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Sowing time and genotypes effects on micronutrient contents of wheat grain

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Abstract
Wheat plays an important role in feeding the world, but climate change threatens its future harvest and nutritional quality. In this study, grain Zinc (Zn), iron (Fe), Manganese (Mn) and Cupper (Cu) concentrations of 07 wheat genotypes, were analyzed. The objective of study was, to find out the suitable genotypes having higher micronutrient content and yield. The investigation was undertaken in the research field of wheat research unit, Dr. PDKV, Akola (M.S), during the *Rabi* season of 2014-15 and 2015-16. An experiment laid out in factorial randomized block design replicated thrice. The experiment comprised of two dates of sowing i.e. 17th November and 11th December with 07 wheat genotypes namely AKAW-4627, AKDW-4021, AKAW-3722, AKW-1071, NIDW-295, AKAW-3997 and AKAW-4210-6. Among micronutrient content in harvested seed, genotype AKAW-4210-6 (36.80 mg/kg) recorded significantly maximum zinc content, the overall 13.93 % reduction occurred due to delayed sowing. Iron content significantly decreased under delayed sowing (39.48 mg/kg) as compared to timely sown condition (44.75 mg/kg). The genotype AKAW-4210-6 (52.25 mg/kg) recorded significantly maximum seed iron content. Manganese content significantly decreased due to delayed sowing (17.93 mg/kg) relative to timely sown condition (18.94 mg/kg). The overall 5.34% reduction in manganese content caused due to high temperature stress induced by delayed sowing. Genotype AKAW-4210-6 (21.69 mg/kg) under timely sown condition recorded significantly highest manganese content. The overall 19.12% mean reduction in copper content noticed under late sown condition.
The genotype AKAW-4210-6 (4.06 mg/kg) significantly excelled all the genotypes. Among yield traits, reduction caused due to heat stress i.e. test weight (g) (2.70%), Grain yield (g) spike^{-1} (10.07%) and Grain yield ha^{-1} (21.12%). Among wheat genotypes AKAW-4210-6 proved superiority in yield i.e. 42.45 and 37.81 qt ha^{-1} respectively, under normal and heat stress condition.

Keywords: wheat, micronutrient, yield and heat stress

Introduction
Maintaining grain quality under climate change is critical for human nutrition, end-use functional properties and commodity value. Wheat (*Triticum aestivum* L.) is one of the significant staple grains with worldwide. Increasing environmental stress on wheat production associated with climate change will affect both the yield and quality of wheat production.
Grain quality is influenced by genetics, management and environment. There is strong genetic control over kernel attributes such as shape, germ tissue, thickness of bran and crease characteristics. However, the post-anthesis environment such as water availability and temperature strongly influence seed size, thus it is important in defining physical properties such as screenings and milling yield. Wardlaw and Wrigley, (1994), Guttieri *et al.*, (2001) [4]. Similarly environmental conditions, particularly atmospheric CO_2 concentration and high temperature heat shock during the grain filling phase effects starch and protein deposition and functional properties including dough rheology and baking quality Fernando *et al.*, (2012) [2].

Materials and Methods
The present investigation was conducted in *Rabi* 2014-15 and 2015-16, in Factorial Randomized Block Design with three replications. Crop was sown at research field of wheat research unit, Dr. PDKV, Akola (M.S) is situated in the subtropical zone at the latitude of 20^0 42' North and longitude of 77^0 02' East. Altitude of the place is 307.41 m above the mean sea level, India; to assess the sowing time and genotypes effects on micronutrient contents of wheat grain. Sowing was done in 1.5 m x 5 m^2 plots with plant spacing 20 cm x 2 cm. The treatment comprised of two dates of sowing i.e. 17th November and 11th December as a factor A and seven wheat genotypes namely AKAW-4627, AKDW-4021, AKAW-3722, AKW-1071, NIDW-295, AKAW-3997 and AKAW-4210-6 as factor B. The observations on phenological and yield contributing traits were recorded as randomly selected five plants from each plot.

