International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(1): 398-402

Received: 11-11-2018
Accepted: 14-12-2018

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Screening of bread and durum wheat cultivars for manganese stress tolerance and manganese fractionation in soil

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Abstract
The study was carried out in screen house of Department of Soil Science, CCS HAU, Hisar. The soil selected for study was sand textured soil. 12 prominent varieties of bread wheat and 6 durum wheat varieties were chosen for study. The order of preponderance of fractions of Mn in soil is as Residual > Fe MnOx bound > Carbonate bound > Exchangeable > Organic matter bound Mn. Application of Mn fertilizer lead to increased grain and straw yield. Protein content was also higher in fertilized plant grain as compared to control. Bread wheat varieties were found tolerant, semi-tolerant and sensitive to Mn stress, whereas none of the durum wheat cultivars was resistant to Mn stress.

Keywords: Mn fractions, protein content, grain yield, straw yield

Introduction

Green revolution has helped in increasing the food production, thereby greatly reduced starvation, calories and protein malnutrition. However, this caused greater depletion of micronutrient reserve in soil and thereby accentuated wide spread deficiency of these nutrients. Their deficiencies are causing not only hidden hunger but also leading to failure of crops and lower content of trace elements in plant parts. Manganese (Mn) is one of the main essential micro-nutrients which have an important contribution in crop production. In the recent past its deficiency has become a widespread nutritional disorder of crops in many countries of the world, which often results in decreased crop yields (Sadana *et al.,* 2002) [4]. Plant nutrition is one of the most important problems in crop production which improve agricultural production quality. In many parts of the world, the concentration of micronutrients with special reference to Mn in soil is too low for maximum plant productivity. Manganese is a relatively abundant element, making up about 0.085% of the Earth's crust. It is broadly dispersed throughout soils, sediments, water and biological materials. Mn deficiency is likely to be intensified particularly in light texture soils due to leaching losses and is going to be a major constraint in realising yield potential of high yielding varieties of wheat (Nayyar *et al.,* 1990) [5].

Mn is needed in small amounts for various physiological functions of the human body. Because the body itself cannot make the this nutrient or synthesize it in adequate quantities, humans need to obtain it from foods. Cereal grains are the most important dietary source of micronutrients in many developing countries. Mn concentration and bioavailability in cereal grains is generally low. Cereal crops play an important role in satisfying daily calorie intake in developing world, but are inherently very low in Mn concentrations in grain, particularly when grown on Mn- deficient soils. The rice-wheat cropping system (RWCS) may be age-old practice but its present worth was triggered by the development of high yielding varieties of both the crops.

The transformation of Mn from one chemical form to another with changing soil properties can be studied by using fractionation techniques. The understanding of the distribution of Mn in different fractions is imperative to appreciate their retention in soils and release to plants. Therefore, speciation analysis is very important to separate and to identify specific or binding forms of metals and allows assessing the availability and mobility of metals in order to understand their chemical behavior. Therefore, an attempt was made to study tolerance of different wheat varieties to Mn stress and the distribution of different fractions of Mn.

Materials and Methods

Location of the experimental site: The study was carried out in screen house of Department of Soil Science CCS HAU, HIsar. Soil was collecte from Balsamand village which was sand textured. The initial physic-chemical properties of soil are given in table 1:

Table 1: Initial physico-chemical properties of pot soil (Balsamand soil)

Soil Property	Value
pH	8.30
EC(dS m^{-1})	0.19
OC (%)	0.07
Soil Texture	Sand
Sand (%)	91.30%
Silt (%)	6.15%
Clay (%)	2.55%
$CaCO_3$ (%)	1.60%
Available N (kg ha^{-1})	67.20
Available P (kg ha^{-1})	9.25
Available K (kg ha^{-1})	85.50
DTPA Extractable- Zn (mg kg^{-1})	0.16
DTPA Extractable- Fe (mg kg^{-1})	0.89
DTPA Extractable- Mn (mg kg^{-1})	0.67

Collection and analysis of samples: The soil samples from each pot were taken after harvesting of wheat crop and were mixed thoroughly, air dried in shade and ground to pass through 2 mm sieve and stored in sealed polythene bags for analysis.

