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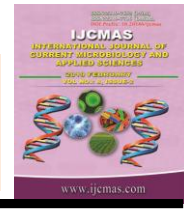

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Nutrient Content in Grain and Straw of Different Wheat Genotypes as Affected by Moisture Stress

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A B S T R A C T

Macronutrient specially K and micronutrient malnutrition, and particularly deficiency in zinc (Zn), iron (Fe) and manganese (Mn), afflicts over three billion people worldwide. A pot culture experiment was conducted to study the effect of water stress on potassium and some micronutrient accumulation in straw and grains of wheat genotypes. Eight wheat genotypes were grown, 4 tolerant and 4 susceptible against water stress for the experiment. Moisture stress treatment to plants was given at anthesis through withdrawal of water. Soil moisture status of pots subjected to stress treatment was maintained throughout the grain growth period. Schedule routine of irrigation was practiced for control plants throughout the crop growth period. Moisture stress caused changes in nutrient balance of the plants. K, Zn, Fe and Mn concentration were measured both in straw and grain under control and water stress condition at the time of harvesting. Harvest index and 1000 grain weight were also recorded. Mean reduction in harvest index and test weight (1000 grain weight) of seeds was noted in all the genotypes. However, in tolerant cultivars very little reduction was observed as compared to susceptible genotypes. Concentration of K, Zn, Fe and Mn were found more in straw compared to grain under both control and water stress condition. Contents of Fe was reduced, and K contents increased under moisture stress condition both in straw and grain. In case of Zn content increase was noted in straw and decrease in grain due to water stress. No clear-cut effect of water stress was seen on Mn content under water stress in both straw and grain. However, moisture stress tolerant wheat genotypes showed lesser alteration in nutrient content than the susceptible genotypes, maintaining optimum nutrient levels in straw and grains.

Keywords

Drought stress, Macro nutrient, Micro nutrient, Moisture stress, Wheat

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Introduction

Drought is a significant limiting factor for agricultural productivity and quit enough to inhibit plant growth through declined water absorption and nutrient uptake. Plant mineral nutrition is critical to plant growth and development and has direct implications in agriculture and human health too. Drought stress may involve accumulation of mineral elements in plant tissues by changing the pattern of root growth, nutrient mobility in soil and nutrient uptake (Fageria *et al.,* 2002; Samarah *et al.,* 2004). Declined water availability under drought generally results in reduced total nutrient uptake and frequently reduced concentrations of individual mineral nutrients in crop plants (Gunes *et al.,* 2007). The most important effects of water deficits are on transport of nutrients to the root and on root growth and extension. Reduced absorption of inorganic nutrients results from interference with nutrient uptake, unloading mechanisms and reduced transpiration flow (Marschner 1995; Baligar *et al.,* 2001).

In the line of crop nutrition, Potassium is considered one of the necessary elements for the complete function of plants especially for N and carbohydrate metabolism, activation of various enzymes and adjustment of stomatal movement and water relations. Potassium ions may act together with sugar and other inorganic and organic ions as osmotic-adjustment substances. In this concern, Thalooth *et al.,* (1990) found that potassium fertilization may increase plant resistance against unfavourable conditions. In addition, Alderfasi (2009) reported that potassium fertilizer is necessary for high yielding production of wheat under arid condition.

Wheat (*Triticum* spp.) is one of the major staple food crops in many parts of the world in terms of cultivated area and food source, contributing 28% of the world edible dry matter (DM) and up to 60% of the daily calorie intake in most of the developing countries (FAO 2006). Therefore, the bio-composition and nutritional quality of the wheat grain has a significant impact on human health and well-being, especially in the developing countries. Micronutrient malnutrition, and particularly deficiency in Zn, Mn and Fe, victimise over three billion people worldwide (Bouis, 2007; Peleg *et al.,* 2008), resulting in overall poor health, anemia, increased morbidity and mortality rates, and lower workers efficiency (Hotz and Brown 2004). Producing micronutrient enriched cereals (biofortification), either agronomically or genetically, and improving their bioavailability are considered promising and cost-effective approaches for eradicating malnutrition (Ghandilyan *et al.,* 2006; Distelfeld *et al.,* 2007). This solution, however, requires a comprehensive exploitation of potential genetic resources and an in-depth understanding of their micronutrient accumulation mechanisms. Differences can be attributed to plant type, plant tissue, moisture stress level, growing conditions and the duration of the study. Moisture stress stimulates as well as inhibits the uptake of some micronutrients by crop plants at differential organ. In order to better understanding of the mechanisms of nutrient partitioning and alteration of nutrient accumulation between straw and grain under water stress and its differential pattern in tolerant and susceptible wheat genotypes this experiment was conducted with eight wheat genotypes (4 susceptible and 4 tolerant).

