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Production potential and nutrient uptake of wheat (*Triticum aestivum*) as affected by organic sources of nutrients and micronutrients

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ABSTRACT

A field experiment was conducted during *rabi* season of 2005-06 and 2006-07 to study the effect of micronutrients and FYM on growth, yield and nutrient uptake by wheat (*Triticum aestivum* L.) in Gangetic alluvial soil of Uttar Pradesh. The experiment was laid out in split plot design with three replications. Wheat crop recorded significantly higher value of growth, yield attributes (effective tillers/m^2, spike length, grains/spike and 1 000 grain weight), yields, benefit: cost ratio and nutrient accumulation under integrated source of nutrients than inorganic fertilizer alone. Maximum grain yield (4.45 tonnes/ha) was recorded with Zn @ 5 kg/ha + FYM @ 10 tonnes/ha + RFD, which was about 36.01% more than the grain yield obtained from application of 2.5 kg Zn /ha + recommended fertilizer dose. There was significant improvement in yield attributes, yields and nutrient uptake due to foliar treatment of micronutrients (Fe and Mn).

Key words : Economics, FYM, Net return, Nutrient, RFD, Wheat, Yield

In high input agriculture, deficiency of micronutrients has become major constraint to productivity, stability and sustainability of soils (Kumar *et al*. 2011). These deficiencies appeared much faster primarily due to the fast adoption of new agricultural technology, including cultivation of high yielding crop varieties, increase in cropping intensity, expansion of irrigation facilities, more use of high analysis fertilizers and poor quality irrigation water. Among micronutrients, Zn is now being regarded as the third most limiting nutrient element in crop production after N and P (Gupta *et al*. 1994). The extent of Fe deficiency in India is next to the Zn (Malewar and Ismail 1995). About 11% of Indian soils are deficient in iron and recently Mn has become critical (Singh 1999). Cereal crops are inherently very low in grain Zn and Fe concentrations and growing them on potentially Zn and Fe-deficient soils further reduces Fe and Zn concentrations in grain (Cakmak *et al*. 2010). Wheat grains are comparatively better source of protein consumed in India. Organic source of plant nutrients helps in increasing soil organic matter and improving soil environments as well as meeting a part of nutrients need of crops. Organic manures are also helpful in alleviating the increasing incidence or deficiency of secondary and micronutrients and are capable of sustaining crop productivity (Yadav *et al*. 2013). Zn, Fe and Mn plays very important role in photosynthesis and growth of plants.

Cultivars with higher Fe and Mn content produced more vigorous plant and yields more than cultivars with a lower content. To obtain high yields without deterioration of soil fertility, it is important to work out optimal combination of fertilizers and manures in the cropping system (Pullicinoa *et al.* 2009). Under progressively increasing cropping intensity the emerging deficiencies of Fe, Zn and Mn, the biofortification of cereal crops with Zn, Mn and Fe is a high-priority global issue. Keeping these in view, the present study was undertaken to evaluate the performance of inorganic fertilizers (high analysis) in combination with FYM and micronutrients (Zn, Fe and Mn) on growth, yield attributes, yield and nutrient accumulation by wheat crop.

MATERIALS AND METHODS

A field experiment was conducted during the winter seasons of 2005-06 and 2006-07 at Agriculture Research Farm of Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, UP, India. Average rainfall during the period of investigation was 721.5 mm, of which maximum was received in the month of August. Maximum temperature of 44.1°C during the experimentation was recorded in the month of June, whereas minimum temperature was 7.4°C in the month of December. Average relative humidity ranged

