Field Crops Research xxx (2013) xxx–xxx

Contents lists available at ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

# Screening diverse wheat genotypes for manganese efficiency based on high yield and uptake efficiency

Shalini Jhanji[a,*], U.S. Sadana[a], N.K. Sekhon[a], M.P.S. Khurana[a], A. Sharma[b], A.K. Shukla[c]

[a] *Department of Soil Science, PAU, Ludhiana 141004, India*
[b] *Department of Plant Breeding and Genetics, PAU, Ludhiana 141004, India*
[c] *Indian Institute of Soil Science, Bhopal 462038, India*

ARTICLE INFO

*Article history:*
Received 17 July 2013
Accepted 17 July 2013

*Keywords:*
Manganese
Wheat
Genotypes
Grain yield
Mn efficiency
Mn efficiency index

ABSTRACT

Manganese deficiency limits wheat production particularly on highly permeable sandy soils cropped with rice. Variation in the ability of genotypes to maintain high yield and Mn uptake on soils with limited Mn availability was investigated to identify Mn efficient genotypes. Twenty four diverse wheat genotypes were evaluated in the field at two Mn levels viz. low (no fertilizer Mn) and high (20 kg Mn $ha^{-1}$ applied as Mn sulphate supplemented with two foliar sprays of 0.5% $MnSO_4$, one at pre flowering and other 7 days post flowering). The grain yield was significantly related with both grain Mn concentration ($r = 0.61$) and uptake ($r = 0.88$). Relative grain yield i.e. Mn efficiency index varied from 75 to 94% and relative grain Mn uptake varied from 42 to 74% among genotypes. Manganese efficiency index and Mn efficiency, respectively explained 86 and 66% of the variation in yield under low Mn. Based on grain yield and Mn efficiency, the genotypes were classified as efficient and responsive (PBW 636, PBW 621, HD 2967, DBW 17, PBW 550, TL 2942, BW 9179, BW 9184, BW 9149, BW 8989, SAMNYT 410 and SAMNYT 413), efficient and non responsive (BW 9183, TL 2908, PBW 590 and BW 9022), inefficient and responsive (PBW 509, PBW 343, GLUPRO 2233 and GLUPRO 2001) and inefficient and non responsive (PDW 233, PDW 291, PDW 314 and BW 9178). The efficient and responsive genotypes are most desirable as they would yield higher under low Mn and respond better to Mn additions.



## 1. Introduction

Green revolution increased food production and reduced starvation and protein malnutrition but at the same time caused greater depletion of micronutrient reserves from the soil. This accentuated wide spread deficiencies of micronutrients in crop plants (Nayyar et al., 2001). Manganese (Mn) deficiency has emerged as a serious nutritional problem of crop plants worldwide (Yang et al., 2007). This deficiency has become a perpetual problem in coarse textured highly permeable alkaline soils of Punjab where rice–wheat rotation has been adopted for the last several years (Nayyar, 1999). Soil submergence during rice cultivation creates reduced conditions that increase the solubility of Mn and facilitate its leaching to deeper soil layers resulting in Mn deficiency in the succeeding wheat crop (Gangoi, 1984). Manganese is an essential micronutrient involved in water splitting reaction of photosynthesis, carbon dioxide assimilation, nitrogen metabolism and key regulator of several enzymatic reactions, thus affecting crop growth and yield (Lidon et al., 2004; Jiang, 2006; Millaleo et al., 2010). Compared to other crops, wheat is very sensitive to Mn deficiency as revealed by its poor growth and large reductions in grain yield (Krahmer and Sattelmacher, 2001; Sadana et al., 2003). It is difficult to correct Mn deficiency by soil application of Mn fertilizers due toits quick conversion to oxidized form that is unavailable to the plants (Reuter et al., 1973). Foliar application of 0.5–1.0% $MnSO_4$ solution is the immediate effective measure to combat Mn deficiency. However, this method is relatively expensive, labor intensive and may prove less effective under severe Mn deficiency and also if not applied timely (Takkar et al., 1986). Growing Mn efficient wheat cultivars could be an effective means to increase yield on soils low in available Mn. Previous studies on screening of wheat varieties for Mn efficiency (Bansal et al., 1991; Bansal and Nayyar, 1998) were based on grain yield i.e. the variety with high yield under deficient conditions was regarded as efficient. Such studies are lacking for current diverse wheat germplasm. The present study was conducted to identify manganese efficient wheat genotypes on a criteria of higher yield as well as higher Mn uptake under Mn deficient conditions so as to assist breeders in incorporating their efficiency characters or genes into high yielding wheat cultivars and improve the malnutrition.

