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Screening of wheat (*Triticum aestivum*) varieties tolerant to manganese-deficiency stress

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ABSTRACT

Manganese deficiency is a problem in bread wheat (*Triticum aestivum* L. emend. Fiori & Paol.) production when grown on highly permeable sandy soils cropped with rice (*Oryza sativa* L.) for 5 or more years. The variation in the ability of wheat varieties to maintain yield on soils with limited Mn availability was investigated. A field experiment was conducted during winter season (*rabi*) 1995–96 to study the tolerance of 6 varieties of wheat to manganese stress in a Mn-deficient field containing 2.2 mg DTPA-Mn/kg soil. The treatments included control and 3 foliar sprays of 0.5% manganese sulphate solution. All the varieties responded to foliar application of Mn and the increase in grain yield varied from 0.30 to 0.85 tonnes/ha. The macaroni (*Triticum durum* Desf.) varieties of wheat responded more to Mn (26.4–34.9%) than the *Triticum aestivum* varieties (7.9–23.0%). Based on the increase (%) in grain yield on foliar application of Mn, the varieties were grouped least tolerant ('PBW 34' and 'PDW 215'), moderately tolerant ('PBW 226' and 'PBW 343') and tolerant ('WH 542' and 'HD 2329'). The grain yield was significantly related with both Mn concentration in flag-leaf (r = 0.80*) and Mn uptake (r = 0.92**).

Key words : manganese deficiency, wheat, *Triticum aestivum*, *Triticum durum*, tolerant strains, bread wheat

Bread wheat (*Triticum aestivum* L. emend. Fiori & Paol.) grown in Mn-deficient soils suffers from severe yield loss. The extent of loss varies with the magnitude of manganese deficiency in the soil and the variety used (Nayyar *et al.* 1985, Bansal *et al.* 1991). Manganese deficiency is difficult to manage because the efficiency of soil-applied Mn is very low due to its rapid oxidation. Thus there is demand for very high rates of $MnSO_4$ application to amend its deficiency through soil mode. Although foliar sprays of 0.5–1.0% $MnSO_4$. H_2O solution is efficient in combating Mn deficiency, these have to be repeated 3–4 times. Further, under severe Mn deficiency even foliar application of Mn may prove less efficient if not done at the right time (Takkar *et al. 1986*). Manganese fertilization has become important in controlling Mn deficiency and in increasing production, but it is expensive. Another method of minimizing yield loss caused by Mn deficiency is to grow wheat varieties that are more Mn efficient. Cereals show marked genotypic differences in sensitivity to Mn deficiency (Marcar and Graham 1987, Longnecker *et al.* 1990). Therefore in this work different wheat varieties were tested in the field for their tolerance to Mn-deficiency stress.

MATERIALS AND METHODS

Six varieties of wheat ('PBW 34', ' PDW 215', 'PBW 226', 'PBW 343', 'WH 542' and 'HD 2329') were grown during winter season (*rabi*) of 1995–96 at village Batha Thua, near Ludhiana (30°56 N, 75° 32 E and 247 m above mean sea-level) in a manganese-deficient field. The soil was loamy sand, belonging to great group Ustochrepts. Soil had *p*H 9.1, electrical conductivity 0.40 dS/m at 25°C (1 : 2 soil : water suspension), organic carbon 0.4%, $CaCO_3$ 1.0% and the DTPA-extractable Mn 2.2 mg/kg soil (Lindsay and Norvell 1978).

Each variety was sown in a plot of 5 m x 8 m and received a basal application of N, P and K @ 120, 26 and 25 kg/ha respectively from urea, diammonium phosphate and muriate of potash. Three replications were provided in completely randomized block design. The treatments were control (no Mn treatment) and 3 foliar sprays of 0.5% $MnSO_4$. H_2O unneutralized solution, each spray at a rate equivalent to 0.8 kg Mn/ha. The first spray was given 4 weeks after seeding and the next 2 afterwards at 1-week intervals. The development of Mn deficiency symptoms was recorded at 45 days after seeding. Flag leaves of each variety were sampled at ear emergence and analysed for total Mn, Zn and Fe. The grain and straw-yields were recorded at maturity and the samples were taken for analysis. Plant samples were successively washed with 0.1 N HCl, distilled and deionized water, dried at 70°C and ground in a stainless steel mill to pass through 20-mesh sieve. One gram of oven-dried plant material was digested in a nitric-perchloric-sulphuric acid mixture, and the Mn, Zn and Fe concentration in the digest

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was determined by atomic absorption spectrometer. Total uptake of Mn, Zn and Fe in different wheat varieties was computed.

The varieties were grouped into different Mn-deficiency tolerant classes, based on response (%) to applied Mn, as least tolerant (>25% response), moderately tolerant (10–25% response) and tolerant (<10% response). Several plant parameters were also related to the degree of tolerance of the varieties. These include Mn concentration, Mn uptake, harvest index (grain yield ÷ total yield x 100) and Mn-translocation index (Mn uptake in grain ÷ total Mn uptake x 100).