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between 79 and 49 per cent. Maximum relative humidity was 92 per cent in July and the minimum 14 per cent in April. Average duration of bright sunshine in the period of investigation was 7.5 hour ranging from 9.5 to 1.9 hours. The soil was Gangetic alluvial (ustochrept) in texture having pH of 8.1. It was moderately fertile being low in organic carbon 0.45%, available nitrogen 202.03 kg/ha, zinc 0.53 mg/kg, iron 9.56 mg/kg and manganese 3.40 mg/kg and medium in available phosphorus 22.02 kg P/ha and available potassium 228.13 kg K/ha. pH was determined in a 1 : 2.5 soil-water suspension (Jackson 1973), organic carbon (OC) following Walkley and Black (1934) available N by the alkaline potassium permanganate method (Subbiah and Asajia 1956) available P by the 0.5 M $NaHCO_3$ Extractable Olsen Colorimetric method (1954) and available K by flame Photometer (Ammonium acetate extract) (Jackson 1973) and available micronutrients (Zn, Mn and Fe) by extraction with DTPA solution (Lindsay and Norvell 1978). Nutrient uptake was computed by multiplying the nutrient content in grain and straw with their respective dry weights (kg/ha).The experiment was laid out in split-plot design with three replications. Main-plot treatments consisted of two zinc levels (2.5 kg Zn/ha and 5 kg Zn/ha) with or without two FYM levels (5 tonnes FYM/ha and 10 tonnes FYM/ha) along with RFD, treatment combinations were six, viz. 2.5 kg Zn/ha + RFD, 5 kg Zn/ha + RFD, 2.5 kg Zn/ha + 5 tonnes FYM/ha + RFD, 2.5 kg Zn/ha + 10 tonnes FYM/ha + RFD, 5 kg Zn/ ha + 5 tonne FYM/ha + RFD and 5 kg Zn/ ha + 10 ton FYM/ ha + RFD and five foliar treatments of micronutrients, viz. 1% $FeSO_4$, 2% $FeSO_4$, 0.5% $MnSO_4$, 1% $MnSO_4$ and control (water as foliar spray) in sub-plot. Chemical analysis of FYM before basal application showed that FYM contained 0.9-.99% N, 0.25-0.30% P, 0.45-0.49% K, Fe 134-138 mg/ kg, Zn 22-25 mg/kg and Mn 70-72 mg/kg. Nutrients were applied as per treatment, nutrient source were di-ammonium phosphate, urea, muriate of potash, $ZnSO_4$, $FeSO_4$ and $MnSO_4$. FYM was applied in the field 15 days before of sowing, however 50% N and full amount of P, K and Zn were applied at the time of sowing. Remaining N was applied in two equal splits as top dressing, first at 30 days after sowing (DAS) and second at 60 DAS. Two foliar fertilizations of Fe and Mn were done at 30 DAS and 60 DAS in respective treatments. Other crop management practices were followed as per the recommendation of the area. Crop response to the treatments was measured in terms of various quantitative and qualitative indices. The plant samples (grain and straw) were collected per treatment at harvest. Samples were ground in a Willey mill, after drying in an oven at 60 ± 5°C for 48 hours. The ground plant material was passed through a 30 mesh sieve and used for determination of micronutrient concentrations. Similarly plant uptake of nutrients N, P, K, Zn, Mn and Fe were also estimated. All observations for each character were subjected to statistical analysis according to the standard method (Panse and Sukhatme 1978). The calculated values of the treatments and error variance ratio were compared with Fisher and Yates F table at 5% level of significance. The differences between significant treatments means were tested against CD at 5 per cent probability.

RESULTS AND DISCUSSION

Growth and yield attributes

Different combination of nutrient sources and its application expressed significant effect on plant height, effective tillers/m^2, spike length, grains/spike, and 1000 grain weight at harvest (Table 1). Combined application of recommended dose of fertilizer (RFD) + 5 kg Zn/ha + 10 tonnes FYM/ha recorded highest value for growth and yield attributing parameters followed by RFD + 2.5 kg Zn/ha + 10 tonnes FYM/ha. Similar findings were reported by Ram and Mir (2006).This might be due to higher availability of applied nutrients and improved physical properties of soil which favors better environment for plant growth along with balanced nutrition and improving the efficiency of chemical fertilizers. The margin of difference with respect to crop growth between different fertility levels was less during initial growth stage and then increased markedly during advanced stage of growth (Fig 1). It can be attributed to slow mineralization of organic matter at initial stage of crop growth. Data showed that with increasing levels of Zn (2.5 to 5 kg/ ha) plant height increases, because of its critical role in important enzyme systems including carbonic anhydrase which play role in transport of CO_2 in photosynthesis (Srivastava and Gupta 1996). Combined application of RFD + FYM + Zn produced higher growth and yield attributes. The results are in close agreement with the observation of Parihar *et al*. (2005). The stimulating effect of zinc on the vegetative growth coupled with its probable influence on the reproductive parts may provide an explanation on its effect on the yield components and also Zn is known to decrease the carbohydrate content of leaves and stem during spike formation, which apparently facilitates the flow of carbohydrates to reproductive organs and contributed to improved grain yield (Hemantaranjan and Garg 1988).