The soil samples were used for detecting manganese and its fractions. Fractionation of soil Mn was carried out with standard procedure. DTPA-extractable Mn was determined from 1:2 soil-extractant ratio using DTPA-TEA buffer (0.005 M DTPA+ 0.001 M $CaCl_2$ + 0.1M TEA, pH 7.3) and concentration of Mn was measured on an Atomic Absorption Spectrophotometer(AAS) Varian AA 240FS as suggested by Lindsay and Norvell, (1978) [2]. Grain and straw samples were digested in diacid mixture of nitric and perchloric acid in 4:1 ratio and Mn in digested plant material was determined by AAS. Grain samples were digested in diacid mixture of sulphuric and perchloric acid in 4:1 ratio and nitrogen in digested plant material was determined by colorimetric method using Nessler's reagent (Lindner, 1944) [1]. The protein content (%) in grain was estimated by multiplying the nitrogen content in grain by factor 6.25. After harvesting grain and straw yield was recorded per pot.

Sequential extraction of soil samples for different fractions: The processed soil samples were used for Mn fractionation into different chemical fractions as per sequential procedure described below.

		Soil (1 g)
		↓
Exchangeable Mn	←————————	8 ml 1 M NaOAc (Shake for 1 hr.)
		↓
		Soil
		↓
Carbonate bounded Mn	←————————	8 ml 1 M NaOAc (pH 5.0, CH_3COOH)
		(Shake for 5 hrs.)
		↓
		Soil
		↓
		3 ml 0.02 M HNO_3 + 5 ml H_2O_2 (pH 2)
Organically bounded Mn	←————————	(3 hrs in boiling on water bath. Stir occasionally,
		Repeat extraction)
		↓
		Soil
		↓
Fe-Mn bounded Mn	←————————	20 ml 0.04 M $NH_2OH.HCl$ (25% HOAc)
		(Shake for 30 min.)
		↓
		Soil
Residual bounded Mn	←————————	Conc., HF, conc. $HClO_4$ and conc. HCl in sequence

Fig 1: Sequential fractionation scheme for partitioning Zn in soils (Tessier *et al.*, 1979)

Results and Discussion

The results obtained from the experiment are presented under following heads:

Effect of Mn application on soil Mn fractions

The result obtained from the experiment (Table 2) showed that with foliar application of manganese, manganese fractions in soil increased non-significantly. DTPA extractable Mn increased to 1.48 mg kg^{-1} from 1.37 mg kg^{-1} in control. Exchangeable Mn increased to 0.59 mg kg^{-1} from 0.40 mg kg^{-1} in control. Carbonate bound zinc increased to 1.29, Fe MnOx bound fraction increased to 71.25 mg kg^{-1}, Organic matter bound fraction raised to 0.046 and residual

Mn increased to 166.34 mg kg^{-1} and this fraction recorded highest value. The order of preponderance of different fractions is as Residual > Fe MnOx bound > Carbonate bound > Exchangeable > Organic matter bound Mn.

Table 2: Effect of Mn application on post harvest soil Mn fractions concentration (mg kg^{-1})

Varietal Set of Experiment	DTPA-Mn (mg kg^{-1})	Mn Fraction (mg kg^{-1})				
		Exch-Mn	Carb- Mn	Fe MnOX- Mn	OM- Mn	Res- Mn
Control	1.37	0.40	1.28	71.17	0.045	165.64
Mn	1.48	0.59	1.29	71.25	0.046	166.34
CD (0.05)	NS	NS	NS	NS	NS	NS

Yield of wheat as affected by Mn application

The results obtained from the experiments on wheat for effect of manganese on yield, grain Mn concentration and uptake are presented in table 3. Application of Mn leads to increase in yield, concentration and uptake of Mn in all the cultivars.