RESULTS AND DISCUSSION

Growth and deficiency symptoms

The wheat varieties showed different degrees of Mn-deficiency symptom in the Mn-untreated plots. At 45 days of growth, 'PBW 34', 'PDW 215' and 'PBW 226' wheat developed severe symptoms of Mn deficiency , whereas 'PBW 343', 'WH 542' and 'HD 2329' showed mild symptoms. Mild symptoms were manifested in the form of interveinal chlorosis of the middle and lower leaves, starting from the base and extending towards the tip. In the chlorotic region, very small light greyish-yellow to greyish-brown specks appeared. Under severe Mn deficiency,these specks enlarged and coalesced to form a streak between the veins and later became necrotic. The deficient plants had stunted growth and a weak and restricted root system

Yield

The grain yield of all the varieties under Mn stress varied from 2.15 to 4.35 tonnes/ha, with a mean value of 3.50. Alleviation of the stress through foliar spray of Mn increased the crop yield by 2.90–4.95 tonnes/ha (Table 1). All the varieties responded to foliar sprays of Mn and the magnitude of response varied widely (0.30–0.85 tonnes/ha). The *Triticum durum* varieties responded more to Mn (26.4–34.9%) than the *Triticum aestivum* varieties (7.9–23.0%). This showed that the varieties differed appreciably in utilizing the limited supply of Mn available from the soil. This is corroborated by the significant variations in the flag-leaf Mn concentration of different wheat varieties and its positive coefficient of correlation (r = 0.80**) with grain yield. Marcar and Graham (1987) and Bansal *et al.* (1991) reported genotypic variations for Mn tolerance in wheat. Similar trend was observed for straw yield. The straw yield of individual varieties under Mn stress was 4.20–7.50 tonnes/ha compared with 6.10–9.85 tonnes/ha in the Mn-treated plots (Table1). There was a significant increase in straw-yield due to Mn application and the interaction effect between varieties and Mn application was also significant. Nayyar *et al.* (1985) also reported increase (0.2–0.5 tonnes/ha) in wheat-grain yield with Mn application on coarse-textured Mn-deficient soils. Significant response of wheat to Mn application confirms that the crop was suffering from Mn deficiency and the increase in grain yield with Mn application resulted from the increased availability of Mn to plants when fed through foliage, as indicated by Mn concentration in the flag-leaf. Loneragan (1988) also reported that the varieties known to be the most efficient absorbed more Mn. Brown and Jones (1974) showed that some oat (*Avena sativa* L.) genotypes with higher tissue-Mn concentration moved greater tolerance to low Mn in solution culture than the plants with low tissue-Mn concentration.

The grain yield of 'PBW 34', 'PDW 215', 'PBW 226' and 'PBW 343' increased significantly with Mn application, whereas that of 'WH 542' and 'HD 2329' did not increase significantly. The macaroni varieties 'PBW 34' and 'PDW

Table 1 Grain and straw yield of wheat as influenced by Mn application

Variety	Yield (tonnes/ha)						
	Grain				Straw		
	–Mn	+Mn	Mean	Increase (%)	–Mn	+Mn	Mean
Macaroni wheat							
'PBW 34'	2.15	2.90	2.47	34.9	4.20	6.10	5.15
'PDW 215'	2.85	3.60	2.97	26.3	5.80	7.15	6.47
Bread wheat							
'PBW 226'	3.70	4.55	4.12	23.0	6.25	9.85	8.05
'PBW 343'	4.25	4.95	4.60	16.5	7.50	9.55	8.52
'WH 542'	4.35	4.75	4.55	9.2	6.35	6.85	6.60
'HD 2329'	3.80	4.10	3.95	7.9	5.60	6.75	6.17
Mean	3.50	4.14			5.95	7.71	
LSD ($P = 0.05$)	Grain	Straw					
Mean of varieties (V)	0.57	0.81					
Mn rates (Mn)	0.33	0.47					
V x Mn	0.66	1.15					

–Mn, without Mn; + Mn, with Mn

Table 2 Mn, Zn and Fe concentration in flag leaf of wheat varieties as influenced by Mn application

Variety	Micronutrient concentration (ug/g)								
	Mn			Zn			Fe		
	-Mn	+Mn	Mean	-Mn	+Mn	Mean	-Mn	+Mn	Mean
'PBW 34'	7.7	13.2	11.0	34.5	32.5	33.5	75.0	74.0	74.5
'PDW 215'	6.0	12.7	9.4	35.0	40.5	37.8	84.0	80.5	82.3
'PBW 226'	20.2	25.0	22.6	27.0	29.0	28.0	106.5	106.0	106.3
'PBW 343'	17.5	23.7	20.6	24.5	21.5	23.0	78.0	73.5	75.8
'WH 542'	15.5	27.5	21.5	32.5	26.5	29.5	83.0	76.5	79.8
'HD 2329'	16.0	26.5	21.4	35.0	28.0	31.5	90.0	87.5	88.8
Mean	13.8	21.6		31.4	29.5		86.1	83.0	
LSD (*P* = 0.05)			*Mn*	*Zn*	*Fe*				
Means of varieties (V)			2.9	6.1	11.3				
Mn rate means (mn)			1.7	NS	NS				
V x Mn			NS	NS	NS				