Seed micronutrients was analysed by using Atomic Absorption Spectrophotometer (Model Spectr AA-220) from di-acid extract as described by Isaac and Kerber (1971) [5] The pooled data of two seasons were analyzed as per Panse and Sukhatme (1967) [9]. Variation in growth environment and heat stress was induced by manipulation of the sowing dates i.e. timely and late sowing; Weather condition during the first season of research trail daily temperature showed the notable variation within the maximum and minimum temperature at the anthesis stage of crop i.e. 1 to 7 meteorological weeks of 2015. The maximum temperature in timely sowing ranged within 29.8 to 24.0^{0}C and minimum temperature ranged in 17.02 to 6.5 ^{0}C. At late sowing maximum and minimum temperature ranged within 27.2 to 32.8 ^{0}C and 7.5 to 16.3 ^{0}C, respectively. During the second season of research trail maximum and minimum temperature at the anthesis stage of crop showed the notable variation also at the second season, i.e. 1 to 7 meteorological weeks of 2016. The maximum temperature at timely sowing ranged within 29.9 to 34.2 ^{0}C and minimum temperature ranged in 9 to 9.17 ^{0}C. At late sown condition the maximum and minimum temperature ranged within 31.0 to 36.0 ^{0}C and 9.5 to 18.4 ^{0}C, respectively.

Results and Discussion

Among grain mineral nutrients, Zn and Fe deficiencies are the most important global challenge. According to the World Health Organization, deficiencies in Zn and Fe rank 5th and 6th, respectively, among the risk factors responsible for illnesses in developing countries. Deficiency in Zn and Fe afflicts over three billion people worldwide resulting in poor health, anemia and increased mortality rates. Producing micronutrient enriched cereals and improving their bioavailability are considered promising and cost-effective approaches for diminishing malnutrition.

Effect heat stress on the nutritional value of wheat grains and yield traits

Zinc is an important trace mineral needed for the body's immune system, cell division, wound healing and sense of smell and taste. The recommended dietary allowance for zinc is 8-11 mg/day. The tolerable upper intake level is 40 mg/day (ConsumerLab.com). The data regarding zinc content (mg/kg) in seed after harvest presented in Table 1, Data revealed that zinc content significantly decreased under late sown condition (29.79) as compared to timely sown condition (34.61). The overall 13.93 % reduction occurred due to late sowing. The significant variation in genotypes was observed for seed zinc content, which was ranged from 26.39 to 36.80 mg/kg. The genotype AKAW-4210-6 (36.80 mg/kg) recorded significantly maximum zinc content and lowest (26.39 mg/kg) value was found in NIDW-295. The interaction effect between sowing dates and genotypes was found significant. Genotype AKAW-4210-6 (40.25 mg/kg) exhibited significantly highest zinc content under timely sown condition followed by AKAW-3722 (36.86 mg/kg), AKDW-4021 (35.27 mg/kg) and AKAW-4627 (33.92 mg/kg) under timely sown condition. However, least zinc content was observed in NIDW-295 (23.28 mg/kg) followed by AKDW-4021 (28.76 mg/kg) under heat stress condition (delayed sowing by one month). On the basis of per cent reduction over timely sowing the genotype AKAW-3997 showed the minimum per cent reduction of 2.15 and maximum per cent reduction 21.08 by the genotype NIDW-295.

Iron is an essential mineral as it is needed for hemoglobin synthesis and its deficiency causes iron-deficiency anemia which is a common problem in women and children (U.S. National Library of General Medicine). The recommended dietary allowance for iron is 8-9 mg/day. The tolerable upper intake level is 45 mg/day (ConsumerLab.com). The data regarding Iron content (mg/kg) revealed that Iron content significantly decreased under delayed sowing (39.48 mg/kg) as compared to timely sown condition (44.75 mg/kg). The significant variation in genotypes was observed for seed iron content, which was ranged from 30.97 to 52.25 mg/kg. The genotype AKAW-4210-6 (52.25 mg/kg) recorded significantly maximum seed iron content followed by AKAW-3722 (49.36 mg/kg) and AKAW-4627 (47.96 mg/kg). However, lowest (30.97 mg/kg) seed iron was found in AKW-1071. On the basis of per cent reduction over timely sowing the genotype AKW-1071 showed the minimum per cent reduction of 3.02 and maximum per cent reduction 30.95 by the genotype NIDW-295. The interaction effect between sowing dates and genotypes was found significant. Genotype AKAW-4210-6 (55.52 mg/kg) exhibited significantly highest Iron content followed by AKAW-3722 (50.57 mg/kg) and AKAW-4627 (49.47 mg/kg) under timely sown condition. However, lower values were observed in AKW-1071 (30.50 mg/kg) under late sown condition (heat stress condition).