Foliar application of $MnSO_4$ resulted in the increase of yield in the range of 7.91% to 48.16% for bread wheat and 15.93% to 51.13% for durum wheat, as compared to that of control. For bread wheat, the maximum increase in yield was found to be 48.16% in the wheat variety RAJ-3765 and the minimum increase in the yield was 7.91% in the wheat variety WH-1080. For durum wheat, the maximum increase in yield was found to be 51.13% in the wheat variety PDW-314 and the minimum increase in the yield was 15.93% in the wheat variety PDW-291.

Mn Concentration and uptake in grain

Increased concentration of manganese was found in the grains harvested from crops treated with 0.5% $MnSO_4$ solution. The increase in concentration was found to be in the range of 34.02% to 58.15% for bread wheat and 36.29% to 46.33% for durum wheat. For bread wheat, the maximum increase in the manganese concentration in grains was found to be 58.15% in the wheat variety WH-283 and the minimum increase was found to be 34.02% in the variety RAJ-3765. For durum wheat, the minimum increase in the manganese concentration in grains was found to be 36.29% in the wheat variety WHD-948 and the maximum increase was found to be 46.33% in the variety PDW-314.

After foliar application $MnSO_4$ the uptake of manganese was found to be increased (Table 3) in all the varieties. The maximum uptake in bread wheat was found to be 591.54µg pot^{-1} for HD-2967 variety of wheat. In case of durum wheat the maximum uptake was found to be 516.10 µg pot^{-1} for WHD-948 variety.

Table 3: Yield of wheat, Mn concentration and uptake in grain as affected by Mn application

Variety	Grain yield (g pot^{-1})		Concentration of Mn in grain (mg kg^{-1})		Uptake (µg pot^{-1})	
	-Mn	+Mn	-Mn	+Mn	-Mn	+Mn
DBW 88	12.82	14.14 (10.30%)	29.35	39.93 (36.05%)	376.27	564.61
WH-147	13.26	14.36 (8.30%)	21.70	30.03 (38.39%)	287.74	431.23
WH-283	13.25	14.83 (11.92%)	20.00	31.63 (58.15%)	265.00	469.07
WH-542	9.94	13.18 (32.60%)	22.35	31.88 (42.64%)	222.16	420.18
WH-711	9.94	12.64 (27.16%)	20.95	30.48 (45.49%)	208.24	385.27
WH-1021	12.08	13.77 (13.99%)	21.75	31.88 (46.57%)	262.74	438.99
WH-1080	13.28	14.33 (7.91%)	28.70	40.83 (42.26%)	381.14	585.09
WH-1105	11.80	13.39 (13.47%)	28.35	40.18 (41.73%)	334.53	538.01
WH-1121	13.08	14.29 (9.25%)	24.20	33.98 (40.41%)	316.54	485.57
WH1142	9.55	10.61 (11.10%)	27.25	38.78 (42.31%)	260.24	411.46
HD-2967	14.37	15.72 (9.39%)	26.85	37.63 (40.15%)	385.83	591.54
RAJ-3765	9.53	14.12 (48.16%)	28.60	38.33 (34.02%)	272.56	541.22
PDW-291	8.85	10.26 (15.93%)	28.35	39.48 (39.26%)	250.90	405.06
PDW-314	8.39	12.68 (51.13%)	25.75	37.68 (46.33%)	216.04	477.78
WH-896	8.14	10.69 (31.33%)	26.80	38.28 (42.84%)	218.15	409.21
WH-912	8.25	11.88 (44%)	26.30	36.63 (39.28%)	216.98	435.16
WHD-943	7.75	11.52 (48.64%)	28.95	40.63 (40.35%)	224.36	468.06
WHD-948	6.82	10.24 (50.14%)	28.60	38.98 (36.29%)	195.05	516.10

Straw yield of wheat as affected by manganese application

The results obtained from the experiments on wheat for effect of manganese on straw yield, Mn concentration and uptake are presented in table 4. Application of Mn lead to increase in straw yield, concentration and uptake of Mn in all the cultivars.