Growth (plant height, dry matter accumulation) and yield attributing parameter (effective tillers/m^2, ear head length, grain/ ear head, test weight) of wheat improved significantly with successively increasing Mn and Fe levels up to 1 and 2% as foliar spray, respectively (Table 1). This might be due to the foliar application of highly reactive micronutrients (Fe and Mn), may cause efficient phloem transport which resulted increase in its availability and consequently uptake to the plants. Similar observation were also reported by Soni *et al.* (1996); Singh and Choudhary (2002); Kulandaivel *et al.* (2004). The highest value of growth and yield attributes were recorded due to application of 2% $FeSO_4$ followed by 1% $MnSO_4$. Iron along with molybdenum, is an element of nitrite and nitrate reductase enzymes which

Table 1 Effect of different treatments on growth, yield and yield attributes of wheat (data pooled over two years)

Treatment	Plant height (cm)	Dry matter accumulation (g/m row length)	No. of effective tillers/m 2	Spike length (cm)	Grains/ spike	Test weight (g)	Grain yield (tonnes/ha)	Straw yield (tonnes/ha)	Benefit: Cost Ratio
Zn and FYM Levels									
RFD + 2.5 kg Zn/ha	81.55	241.86	492.88	8.35	31.53	30.17	3.27	3.93	1.72
RFD + 5 kg Zn/ha	85.12	254.38	505.51	8.75	34.11	31.37	3.51	4.16	1.87
RFD + 2.5 kg Zn/ha +5 tonnes FYM/ha	92.57	274.67	558.44	9.43	36.43	34.13	3.87	4.45	2.00
RFD + 5 kg Zn/ha +5 tonnes FYM/ha	93.46	280.85	564.99	9.52	36.09	34.23	3.94	4.53	2.02
RFD + 2.5 kg Zn +10 tonnes FYM/ha	96.14	290.97	583.47	9.73	36.96	35.34	4.35	4.88	2.22
RFD + 5 kg Zn +10 tonnes FYM/ha	98.08	301.05	604.33	9.99	40.00	35.87	4.45	4.95	2.25
SEM ±	3.32	10.02	20.12	0.34	1.35	1.22	0.14	0.16	0.08
CD (P = 0.05)	10.46	31.58	63.40	1.06	4.25	3.84	0.46	0.52	0.24
Micronutrient treatments									
1% $FeSO_4$ foliar application	92.19	277.90	558.13	9.40	35.96	33.86	3.92	4.53	2.03
2% $FeSO_4$ foliar application	94.06	282.69	572.18	9.59	41.77	35.47	4.19	4.65	2.21
0.5% $MnSO_4$ foliar application	91.55	276.48	552.51	9.33	33.61	33.28	3.78	4.49	1.94
1% $MnSO_4$ foliar application	92.88	278.31	562.62	9.46	37.77	34.46	4.03	4.55	2.10
Water foliar application	85.10	254.45	512.57	8.71	30.17	30.52	3.58	4.20	1.79
SEM ±	1.99	5.99	12.06	0.20	0.78	0.73	0.09	0.10	0.04
CD (P = 0.05)	5.66	17.00	34.26	0.58	2.21	2.08	0.24	0.28	0.12

* RFD (120, 60, 60 NPK kg/ha respectively)

is essential for growth and development of plants. Application of Mn also showed positive effect since Mn might enhance chlorophyll content, photosynthetic efficiency and ultimately plant height and yield attributes (Liu *et al.* 2005, Habib 2009).