Manganese is a mineral that is found in several foods including nuts, legumes, seeds and leafy vegetables. Deficiency of manganese leads to osteoporosis and other illnesses. The recommended dietary allowance for manganese is 1.8-2.6 mg/day. The tolerable upper intake level is 11 mg/day (ConsumerLab.com). It was evident from Table 1 that, manganese content significantly decreased due to delayed sowing (17.93 mg/kg) relative to timely sown condition (18.94 mg/kg). The overall 5.34% reduction in manganese content caused due to high temperature stress induced by delayed sowing. Among wheat genotypes AKDW-4021 (21.14 mg/kg) recorded significantly highest manganese content followed by AKAW-4210-6 (20.21 mg/kg), NIDW-295 (19.59 mg/kg), AKAW-3722 (19.08 mg/kg) and AKW-1071 (17.15 mg/kg). Lowest manganese content was found in genotype AKAW-3997 (14.94 mg/kg). In response to interaction effects, genotype AKAW-4210-6 (21.69 mg/kg) under timely sown condition recorded significantly highest manganese content, which was at par with AKDW-4021 (21.29 mg/kg) and remain significantly superior over rest of the genotypes under timely sown condition. Under late sown condition, genotype AKDW-4021 (21.00 mg/kg) recorded superior manganese content than all other genotypes. However, lowest manganese content was found in AKAW-3997 15.61 and 14.61 mg/kg under timely and late sown condition respectively. On the basis of per cent reduction over timely sowing the genotype AKDW-4021 showed the minimum per cent reduction of 1.35 and maximum per cent reduction (13.63) by the genotype AKAW-4210-6.

Copper is an essential mineral that keeps blood vessels, nerves and immune system healthy and aids in iron absorption. The recommended dietary allowance for copper is 1 mg/day. The tolerable upper intake level is 10 mg/day (ConsumerLab.com). The data related to copper content (mg/kg) in seed after harvest indicated that, mean copper content significantly increased under timely sown crop (3.72 mg/kg) relative to late sown crop (3.01 mg/kg) in wheat. The overall 19.12% mean reduction in copper content noticed under late sown condition. Among the genotypes tested showed, significant variation in a mean copper content ranging from 2.31 to 4.06 mg/kg. The genotype AKAW-

4210-6 (4.06 mg/kg) significantly excelled all the genotypes followed by AKDW-4021 (3.90 mg/kg), AKW-1071 (3.57 mg/kg) and AKAW-3997 (3.43 mg/kg) over the general mean (3.37 mg/kg). Lowest copper content found in genotype AKAW-4627 (2.31 mg/kg). The interaction effect between sowing dates and genotypes was found significant. Genotype AKAW-4210-6 (4.61 mg/kg) exhibited maximum copper content at timely sown condition. However, minimum copper content was observed in genotype AKAW-4627 2.52 and 2.09 mg/kg under timely and late sown condition respectively. General mean for copper content of all genotypes tested was 3.37 mg/kg. On the basis of per cent reduction over timely sowing the genotype AKAW-3722 showed the minimum per cent reduction of 3.75 and maximum per cent reduction 44.79 by the genotype NIDW-295.

In present investigation micronutrient content in the seed is decreased under high temperature stress induced by late sowing. The findings are in agreement with those of Gomez *et al.* (2009) [3] reported that the concentration of grain's Fe and Zn in modern wheat cultivars is on an average around 35 and 25 mg/kg, respectively. Peleg *et al.* (2008) [10] have reported that stress conditions either result in an increase, decrease, or no changes in grain micronutrients in wheat. In other words, no definite trend on the accumulation of micronutrient under stress conditions can be predicted. In the present work, just by changing sowing time, a significant variation in seed micronutrient was observed. This variation could be useful for selection of superior germplasm for breeding programs aimed at mineral biofortification. In contrast, in the present investigation delayed sowing condition resulted in decreased micronutrients *i.e* Zn-13.93%, Fe-11.79%, Mn-5.34% and Cu-19.12% reduction, on per cent reduction basis. So optimum temperature of timely sowing condition (First forthright of November) during grain filling stage could offer a new approach for biofortification of wheat grains without any additional economic inputs.