Foliar application of $MnSO_4$ resulted in the increase of straw yield in the range of 7.99% to 44.93% for bread wheat and 16.44% to 93.65% for durum wheat, as compared to that of control. For bread wheat, the maximum increase in straw yield was found to be 44.93% in the wheat variety RAJ-3765 and the minimum increase in the yield was 7.99% in the wheat variety WH-1080. For durum wheat, the maximum increase in straw yield was found to be 93.65% in the wheat variety WHD-948 and the minimum increase in the yield was 16.44% in the wheat variety PDW-291.

Mn concentration and uptake in straw

Mn concentration and uptake by different wheat cultivars is presented in table 4. Increased concentration of manganese was found in the straw harvested from crops treated with 0.5% $MnSO_4$ solution. The increase in concentration was found to be in the range of 28.69% to 44.68% for bread wheat and 28.93% to 37.87% for durum wheat. For bread wheat, the maximum increase in the manganese concentration in straw was found to be 44.68% in the wheat variety WH-283 and the minimum increase was found to be 28.69% in the variety DBW-88. For durum wheat, the minimum increase in the manganese concentration in straw was found to be 28.93% in the wheat variety WHD-948 and the maximum increase was found to be 37.87% in the variety PDW-314.

After $MnSO_4$ solution application the uptake of manganese was found to be increased in all the varieties. The maximum uptake in bread wheat was found to be 823.21 µg pot^{-1} for WH-1080 variety of wheat. In case of durum wheat the maximum uptake was found to be 713.05 µg $pot^{-1}$for WHD-948 variety.

Table 4: Straw yield of wheat, Mn concentration and uptake in strawas affected by Mn application

Variety	Straw yield (g pot^{-1})		Concentration(mg kg^{-1})		Uptake (µg pot^{-1})	
	-Mn	+Mn	-Mn	+Mn	-Mn	+Mn
DBW-88	15.88	17.56 (10.58%)	34.75	44.72 (28.69%)	551.83	785.28
WH-147	16.30	17.83 (9.39%)	26.85	35.02 (30.43%)	437.66	624.41
WH-283	16.37	18.25 (11.48%)	25.00	36.17 (44.68%)	409.25	660.10
WH-542	12.50	16.32 (30.56%)	26.95	36.57 (35.69%)	336.88	596.82
WH-711	12.44	15.71 (26.29%)	25.50	35.82 (40.47%)	317.22	562.73
WH-1021	14.92	17.05 (14.28%)	26.45	36.57 (38.26%)	394.63	623.52
WH-1080	16.51	17.83 (7.99%)	33.40	46.17 (38.23%)	551.43	823.21
WH-1105	14.65	16.68 (13.86%)	32.85	45.02 (37.05%)	481.25	750.93
WH-1121	16.18	17.75 (9.70%)	29.75	38.52 (29.48%)	481.36	683.73
WH-1142	11.83	13.27 (12.17%)	31.90	43.42 (36.11%)	377.38	576.18
HD-2967	17.86	19.49 (9.13%)	32.25	42.07 (30.45%)	575.99	819.94
RAJ-3765	12.13	17.58 (44.93%)	32.75	43.32 (32.27%)	397.26	761.57
PDW-291	11.01	12.82 (16.44%)	33.60	44.97 (33.84%)	369.94	576.52
PDW-314	10.52	15.77 (49.90%)	30.95	42.67 (37.87%)	325.59	672.91
WH-896	10.24	13.36 (30.47%)	32.15	42.82 (33.19%)	329.22	572.08
WH-912	10.36	14.80 (42.86%)	30.95	41.17 (33.02%)	320.64	609.32
WHD-943	9.57	14.36 (50.05%)	33.25	45.17 (35.85%)	318.20	648.64
WHD-948	8.50	16.46 (93.65%)	33.60	43.32 (28.93%)	285.60	713.05

Protein content

All the treatments showed the increase in the protein content compared to the control as presented in table 5.