Grain and straw yield

Combined application of RFD + 5 kg Zn/ha + 10 tonnes FYM/ha recorded (Table 1) significantly higher grain (4.45 tonnes/ha) and straw (4.95 tonnes/ ha) yield followed by application of 2.5 kg Zn/ha + 10 tonnes FYM/ha along with RFD. This may be attributed to the increased in plant growth and yield attributing characters owing to increased nutrient availability to crop through improved soil fertility. The stimulating effect of zinc on the vegetative growth coupled with its probable influence on the reproductive parts may provide an explanation on its effect on the yield components. Zn is known to decrease the carbohydrate content of leaves and stem during spike formation, which apparently facilitates the flow of carbohydrates to reproductive organs and contributed to improved grain yield (Hemantaranjan and Garg 1988).

Effect of foliar fertilization of micronutrients (Mn and Fe) on grain and straw yields of wheat was significant and increased with increasing concentration of micronutrients in foliar fertilization (2% $FeSO_4$ > 1% $MnSO_4$ > 1% Fe SO_4 > 0.5% Mn SO_4). This has been due to better availability of nutrients due to balanced fertilization produced vigorous seedling having more plant growth and yield attributing characters which resulted higher yield (Table 1). These results were in accordance with Soni *et al.* (1996); Singh and Choudhary (2002); Kulandaivel *et al.* (2004). Amongst the different foliar treatments application of Fe in 2% concentration proved superior, perhaps because of its availability and translocation into the plants in required amount. Performance of nutrient treatments in terms of grain and straw yields followed the order of 2% $FeSO_4$ > 1% $MnSO_4$ > 1% Fe SO_4 > 0.5% Mn SO_4. The treatment, however, exhibited statistical parity with each-other.

Uptake of N, P, K, Zn, Mn and Fe in grain and straw

Uptake of N, P, K, Zn, Mn and Fe in grain and straw of wheat were increased with corresponding increase in fertility levels (Table 2 and 3). The maximum uptake of all these nutrients in the wheat grain and straw were recorded when nutrients were applied with highest fertility levels, i.e. RFD +5 kg/ Zn ha + 10 tonnes FYM/ha. Increase in uptake in these nutrients may be due to the increase in fertility