The data regarding test weight (g) indicated that The high temperature stress induced by late sowing caused 2.70% reduction in test weight. Among the genotypes, AKAW-4210-6 (39.55 g) was found significantly superior over rest of the genotypes under study, next to AKAW-3997 (38.93 g), AKAW-4627 (38.76 g) and AKW-1071 (38.33 g) recorded significantly higher test grain weight than the mean (38.17 g). Lowest test weight was recorded in AKDW-4021 (36.39 g). The interaction effect between sowing dates and genotypes was found statistically significant. Early duration genotype AKAW-4210-6 when sown under timely condition exhibited significantly highest test grain weight (40.40 g) over all combinations. Whereas, under late sowing, AKAW-4210-6, one of the high yielding genotype recorded significantly highest (38.70 g) test grain weight followed by AKAW-3997 (38.67 g), AKAW-1071 (37.81 g) and AKAW-4627 (37.59 g). On the contrary, genotype AKDW-4021 (36.14 g) and AKAW-3722 (37.12 g) recorded lowest test weight under delayed sown condition. The reduction in test weight under late sowing was mainly due to high temperature, reduction in grain growth period and shriveling of grains. The reduction in grain weight under late sowing and high temperature was reported by Wardlaw (2002) [12], Khan *et al*. (2007) [6], Bahar *et al*. (2008) [1], Mukherjee (2012) [8], and Ram *et al*. (2012) [11].

The grain weight spike^{-1} (g) was found significantly maximum under timely sown condition (1.72 g) relative to late sown condition (1.55 g). The reduction in grain weight spike^{-1} to the extent of 10.07% was caused due to late sowing. Among the wheat genotypes tested, top ranking genotype AKAW-4210-6 in grain yield (kg ha^{-1}) has recorded significantly highest mean grain weight spike^{-1} of 1.85 g over all the genotypes. However, least (1.51 g) grain weight spike^{-1} was recorded in NIDW-295. The interaction effects, Genotype AKAW-4210-6 recorded highest grain weight spike^{-1} of 1.96 and 1.75 g under timely and late sown conditions respectively. Genotypes *viz*., AKDW-4021 (1.83 g) and AKAW-4627 (1.70) also recorded significantly higher grain weight spike^{-1} next to AKAW-4210-6 under timely sown condition, whereas genotypes *viz*., AKAW-4627 (1.64 g) and AKAW-3997 (1.60 g) were next to AKAW-4210-6 under late sown condition. In the present investigation, All wheat genotypes showed decreasing trend in grain weight spike^{-1} under delayed sowing, decrease in grain weight spike^{-1} under late sown condition (high temperature stress of 2.87ºC) and some genotypes was mainly due to reduction in grain number earhead^{-1} as well shriveled grain because of competition for assimilate between grains of the same ear head has been much prominent and they could not get sufficient assimilate (source limitation of grain development).

The data pertaining to grain yield ha^{-1} evident that, crop sown on 17th November (timely sowing) recorded the significantly higher grain yield of 35.94 qt ha^{-1} as compared to the crop sown on 11th December (late sowing) i.e., 28.35 qt ha^{-1} mean grain yield ranged from 31.38 to 42.45 qt ha^{-1} under timely sowing and 20.67 to 37.81 qt ha^{-1} under late sowing in present investigation. The 21.12% reduction in grain yield under late sown condition caused due to high temperature stress of 2.87^{0}C occurred at post anthesis stage. The significant genotypic differences were found for grain yield, among the genotypes; early duration genotype AKAW-4210-6 recorded the significantly highest grain yield of 40.13 qt ha^{-1} than all the wheat genotypes. The another early duration genotype AKAW-4627 recorded the significantly higher grain yield of 34.47 qt ha^{-1} than all the wheat genotypes except AKAW-4210-6 and it was followed by genotype AKAW-3997 (32.43 qt ha^{-1}), AKAW-3722 (31.76 qt ha^{-1}), AKDW-4021 and (28.85 qt ha^{-1}). Genotypic differences in grain yield might be due to genetic potential of different varieties to express in terms yield attributing traits in differential environmental condition.