Manganese treatments resulted in the protein content ranging from 6.46% to 8.21% for bread wheat and 6.55% to 8.41% for durum wheat which were better than that of control. In case of bread wheat, maximum protein content was found to be 8.21% in the wheat variety DBW-88 and the minimum protein content was 6.46% in the variety WH-147 (The values were higher as compared to control). For durum wheat, maximum protein content was found to be 8.41% in the wheat variety WHD-943 and the minimum protein content was 6.55% in the variety WH-896 (The values were higher as compared to control).

Table 5: Protein content in different wheat cultivars as affected by Mn application

Variety	Protein content	
	Control	Mn @ 0.5% foliar spray
DBW-88	8.11	8.21
WH-147	6.36	6.46
WH-283	6.45	6.65
WH-542	6.94	7.04
WH-711	6.45	6.55
WH-1021	6.65	6.75
WH-1080	7.33	7.53
WH-1105	7.53	7.72
WH-1121	7.04	7.14
WH-1142	7.72	7.92
HD-2967	7.82	7.72
RAJ-3765	7.72	7.82
PDW-291	8.21	8.31
PDW-314	7.72	7.92
WH-896	6.45	6.55
WH-912	7.82	8.02
WHD-943	8.11	8.41
WHD-948	7.92	8.11
CD (0.05)	NS	NS

Relative response of wheat varieties to Mn application

Results on response of wheat cultivars are presented in table 6. For bread wheat, four varieties were found to be tolerant category i.e. the percentage increase in yield was less than 10%. The minimum increase in yield was found to be 7.91% in the wheat variety WH-1080 and the maximum increase was of 9.39% in the wheat variety HD-2967. Five other varieties of bread wheat were found to be semi tolerant i.e. the percentage increase in yield was in the category of 10-25%. The minimum increase in yield was found to be 10.30% in the wheat variety DBW-88 and the maximum increase was of 13.99% in the wheat variety WH-1021. Rest three varieties of bread wheat were found to be susceptible i.e. the percentage increase in yield was more than 25%. The minimum increase

in yield was found to be 27.16% in the wheat variety WH-711 and the maximum increase was of 48.10% in the wheat variety RAJ-3765.
For durum wheat, five varieties were found to be susceptible i.e. the percentage increase in yield was more than 25%. The minimum increase in yield was found to be 31.33% in the wheat variety WH-896 and the maximum increase was of 51.13% in the wheat variety PDW-314. One variety of durum wheat fell in the semi tolerant i.e. the percentage increase in yield was in the category of 10-25%. The wheat variety PDW-291 showed the increase of 15.93% in the yield.

Table 6: Relative response of wheat varieties to Mn application

Increase in yield category		
<10% (Tolerant)	**10-25% (Semi tolerant)**	**>25% (Susceptible)**
Wheat Varieties		
WH-147 (8.30%)	DBW-88 (10.30%)	WH-542 (32.60%)
WH-1080 (7.91%)	WH-283 (11.92%)	WH-711 (27.16%)
WH-1121 (9.25%)	WH-1021 (13.99%)	RAJ-3765 (48.10)
HD-2967 (9.39%)	WH-1105 (13.47%)	-
-	WH-1142 (11.10%)	-
Durum Wheat Varieties		
-	PDW-291 (15.93%)	PDW-314 (51.13%)
-	-	WH-896 (31.33%)
-	-	WH-912 (44%)
-	-	WHD-943 (48.64%)
-	-	WHD-948 (50.14%)

Conclusion

Based on experimental findings it is concluded that different fractions of soil Mn are in dynamic equilibrium with each other. The order of preponderance of Mn fractions is as Residual > Fe MnOx bound > Carbonate bound > Exchangeable > Organic matter bound Mn. Application of Mn fertilizer lead to increased protein content. Different cultivars showed their own level of tolerance to Mn stress. For bread wheat, four varieties were found to be tolerant category, five were semi tolerant and remaining three were sensitive to strees. In durum wheat one variety was found semi tolerant and five were sensitive to Mn stress.

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