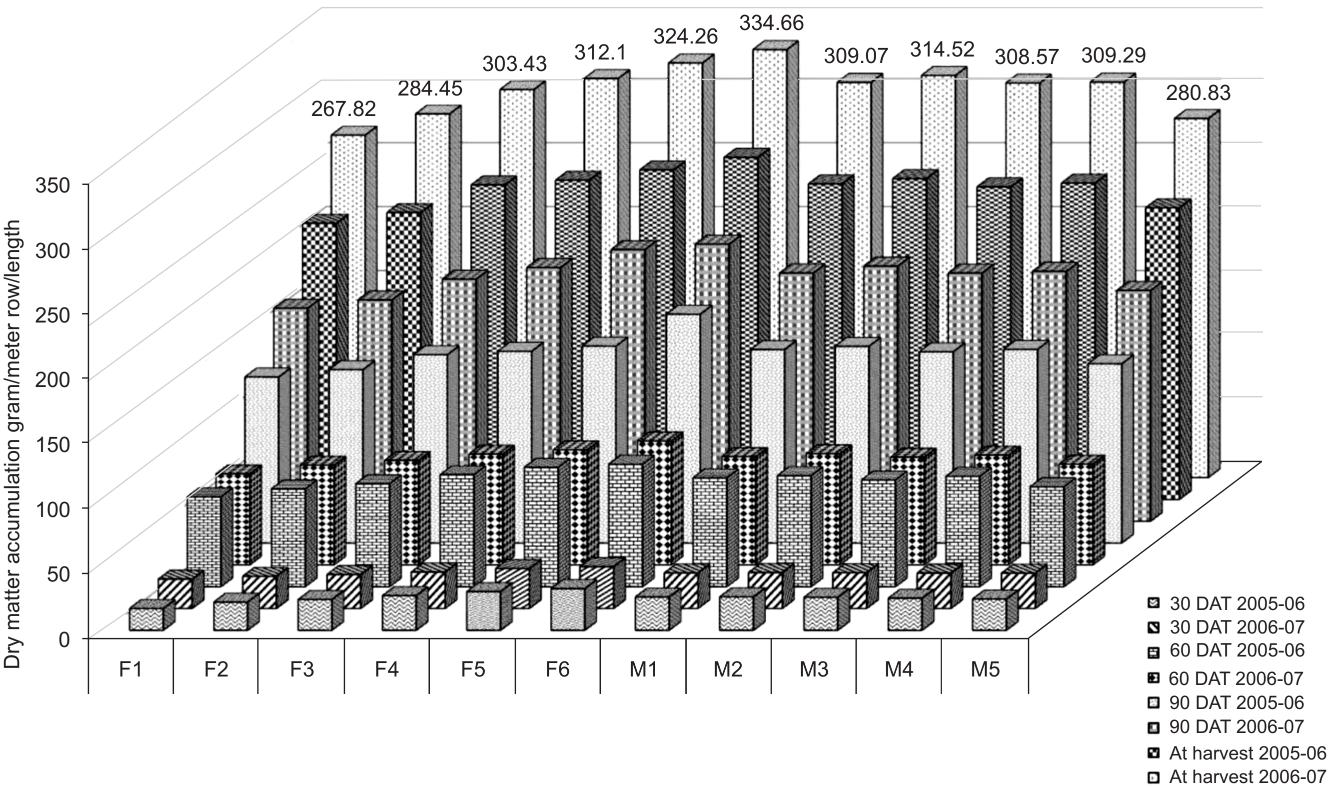

Fig 1 Effect of Zn, Mn and Fe fertilizers with FYM levels on dry matter accumulation of wheat at different growth stages.

Table 2 Effect of different treatments on N, P and K uptake (kg/ha) by wheat (data pooled over two years).

Treatment	Nitrogen uptake (kg/ha)		Phosphorus uptake (kg/ha)		Potassium uptake (kg/ha)	
	Grain	Straw	Grain	Straw	Grain	Straw
Zn and FYM Levels						
RFD + 2.5 kg Zn/ ha	54.59	18.35	11.09	2.60	13.56	41.61
RFD + 5 kg Zn/ha	63.80	19.89	12.19	2.95	15.84	47.38
RFD + 2.5 kg Zn/ha + 5 tonnes FYM/ha	74.40	23.94	14.98	3.38	19.32	57.70
RFD + 5 kg Zn/ha +5 tonnes FYM/ ha	77.71	24.40	15.50	3.52	20.62	61.22
RFD + 2.5 kg Zn +10 tonnes FYM/ ha	86.98	27.03	17.27	3.83	24.23	70.58
RFD + 5 kg Zn +10 tonnes FYM ha	90.36	28.32	17.97	3.95	25.56	73.62
SEM ±	5.78	1.81	1.15	0.26	1.56	4.56
CD (P = 0.05)	18.20	5.71	3.61	0.81	4.92	14.36
Micronutrient treatments						
1% $FeSO_4$ foliar application	75.69	24.15	15.11	3.45	20.23	60.44
2% $FeSO_4$ foliar application	82.97	25.37	16.45	3.62	22.06	62.88
0.5% $MnSO_4$ foliar application	72.32	23.74	14.36	3.38	19.26	57.69
1% $MnSO_4$ foliar application	78.30	24.33	15.56	3.47	20.84	61.22
Water foliar application	63.94	20.68	12.68	2.96	16.88	51.19
SEM ±	3.28	1.04	0.65	0.15	0.88	2.59
CD (P = 0.05)	9.31	2.94	1.85	0.42	2.49	7.35

RFD: 120N+ $60P_2O_5$+$60K_2O$

Table 3 Effect of different treatments on Zn, Mn and Fe uptake (g/ha) by wheat (data pooled over two years)