Table 3 Mn, Zn and Fe uptake in wheat varieties at maturity as influenced by Mn application

Variety	Micronutrient uptake (g/ha)								
	Mn			Zn			Fe		
	-Mn	+Mn	Mean	-Mn	+Mn	Mean	-Mn	+Mn	Mean
'PBW 34'	72	135	104	158	211	185	680	950	815
'PDW 215'	76	117	97	230	248	239	877	1 070	974
'PBW 226'	130	230	180	330	398	364	1 123	1 633	1 378
'PBW 343'	143	247	195	329	369	349	1 410	1 765	1 588
'WH 542'	124	156	140	356	371	364	1 041	1 116	1 079
'HD 2329'	121	192	157	401	429	415	1 112	1 312	1 213
Mean	111	180		300	337		1 041	1 308	
LSD (*P* = 0.05)			*Mn*	*Zn*	*Fe*				
Means of varieties (V)			31	65	256				
Mn rate means (Mn)			13	37	148				
V x Mn			45	NS	NS				

215' suffered the maximum yield reduction under Mn stress and thus proved least tolerant, whereas 'PBW 226' and 'PBW 343' were categorized moderately tolerant. 'WH 542' and 'HD 2329' showed marked tolerance to Mn deficiency in the soil and did not suffer much loss in yield and were grouped into tolerant category.

Mn concentration and uptake in tissue

Under Mn stress the concentration of Mn in the flag-leaf was 6.0–20.2 ug/g which increased significantly to 12.7–27.5 ug/g with foliar application of Mn, with respective mean values of 13.8 and 21.6 µg/g (Table 2). The Mn concentration in flag leaf of *Triticum durum* varieties was lower (6.0–7.7 µg/g) than in that of *Triticum aestivum* varieties (15.5–20.2 µg/g). There was a non-significant decrease in the concentration of Zn and Fe in the flag-leaf of different wheat varieties with the application of Mn. The concentration of Zn and Fe in the flag-leaf varied significantly among the varieties. The mean concentration of Zn and Fe was 23.0–37.8 ug/g and 74.5–106.3 ug/g respectively (Table 2). The Mn uptake by different varieties showed marked variation. In the absence of applied Mn, it was 72–143 g/ha compared with 117–247 g/ha on application of Mn. There was a significant increase in Mn uptake with its application. The Mn uptake was the lowest in *Triticum durum* varieties compared with *Triticum aestivum* varieties of wheat. Also, there were significant differences in Mn uptake among the varieties. The mean increase in Mn uptake by different varieties also showed marked variations. In the absence of applied Mn, the tolerant varieties had its amount 1.5 times higher than that of the least tolerant varieties. In the Mn-applied plants also, the uptake was significantly lower in the least tolerant varieties compared with the tolerant ones.

The Zn and Fe uptake in different wheat varieties was 158–401 g/ha and 680–1410 g/ha in the control compared with 211–429 g/ha and 950–1765 g/ha, respectively with the foliar application on Mn (Table 3). There was a significant increase in Zn and Fe uptake with the application of Mn. The varieties also differed among themselves in their uptake behaviour of Zn and Fe. Under Mn stress, Zn and Fe uptake was 2.3 and 1.7 times higher in *Triticum aestivum* varieties compared with that in the *Triticum durum* varieties. There are conflicting reports about the effect of Mn on the utilization of Zn by a crop. Ishizuka and Ando (1968) found a decrease in Zn absorption by roots and shoots of rice (*Oryza sativa* L.) with addition of Mn in nutrient solution. However, Singh and Steinberg (1974) in a sand-culture experiment found that the uptake of Zn in maize (*Zea mays* L.) and barley (*Hordeum vulgare* L.) were not affected by Mn application. But Brar and Sekhon (1976) reported a decrease in an absorption with Mn addition to rice. There was decrease in Fe absorption with the increase in Mn application in oat (Singh and Dahiya 1980) and soybean [*Glycine max* (L.) Merr.] (Heenan and Campbell 1983). The concentration of Fe and Mn in wheat leaves in the present study (Table 2) was not significantly affected by Mn application. The observed decrease in Fe and Mn has resulted from the significant increase in biomass production with Mn application.

There was a significant coefficient of correlation between grain yield under Mn stress and Mn uptake ($r = 0.92^{**}$)as well as with harvest index ($r = 0.76$). This indicates that the tolerant varieties have also the ability to distribute Mn in the plant under Mn stress efficiently . The result revealed that among the investigated varieties the *Triticum durum* varieties ('PBW 34' and 'PDW 215') are more susceptible to Mn-deficiency stress compared with the *Triticum aestivum* varieties.

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