Materials and Methods

Plant material and treatments

An experiment was conducted in the pot culture, Division of Plant Physiology, Indian Agricultural Research Institute, Pusa, New Delhi, India with 8 wheat genotypes viz. C 306, HD 2987, HD 3016, NI 3039 (tolerant to moisture stress) (Kumari *et al.,* 2014), and PBW 343, HD 2733, PBW 373 and HD 2967 (susceptible to moisture stress) (Kumari *et al.,* 2014) sown in 30 cm earthen pots of uniform size (30x30 cm) and filled with 10 kg mixture of air dried soil and farm yard manure in 3:1 ratio during the winter seasons of 2011-12.

Nitrogen, phosphorus and potash fertilizers were applied at the rate of 60: 60: 60 kg per hectare respectively in the form of urea, single super phosphate and muriate of potash at the time of sowing. Remaining 60 kg N ha^{-1} was given at the completion of 25 days of sowing. Moisture stress treatment to plants was given at anthesis through withdrawal of water. Measurement of water stress was done through tensiometer. A calibration curve was made with the help of pressure Fig. apparatus at different pressure from 0 to 15 bars for the same soil and farm yard mixture. One bar soil pressure condition, which is nearly 67-70% moisture of field capacity, was optimized for taking plant samples. Soil moisture status of pots subjected to stress treatment was maintained throughout the grain growth period. Schedule routine of irrigation was practiced for control plants throughout the crop growth period. Each treatment was replicated 20 times in the form of pots for all the genotypes.

Sample collection

Straw and grains were sampled for recording observations at harvest stage. For each genotype samples were collected in triplicate from 3 pots. Plant materials were dried in an oven at 60°C and ground to fine powder in a grinding machine.

Yield Parameters

1000-grain weight (g) and harvest index were recorded in control and treated plants at the time of harvest.

Estimation of macro and micronutrients (Potassium, iron, copper, zinc and manganese)

A representative ground plant sample (0.5 g) was digested in a di-acid mixture (20 ml) containing HNO_3 and $HClO_4$ acid (9:4) on digestion unit (Gerhardt Turbotherm). After digestion the volume was made 50 ml. Potassium was estimated using Flame Photometer (Elico, CL-361). The micro nutrients content (Fe, Zn and Mn) in samples were estimated using Atomic Absorption Spectrophotometer (Perkil Elmer, AAnalyst 200). By plotting standard curves with the known concentration of Fe, Zn, and Mn; the content of K, Fe, Zn, and Mn were calculated in straw and grain samples of wheat genotypes.

Statistical analyses

The data obtained was subjected to analysis of variance appropriate to the experimental design. F-test was carried out to test the significance of the treatment differences and the least significant difference (LSD) was computed to test the significance of different treatments at 5 % level of probability by the SPSS 10.0.

Results and Discussion

Harvest index

Results on the effect of moisture stress on the harvest index of wheat genotypes are shown in Table 1. Mean reduction in harvest index was about 23%. In case of genotypes C 306, HD 2987, HD 3016 and NI 5439 reductions were very minute, 2 to 5%. But in genotypes PBW 343, HD 2733, PBW 373 and HD 2967 yield reductions were very high, which varied from 28 to 49%.

1000 grain weight

Results on 1000 grain weight of wheat genotypes under moisture stress condition are reported in Table 1. Test weight (1000 grain weight) of seeds decreased significantly under water stress in all genotypes. Genotypes C 306, HD 2987, HD 3016 and NI 5439 showed lesser reductions in test weight, which varied from 13 - 29%, while in case of PBW 343, HD 2733, PBW 373 and HD 2967, it varied from 25 - 44%.

Potassium content

The data on the effect of moisture stress treatment on potassium content in the grains and straw of different wheat genotypes are presented in Table 2. The data showed that there was increase in potassium content both in straw and grains in all the genotypes under moisture stress treatment as compared to control. However, potassium content was higher in straw as compared to grain, both under control and moisture stress condition. Overall enhancement in potassium content due to moisture stress was 47 to 76% in grains of tolerant genotypes and 19 to 39% in that of moisture stress susceptible wheat genotypes. The increase in potassium content was 44 to 87 % in straw of tolerant genotypes and 14 to 36% in that of moisture stress susceptible wheat genotypes.