Table 1: Biochemical traits in wheat genotypes as influenced by sowing dates, genotypes and their interactions (pooled data for 2014-15 and 2015-16)

Particulars	Zinc content in seed (mg/kg)			Iron content in seed (mg/kg)			Manganese content in seed (mg/kg)			Copper content in seed (mg/kg)		
Treatment	**(D_1) Timely sowing**	**(D_2) Late sowing**	**Mean**	**(D_1) Timely sowing**	**(D_2) Late sowing**	**Mean**	**(D_1) Timely sowing**	**(D_2) Late sowing**	**Mean**	**(D_1) Timely sowing**	**(D_2) Late sowing**	**Mean**
G_1 (AKAW-4627)	33.92	29.22	31.57	49.47	46.45	47.96	17.74	16.04	16.89	2.52	2.09	2.31
G_2 (AKDW-4021)	35.27	28.76	32.02	46.26	39.19	42.73	21.29	21.00	21.14	4.07	3.73	3.90
G_3 (AKAW-3722)	36.86	29.91	33.38	50.57	48.14	49.36	19.44	18.73	19.08	3.11	2.99	3.05
G_4 (AKW-1071)	32.80	31.06	31.93	31.44	30.50	30.97	17.32	16.99	17.15	3.95	3.18	3.57

G_5 (NIDW-295)	29.50	23.28	26.39	45.09	31.14	38.12	19.80	19.39	19.59	4.18	2.31	3.24
G_6 (AKAW-3997)	33.70	32.97	33.33	34.91	31.95	33.43	15.28	14.61	14.94	3.61	3.25	3.43
G_7 (AKAW-4210-6)	40.25	33.35	36.80	55.52	48.97	52.25	21.69	18.74	20.21	4.61	3.52	4.06
Mean	34.61	29.79	32.20	44.75	39.48	42.12	18.94	17.93	18.43	3.72	3.01	3.37

	SE (m) ±	**CD at 5%**	**SE (m) ±**	**CD at 5%**	**SE (m) ±**	**CD at 5%**	**CD at 5%**	**SE (m) ±**
Sowing Date (D)	0.24	0.69	0.19	0.56	0.07	0.20	0.02	0.06
Genotype (G)	0.45	1.29	0.36	1.05	0.13	0.37	0.04	0.12
Interaction (D x G)	0.63	1.83	0.51	1.49	0.18	0.52	0.06	0.16

Table 2: Yield traits in wheat genotypes as influenced by sowing dates, genotypes and their interactions (pooled data for 2014-15 and 2015-16)

Particulars	**Test weight (g)**			**Grain weight (g) spike^{-1}**			**Grain yield (q) ha^{-1}**		
Treatment	**(D_1) Timely sowing**	**(D_2) Late sowing**	**Mean**	**(D_1) Timely sowing**	**(D_2) Late sowing**	**Mean**	**(D_1) Timely sowing**	**(D_2) Late sowing**	**Mean**
G_1 (AKAW-4627)	39.92	37.59	38.76	1.70	1.64	1.67	36.31	32.64	34.47
G_2 (AKDW-4021)	36.63	36.14	36.39	1.83	1.47	1.65	33.29	24.40	28.85
G_3 (AKAW-3722)	37.83	37.12	37.47	1.66	1.56	1.61	33.96	29.55	31.76
G_4 (AKW-1071)	38.85	37.81	38.33	1.60	1.49	1.55	35.40	27.36	31.38
G_5 (NIDW-295)	38.11	37.36	37.74	1.67	1.35	1.51	31.38	20.67	26.03
G_6 (AKAW-3997)	39.08	38.67	38.93	1.66	1.60	1.63	38.82	26.04	32.43
G_7 (AKAW-4210-6)	40.40	38.70	39.55	1.96	1.75	1.85	42.45	37.81	40.13
Mean	38.69	37.64	38.17	1.72	1.55	1.64	35.94	28.35	32.15

	SE (m) ±	**CD at 5%**	**SE (m) ±**	**CD at 5%**	**SE (m) ±**	**CD at 5%**
Sowing Date (D)	0.09	0.26	0.01	0.04	0.29	0.86
Genotype (G)	0.17	0.50	0.03	0.07	0.55	1.60
Interaction (D x G)	0.24	0.70	0.04	0.10	0.78	2.27

Conclusion

In the present investigation, grain micronutrient content and yield traits of wheat genotypes were significantly influenced by heat stress created by delayed sowing. In regards to grain yield and micronutrient content (Zn, Fe and Cu) of harvested seed, genotype AKAW-4210-6 was identified as superior. These genotype can be utilized in further breeding programs for the development of biofortified wheat cultivars for heat stress tolerant under delayed sown condition to cope with the problem of malnutrition in rural masse where wheat is the main cereal for consumption.

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