* Corresponding author. Tel.: +91 9872972526.
*E-mail address:* shalini_jhanji@yahoo.com (S. Jhanji).

0378-4290/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.fcr.2013.07.015

**Table 1**
Parentage and seed Mn concentration ($\mu g\,g^{-1}$) of wheat genotypes before sowing.

| Genotype | Parentage | Seed Mn concentration ($\mu g\,g^{-1}$) |
|---|---|---|
| Released cultivars | | |
| PBW 550 | WH 594/RAJ 3856//W 485 | 35.9 ± 0.43 |
| PBW 590 | WH 594/RAJ 3814//W 485 | 32.8 ± 1.39 |
| PBW 509 | W 1634/PBW 381 | 31.9 ± 0.95 |
| DBW 17 | CMH 79 A.95/3 *CNO 79//RAJ 3777 | 29.7 ± 1.24 |
| PDW 291 | BOOMER 21/MOJO 2 | 28.8 ± 0.64 |
| TL 2908 | Tl2732/DT54 | 28.8 ± 0.44 |
| TL 2942 | TL2614/TNIT 141 | 27.6 ± 0.83 |
| PBW 343 | ND/VG 9144//KAL/BB/3/Yaco ‘s’/4/Vee 5[c] | 27.5 ± 0.84 |
| PDW 233 | YAV “S”/TEZ“S” | 27.5 ± 0.81 |
| PDW 314 | Ajaia12/F3local(sel.Ethio.135.85)//Plata13/3/ somat3/4/sooty9/Rascon37 | 26.6 ± 0.88 |
| Advance stable lines | | |
| PBW 636 | KS-IWO49-15-1/GUAMUCHIL/M92//920750-A-11-2-3/HBCO59E/4/PBW552 | 34.2 ± 0.19 |
| GLUPRO2233 | Glupro/3* PBW 571 | 32.2 ± 1.56 |
| SAMNYT 413 | T.dicoccum PI 94625/Ae. Squarossa 372//Tui. | 32.4 ± 0.95 |
| HD 2967 | ALD/COC//URES/HD 216 OM/HD 2278 | 33.1 ± 0.06 |
| SAMNYT 410 | T.dicoccum PI 94625/Ae. Squarossa 373//Tui. | 31.2 ± 0.53 |
| BW 9183 | PBW 343*3/KUKUNA//UP 2632 | 30.4 ± 1.17 |
| BWL 0088 | *Lr 37* rust res., PBW 343*3/KUKUNA//UP 2632 | 29.5 ± 1.21 |
| BW 9022 | C 591/*3 PBW 343 | 30.0 ± 0.61 |
| BWL 0089 | *Lr34*, dur res. INQ 91*3/TUKURU//DBW 18 | 29.2 ± 0.42 |
| PBW 621 | KAUZ/ALTAR84/AOS/3/MILAN/KAUZ/4/HUITES | 29.0 ± 0.58 |
| GLUPRO2001 | Glupro/3* PBW 563 | 29.1 ± 0.45 |
| BW 8989 | C 273/*2 PBW 534 | 27.1 ± 0.64 |
| BW 9178 | INQ 91*3/TUKURU//DBW 18 | 26.7 ± 0.81 |
| BW 9149 | K-S-1 . . . X PBW 562 | 24.3 ± 1.91 |
| SED[a] | 1.299 | |
| LSD[b] | 2.610 | |

[a] Standard error of difference.
[b] Least significant difference at 5%.
[c] $a \pm b$; where $a$ = mean and $b$ = standard error of mean.