Zinc content

The data on the effect of moisture stress treatment on zinc content in the grains and straw of different wheat genotypes are presented in Table 3. The data showed that there was increase in zinc content in straw and decline in zinc content of grains in all the genotypes under moisture stress treatment as compared to control. When comparison of grain and straw Zn content was done, it was found that potassium content was higher in grain under control condition and more in straw under water stress condition, both under control and moisture stress condition. Overall decline in zinc content due to moisture stress was 5 to 17% in grains of tolerant genotypes and 16 to 27% in that of moisture stress susceptible wheat genotypes. The increase in zinc content was 44 to 83 % in straw of tolerant genotypes and 28 to 42% in that of moisture stress susceptible wheat genotypes.

Iron content

The data on the effect of moisture stress treatment on iron content in the grains and straw of different wheat genotypes are presented in Table 4. The data showed that there was decline in iron content in straw and grains of all the genotypes under moisture stress treatment as compared to control. However, iron content was higher in straw as compared to grain, both under control and moisture stress condition. Overall decline in iron content due to moisture stress was 12 to 17% in grains of tolerant genotypes and 24 to 62% in that of moisture stress susceptible wheat genotypes. The decline in iron content was 8 to 39 % in straw of tolerant genotypes and 39 to 83% in that of moisture stress susceptible wheat genotypes.

Manganese content

The data on the effect of moisture stress treatment on manganese content in the grains and straw of different wheat genotypes are presented in Table 5. The data showed that there was no clear-cut effect of moisture stress on Mn content under water stress in both straw and grains. In some genotypes manganese content was increasing, while in some genotypes it was decreasing due to moisture stress, both in the case of straw and grains. However, manganese content was higher in straw as compared to grain, both under control and moisture stress condition.

Availability of water is one of the critical factors determining plant distribution and survival in different natural ecosystems. During the past many decades, the primary objective of plant breeding programs has been to increase yield, a subject that will remain a principal concern in providing the calorie intake required for the increasing world population. However, equally important, but largely overlooked in breeding programs, is the nutrient composition and concentration, particularly the micronutrients, in the straw and grains of staple food crops (Welch and Graham, 1999; Cakmak, 2002). Breeding programs directed towards increased yield have narrowed the genetic basis of modern crop plants. Therefore, it is essential and urgent to exploit genetic resources from relatives of wheat which harbour a richness of desirable genes (Peleg *et al.,* 2008). Scarcity of water is a drastic environmental constraint to plant productivity. Drought-induced loss in crop yield probably exceeds losses from all other causes, since both the severity and duration of the stress are critical (Farooq *et al.,* 2009).

The present study revealed that water stress affects various yield parameters like harvest index and test weight; as well as potassium and micro nutrient content both in straw and grain. Similar result was reported Kumari *et al.,* (2014) for yield parameters and by Gunes *et al.,* (2007) for micronutrient status in case of wheat under moisture stress treatment. Moisture stress has drastic effect on these parameters, but tolerant genotypes have shown lesser alteration in nutrient accumulation and portioning of it between straw and grains in wheat genotypes.

Drought stress leads to hastened maturity and there will be disturbed nutrient uptake efficiency and photosynthate translocation in the plant that produces shrivelled kernels with decreased 1000 kernel weight (Riaz and Chowdhry, 2003; Kumari *et al.,* 2014). It turns into decline in harvest index and test weight of grains in wheat genotypes. Under such circumstances, a genotype that can mobilize reserves of carbohydrates from the stem and mineral nutrients into stem and grain will be able to maintain better seed filling. Drought tolerant genotypes show lesser decline in yield and yield components as compared to susceptible wheat genotypes (Kumari *et al.,* 2014).

Potassium was more in straw as compared to grains both in control and moisture stress condition. Under water stress condition its concentration was increased both in straw and grain as compared to control. Potassium accumulation in plant parts is positively correlated with stimulation in root growth and hence, efficient exploration of soil water (Saxena, 1985). Further, it decreases the loss of soil moisture by decreasing the transpiration and increasing the water retention in plants (Umar and Moinuddin, 2002). Potassium ions may act together with sugar and other inorganic and organic ions as osmotic-adjustment substances. Under water-deficit conditions, K fertilization enhances crop tolerance to water stress by utilizing the soil moisture more effectively than in K-deficient plants.

