nutrients (Ca^{++}, Zn^{++} and K^{+}) are very important in enhancing germination and seedling growth (Rahmatullah *et al.,* 2012). Likewise, seed priming has recovered wheat varieties from late germination, by breaking the dormancy of seeds when exposed to salinity. The reason behind the positive role of seed priming could be the capability of seed to make all the necessary arrangements, which will be needed by the seed for proper germination. Hence the prime seed has completed initial stage of germination, which caused early germination in the soil and later on caused early emergence from the soil and uniform stand establishment. The priming process initiates important metabolic processes needed for germination (Nawaz *et al.,* 2013). Seed priming with hydrated calcium chloride has reduced the time for germination; enhanced the energy of germination and growth of rice (Ameri *et al.,* 2011). Our results were supported by research work on seed halo-priming technique with 50 mM $CaCl_2.2H_2O$ (Afzal *et al.,* 2006a; Yasmeen *et al.,* 2013; Hameed *et al.,* 2008). Improved germination, seedling growth, enhanced emergence (%) were reported in primed seed (Jabbarpour et al., 2012.) Aymen et al. (2012) revealed poor germination of sunflower in salinity which leads to poor crop stand establishment and sometime results in complete crop failure. Afzal et al. (2006b) reported that harmonal seed priming is another way to significantly reduce the seed leachates electrolyte conductivity. Elevated electrolyte conductivity causes to prolong imbibition stage of seed germination.

Results revealed that emergence m^{-2} is significantly affected by different priming sources during both the season. More numbers of durum wheat emerged in hydro-priming treated plots followed by halo-priming plots however, least number of durum seedling emerged in control experimental units. Our results are in correspondence with the higher number of emergence recorded for primed seed followed by dry seed (Imranuddin *et al.,*2017). Results are supported by Brahma et al. (2006) who recorded maximum number of emergence in frequently irrigated treatments. Similarly Akhtar, (2001) found that plants m^{-2} significantly increased by increasing levels of N (Harris et al. 2004) argued that increase in spikes m^{-2} due to priming might be due to improved emergence and better seedling growth.

Priming sources (PS) significantly affect days to tillering of durum wheat during both the years while, no differences were noticed for days to tillering of durum wheat during both the growing season i.e. 2020-21 and 2021-22. Results indicate that more days to tillering were noted in a control plots where dried seed was sown followed by hydro-primed statistically followed by halo-primed treated seeds.

Foliar zinc application had a significant effect on days to anthesis of durum wheat. Averaged over the two year data, plots where zinc was applied at the rate 6.75 kg ha^{-1} took maximum numbers of days to anthesis followed by plots foliar fertilized with 4.5 kg ha^{-1} Zn while, minimum days to anthesis in durum wheat were noted in a control experimental plots. Days to anthesis were increased with the increasing Zn level as zinc application increased the potentiality of crop to uptake more nutrients from the soil and also regulate the growth hormone in the roots (Keram *et al.*,2014). This might be due the provision of Zn which help in enzyme activation, synthsis of protein, auxin accumulation and maintenance of cellular membrane (Keram *et al.*,2014; Marschner, 1995).

Foliar zinc applied 50% each at tillering and boot stages took maximum days to maturity followed by plots fertilized with zinc 100% at boot stage however, minimum days to maturity were noted in a plot where Zn was applied 100% at tillering stage. Foliar application of nutrient at tillering and boot stage significantly improve the carotene pigments, chlorophyll content, activation of enzyme, protein synthesis, auxin accumulation and maintenance of cellular membrane which enhance the vegetative growth and also the duration of maturity (Nazran *et al.*,2010; Hafeez *et al.*,2013). In case of foliar Zn application delayed in crop maturity was observed in plots fertilized with 2.5 kg ha^{-1} Zn application followed by 6.75 and 2.25 kg ha^{-1} Zn while, early maturity was observed in control experimental plots. Zinc application increased the potentiality of crop to uptake more nutrients from the soil and also regulate the growth hormone in the roots (Keram *et al.*,2014). The delay in durum maturity could be due the provision of Zinc fertilizer which help in enzyme activation, synthsis of protein, auxin accumulation and maintenance of cellular membrane which enhance the vegetative growth and took more time to maturity (Keram *et al.,* 2014; Marschner, 1995).

Plant height is the most important trait used to measure the vertical growth of a plant. Plant height (cm) is the vegetative growth pattern showed by plant environmental as well as genetic conditions. It is the most important attribute used to measure the vertical plant growth. Priming sources had a considerable impact on plant height. Among priming sources tallest plants were recorded in plots where hydro-primed seeds were sown followed by halo-priming and the short statured plant height was noted in plots where dry seeds were sown. Under normal environmental situations priming of seed not only improved the growth related traits of crop but showed an exemplary potential under stressful condition (Du *et al.,* 2019). Priming of wheat seed showed potential growth attribute under stressful condition that initiate the process of enzyme activation i.e. catalase, peroxidase, malonldehyde, superoxide dismutase and water production that finally release oxidative stress and improve growth attributes of the plant (Li *et al.*,2021; Singhal *et al.,* 2021). Plant height was also significantly affected by foliar zinc levels. Zn applied at the rate of 4.5 kg ha^{-1} produced tallest plants followed by plots fertilized with 6.75 kg ha^{-1} Zn however, the smallest plants were observed in control experimental units. The reason for maximum plant height could be the Zn fertilization as it play a vital role in the synthesis of chlorophyll and increase the internode length (Bemeri *et al.,* 2012; Kaya and Heggs, 2002). The formation of IAA with application of Zn could increase internode length which leads to plant height (Marschner, 1995).

Maximum SPAD value was noted in experimental units where foliar Zn was applied 50% each at tillering and boot stages followed by 100% Zn applied at boot stage while, the lowest SPAD value was measured in plots where foliar Zn was applied 100% at tillering stage. Different Zn concentration had a significant effect on SPAD value of durum wheat. Amongst various zinc levels highest SPAD value was noted in a plot treated with 4.5 kg ha^{-1} Zn level followed by 6.75 kg ha^{-1} Zn however, the lowest SPAD value for durum wheat was observed in control experimental plots. Many studies affirm that involvement of Zn in the chlorophyll synthesis, protein content, nitrate reductase activities and their percentage was found maximum when plants were fertilized with ZnSO4 (Singh *et al.,* 2020; Mondal *et al.,* 2018). Application of ZnSO4 to the rice crop enhances seed and plant protein content (Bose *et al.,* 1999; Cakmak *et al.,* 2000). Kumar *et al.,* (2017) reported that zinc fertilization involved in the process of enzymes activation responsible for protein synthesis.

IV. CONCLUSION

The findings obtained from the present study showed that maximum days to emergence, days to tillering and days to boot stage were noted in dry sown seed compared to hydro and halo-priming. Early days to anthesis and days to maturity were recorded in dry sown seed compared to hydro and halo-priming. Maximum emergence m^{-2} was recorded in experimental trials where hydro-primed seed was sown followed by halo-priming treated seeds. Zinc applied on various growth stages significantly affected all the growth and phonological parameters of durum wheat. Maximum values recorded for almost all the studied traits of durum wheat in plots treated with foliar zinc application 50% at tillering + stage 50% boot stage. To maximize the phonological and yielding attributes of durum wheat it is recommended to ensure seed hydro-priming and foliar zinc application @ 2.4 kg ha^{-1} 50% at tillering+50% at boot stage.

APPENDIX

Appendixes, if needed, appear before the acknowledgment.

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