## 2. Materials and methods

### 2.1. Experimental design

Field experiment was conducted during Rabi seasons of 2009–2010 and 2010–2011 at the research farm of Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, located at latitude 30°56′ N, longitude 75°32′ and 247 m above sea level, The experimental soil was Mn deficient (DTPA extractable Mn 2.20 mg $kg^{-1}$) Typic Ustrochrept loamy sand having pH 7.1, organic carbon 5.6 g $kg^{-1}$ soil and $CaCO_3$ 3.5 g $kg^{-1}$ soil (Table 1). The experiment was laid out in split plot design with Mn treatments in the main plots and the genotypes in sub plots with three replications. Manganese treatments consisted of two Mn levels viz. low (No fertilizer Mn) and high (20 kg Mn $ha^{-1}$ applied as Mn sulphate supplemented with two foliar sprays of 0.5% $MnSO_4$ at pre flowering and 7 days post flowering stages). Twenty-four diverse wheat genotypes included 5 released cultivars of *Triticum aestivum*, 5 advanced lines of *Triticum aestivum*, 3 released cultivars of *Triticum durum*, 2 released cultivars of *Triticale* and 4 advanced lines derived from wild wheats, with different parentage and seed Mn content (Table 2). The two ploidy levels {*Triticum aestivum* (hexaploid) and *Triticum durum* (tetraploid)} were selected to provide ample opportunity for checking the Mn efficiency as durum is known to be sensitive to nutrient stresses than aestivum. Preliminary studies indicated diversity amongst the selected genotypes for tolerance to abiotic stresses. Recommended levels of nitrogen as urea, phosphorous and potassium as $KH_2PO_4$ were applied at the time of sowing.

### 2.2. Plant sampling and analysis

Crop was harvested at maturity and grain yield (g $m^{-2}$) and grain Mn content ($\mu g\,g^{-1}$) was determined. Grains were dried in an oven at 70 °C to a constant weight and then milled. Ground material was digested with 2:1 mixture of nitric ($HNO_3$) and perchloric acid ($HClO_4$) and analyzed for manganese concentration by atomic absorption spectroscopy (Isaac and Kerber, 1971) using atomic absorption spectrophotometer Model A A 240 F S, Company Varian, Germany. The following parameters were then calculated (Graham, 1984):

$$\text{manganese uptake in grain} = \text{grain yield} \times \text{grain Mn content}$$

$$\text{manganese efficiency index} = \left(\frac{\text{grain yield at low Mn}}{\text{grain yield at high Mn}}\right) \times 100$$

**Table 2**
Physico-chemical characteristics of Mn-deficient soil used for experiment.

| Physico-chemical characteristics | | Value |
|---|---|---|
| Particle density (g $cm^{-3}$) | | 2.58 |
| Bulk density (g $cm^{-3}$) | | 1.52 |
| Textural class | | Loamy sand |
| Sand (%) | | 83.5 |
| Silt (%) | | 5.9 |
| Clay (%) | | 10.6 |
| [a]pH | | 7.1 |
| [a]EC (dS $m^{-1}$) | | 0.2 |
| $CaCO_3$ (g $kg^{-1}$) | | 3.5 |
| Organic carbon (g $kg^{-1}$) | | 5.6 |
| Available NPK (mg $kg^{-1}$ soil) | N | 55 |
| | P | 9.4 |
| | K | 60.7 |
| DTPA-extractable micronutrients (mg $kg^{-1}$ soil) | Zn | 4.6 |
| | Fe | 19.3 |
| | Mn | 2.20 |
| | Cu | 0.96 |

[a] 1:2 soil: water suspension.

Please cite this article in press as: Jhanji, S., et al., Screening diverse wheat genotypes for manganese efficiency based on high yield and uptake efficiency. Field Crops Res. (2013), http://dx.doi.org/10.1016/j.fcr.2013.07.015