This is the cause for increased K content in grain and straw in wheat genotypes under water stress in our experiments. The positive effects of K on water stress tolerance may be through promotion of root growth accompanied by a greater uptake of other nutrients and water by plants (Rama Rao, 1986) and through the reduction of transpirational water loss (Beringer and Trolldenier, 1978), is the explanation of higher increase in K content in grain and straw of moisture stress tolerant wheat genotypes under drought compared to susceptible in our investigation. Also, K maintains the osmotic potential and turgor of the cells (Hsio, 1973; Lindhauer, 1985) and regulates the stomatal functioning under water stress conditions (Kant and Kafkafi, 2002), which is reflected in improved crop yield in drought conditions (Umar and Bansal, 1995; Umar and Moinuddin, 2002).

Table.1 Effect of moisture stress on harvest index and test weight in wheat genotypes

Genotype	Harvest index (%)			1000 grain weight (g)		
	Control	Moisture stress	% Decrease	Control	Moisture stress	% Decrease
C 306	38.50	37.40	2.86	46.15	38.35	16.90
HD 2987	39.65	38.85	2.01	42.99	37.15	13.58
HD 3016	45.19	33.07	26.83	45.98	36.75	20.07
NI 5439	43.24	40.88	5.46	42.55	29.88	29.79
HD 2733	37.61	27.08	27.98	52.25	36.30	30.53
PBW 343	40.71	27.06	33.53	49.58	27.60	44.33
PBW 373	42.23	21.64	48.75	46.35	34.35	25.89
HD 2967	42.19	25.39	39.82	43.69	30.50	30.19
Mean	41.17	31.42		46.19	33.86	
CD at 5%						
Treatment (T)		0.022			0.789	
Variety (V)		0.044			1.577	
T x V		0.063			2.231	

Table.2 Effect of moisture stress on K content (%) in grain and straw in wheat genotypes

Genotype	K content in grains (%)				K content in straw (%)		
	Control	Moisture stress	% Decrease		Control	Moisture stress	% Decrease
C 306	0.45	0.79	75.6		1.20	1.92	60.0
HD 2987	0.39	0.66	71.6		1.06	1.52	43.7
HD 3016	0.32	0.48	48.1		0.95	1.78	87.1
NI 5439	0.40	0.59	47.1		0.78	1.35	73.1
HD 2733	0.39	0.54	39.0		0.82	0.93	14.2
PBW 343	0.40	0.54	37.2		0.87	1.13	29.9
PBW 373	0.42	0.51	22.9		1.00	1.33	33.0
HD 2967	0.38	0.45	19.1		0.77	1.04	35.9
Mean	0.39	0.57			0.93	1.38	
	Plant part (P)	Treatments (T)	PXT	Genotypes (G)	P X G	T X G	P X T X G
SEm±	0.01	0.01	0.015	0.021	0.029	0.029	0.041
LSD (P ≤ 0.05)	0.029	0.029	0.041	0.058	0.082	0.082	0.116

Table.3 Effect of moisture stress on Zn content (ppm) in grain and straw in wheat genotypes

Genotype	**Zn content in grains (ppm)**				**Zn content in straw (ppm)**		
	Control	**Moisture stress**	**% Decrease**		**Control**	**Moisture stress**	**% Increase**
C 306	31.8	26.3	17.3		27.5	50.2	82.5
HD 2987	31.7	28.1	11.4		21.6	37.0	71.3
HD 3016	22.2	19.8	10.8		24.0	37.0	54.2
NI 5439	27.3	25.8	5.3		20.9	33.3	59.3
HD 2733	28.8	23.7	17.8		26.5	37.7	42.3
PBW 343	30.4	24.2	20.4		22.4	31.3	39.7
PBW 373	26.4	19.4	26.5		21.9	29.9	36.5
HD 2967	26.8	22.4	16.4		26.4	33.9	28.4
Mean	28.18	23.72			23.90	36.18	
	Plant part (P)	**Treatments (T)**	**PXT**	**Genotypes (G)**	**P X G**	**T X G**	**P X T X G**
SEm±	0.198	0.198	0.28	0.395	0.559	0.559	0.791
LSD (P ≤ 0.05)	0.559	0.559	0.79	1.117	1.58	1.58	2.235

Table.4 Effect of moisture stress on Fe content (ppm) in grain and straw in wheat genotypes