Treatment	Zinc uptake (g/ha)		Manganese uptake (g/ha)		Iron uptake (g/ha)	
	Grain	Straw	Grain	Straw	Grain	Straw
Zn and FYM Levels						
RFD + 2.5 kg Zn/ha	105.89	53.46	80.15	62.31	167.21	294.85
RFD + 5 kg Zn/ha	124.46	61.68	89.63	67.90	185.63	338.52
RFD + 2.5 kg Zn/ha +5 tonnes FYM/ha	149.79	69.71	108.11	83.71	226.18	399.16
RFD + 5 kg Zn/ha +5 tonnes FYM/ha	157.80	70.83	113.74	87.94	242.35	427.08
RFD + 2.5 kg Zn +10 tonnes FYM/ha	175.11	77.83	131.95	99.17	284.69	490.48
RFD + 5 kg Zn +10 tonnes FYM ha	183.53	82.41	146.84	108.83	328.14	547.07
SEM ±	11.58	5.31	8.78	6.58	19.19	32.83
CD (P = 0.05)	36.48	16.74	27.68	20.74	60.45	103.43
Micronutrient treatments						
1% $FeSO_4$ foliar application	150.94	70.62	110.48	85.16	252.82	443.37
2% $FeSO_4$ foliar application	168.71	74.80	120.63	88.33	278.70	465.39
0.5% $MnSO_4$ foliar application	143.80	69.14	113.63	88.35	225.14	396.53
1% $MnSO_4$ foliar application	157.51	71.87	124.31	92.39	251.19	433.18
Water foliar application	126.19	60.17	89.64	70.65	187.33	342.48
SEM ±	6.60	3.03	4.93	3.76	10.58	18.40
CD (P = 0.05)	18.73	8.61	14.00	10.66	30.03	52.26

RFD: 120N+ $60P_2O_5$+$60K_2O$

levels attributed to the better availability of nutrients and their transport to the plant from the soil. Similar results have been reported by Parihar *et al.* (2005), Gupta and Handore (2009) and Khan *et al.* (2009). The beneficial effect of application of higher amounts of organic manure or FYM are not only favored the greater availability of nutrients throughout crop growth, fertilization into different stages resulting in significant improvement in nutrient content and uptake. This result corroborates the finding of Ghuman and Sorc (2006) and Zhang *et al.* (2010). Since uptake of nutrient is a function of concentration of nutrient and yield/ha, at higher fertility levels, nutrient absorption increased resulting in a luxuriant growth and accumulation of more nutrients in the grain and straw that might have increased the uptake of nitrogen, phosphorus, potassium, zinc, manganese and iron. Higher concentration of Fe in soil solution could be attributed to the formation of complexes of Fe^{++} with organic acids produced during degradation of FYM along with sharp decrease in pH. This might be the main reason behind the higher production of grain and straw yield with maximum nutrient uptake in the crop (Yadav 2008).

Significant improvement in nitrogen, phosphorus potassium, zinc, iron and manganese uptake by wheat grain and straw when foliar application of Mn and Fe made. The maximum nutrient uptake were recorded from 2% $FeSO_4$ followed by 1% $MnSO_4$ foliar application. This was due to the vital physiological role of Fe and Mn in plant cells, which promotes uptake of plant nutrients (Abd El-Hady 2007) and increased supply of nutrients, which enhanced proliferation of root essential for further more uptakes of nutrients (Abbas *et al.*2009).

Economics

Amongst the different combination of nutrient sources, higher mean benefit: cost ratio of 2.25 was recorded from RFD +5 kg/Zn ha + 10 tonnes FYM/ha, followed by RFD +2.5 kg/Zn ha + 10 tonnes FYM/ha. The yield advantages through application of FYM was found to be more than proportionate increase in cost of cultivation, which were at par and statistically superior over treatments with FYM and inorganic treatments (Table 1). In micronutrients foliar treatments, 2% $FeSO_4$ and 1% $MnSO_4$ gave maximum benefit: cost ratio of 2.21 and 2.10, respectively.

Hence, it may be concluded that conjoint use of RFD + Zn + 10 tonnes FYM along with foliar application of micronutrient (2% $FeSO_4$ and 1% $MnSO_4$) is capable of sustaining higher wheat productivity, improving nutrient acquisition and profitability on long term basis.

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