Genotype	**Fe content in grains (ppm)**				**Fe content in straw (ppm)**		
	Control	**Moisture stress**	**% Decrease**		**Control**	**Moisture stress**	**% Decrease**
C 306	92.6	81.4	12.1		617.90	569.8	7.8
HD 2987	85.6	70.9	17.2		674.50	495.7	26.5
HD 3016	113.1	98.6	12.8		802.3	491.0	38.8
NI 5439	99.5	84.7	14.9		849.6	569.1	33.0
HD 2733	109.3	72.6	33.6		786.00	443.4	43.6
PBW 343	95.7	64.9	32.2		846.70	456.6	46.1
PBW 373	178.1	67.6	62.0		953.4	581.3	39.0
HD 2967	109.4	83.2	23.9		746.9	124.4	83.3
Mean	110.41	77.99			784.66	466.42	
	Plant part (P)	**Treatments (T)**	**PXT**	**Genotypes (G)**	**P X G**	**T X G**	**P X T X G**
SEm±	0.397	0.397	0.562	0.795	1.124	1.124	1.590
LSD (P ≤ 0.05)	1.123	1.123	1.588	2.246	3.176	3.176	4.492

Table.5 Effect of moisture stress on Mn content (ppm) in grain and straw in wheat genotypes

Genotype	Mn content in grains (ppm)				Mn content in straw (ppm)		
	Control	Moisture stress	% Decrease /Increase		Control	Moisture stress	% Decrease /Increase
C 306	29.3	23.2	-20.8		26.0	41.0	57.7
HD 2987	18.4	29.0	57.6		32.5	38.4	18.2
HD 3016	36.3	33.8	-6.9		40.8	36.3	-11.0
NI 5439	24.1	28.4	17.8		38.5	35.8	-7.0
HD 2733	24.2	33.2	37.2		28.5	37.8	32.6
PBW 343	20.9	21.5	2.9		34.8	33.8	-2.9
PBW 373	26.4	25.2	-4.5		48.8	42.7	-12.5
HD 2967	35.6	27.1	-23.9		35.3	25.7	-27.2
Mean	27.04	27.69			35.64	36.46	

	Plant part (P)	Treatments (T)	PXT	Genotypes (G)	P X G	T X G	P X T X G
SEm±	0.291	0.291	0.412	0.582	0.823	0.823	1.165
LSD (P ≤ 0.05)	0.823	N/A	N/A	1.645	2.327	2.327	3.291

Note: In % Decrease/Increase column -ve value shows decline in Mn content, while +ve value shows increase in Mn content.

Besides, it takes part in many essential processes in plants (Marschner, 1995) and enhances photosynthetic rate, plant growth and yield under stress conditions (Egila *et al.*, 2001; Umar and Moinuddin, 2002). As per Cakmak (1997), the protective role of K in plants suffering from drought stress has been attributed to the maintenance of a high pH in stroma and in oppose to the photo-oxidative damage to chloroplasts.

Two major micro nutrients i.e. iron, and zinc contents were severely reduced by moisture stress in wheat straw. In grain iron increased, while zinc decreased under moisture stress. The reductions were relatively lesser in case of the tolerant genotypes; similarly increase in accumulation was comparatively more in tolerant genotypes as compared to susceptible. Alderfasi and Alghamdi (2010) also reported moisture stress induced decrease in Fe content in case of faba beans straw. It is noticeable that Mn concentration had no definite trend under control and water stress, both in case of straw and grains.

Whole plant senescence in monocarpic plants such as wheat (*Triticum aestivum* L.) is the final stage of growth and development (Nooden *et al.*, 1997). It is a genetically programmed process that involves remobilization of nutrients among vegetative tissues and grains (Nooden, *et al.*, 1997; Ori *et al.*, 1999). But this remobilization got disturbed under moisture stress condition. Same is noted in our investigation that moistute stress either increase or decrease K, Zn and Fe accumulation in straw and grains, which is the outcome of disturbed mineral nutrient portioning among vegetative and reproductive plant parts. But moisture stress tolerant genotypes have shown less alteration in mineral nutrient partitioning among various plant parts as compared to susceptible wheat genotypes.

From the above results, it can be concluded that moisture stress results in nutrient imbalances by affecting nutrient uptake, availability and partitioning within the plant and among various plant parts. Moisture stress tolerant genotypes, which effectively maintained nutrient concentration could tolerate moisture stress by maintaining nutrient levels within the optimum level. Moisture stress susceptible wheat genotypes showed severe nutrient imbalances like reduced contents of magnesium, manganese, and iron and increased levels of potassium. Moisture stress tolerant performed better most probably due to its capacity to maintain higher relative water content in root and other plant tissues, thus alleviate the ill effect of moisture stress on ion uptake and partitioning.

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