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**Research Paper**

# Effect of zinc and magnesium nutrition on yield, quality and removal of nutrients in wheat (*Triticum aestivum*)

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## ABSTRACT

A field experiment was conducted during the winter (*rabi*) season of 2008–10 on alluvial soil of Bichpuri, Agra, to study the effects of Zn (0, 2.5, 5.0 and 10 kg/ha) and magnesium (0, 10, 20 and 40 kg/ha) on wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] in respect of yield, quality and uptake of nutrients. Application of Zn up to 5 kg/ ha increased the grain and straw yield by 9.7 and 11.5% over the control, respectively. Application of 5 kg Zn/ ha also recorded the highest values of net returns (₹70.2 × $10^3$/ha) and benefit: cost ratio (2.74). The addition of Mg up to 20 kg/ha enhanced the mean grain (5.11 t/ha) and straw (6.13 t/ha) yield significantly over the control. The highest net returns (₹68.4 × $10^3$/ha) and benefit: cost ratio (2.70) were recorded at 20 kg Mg/ha. The interaction effect between Zn and Mg significantly and synergistically influenced the yields, being highest at 5 kg Zn in conjunction with 20 kg Mg/ha. The removal of Zn by grain and straw increased from 152.8 to 202.5 and 129.5 to 182.5 g/ ha with the increase in Zn levels. The removal of Mg by grain and straw also increased significantly with the levels of Mg from 11.4 to 15.6 and 7.8 to 12.1 kg/ha, respectively. On the other hand, Zn and Mg showed antagonistic effect on their removal by wheat. The removal of N, P and K increased up to 5 kg Zn and 20 kg Mg /ha level. Protein content and yield also increased significantly with the increase of Zn and Mg over the control. The values of efficiency indices decreased with increasing levels of Mg and Zn.

***Key words*:** Alluvial soil, Cereal production, Magnesium, Nutrient uptake, Protein, Wheat, Yield, Zinc

Wheat is the most important staple food-grain crop in Indian diet and main source of protein and calories for a large section of population. Stagnation in wheat production, lower productivity and inferior quality of the produce is due to various constraints including inadequate and imbalanced nutrient application. In India the prominent wheat-growing areas are in arid and semi-arid regions having sandy-loam soils which are low in organic carbon and prone to be deficient in Mg and Zn. Magnesium deficiency has been aggravated in the soil due to its continuous removal under intensive cropping. Among the micronutrients, zinc has received the maximum attention in soil and crop research with special reference to wheat. Zinc is now considered an important yield-raising input, which in principle and practice is a part of balanced fertilizer use. Being an essential constituent of ribosomes, it is associated with the activity of tryptophane synthates enzymes also. Magnesium is popularly known as secondary nutrient because of its lesser requirement than primary nutrients and is a constituent of chlorophyll, essential for photosynthesis. Magnesium is also an activator of many enzymes and takes part in protein synthesis. It increases resistance to harmful environmental influence such as drought and diseases. Singh and Pathak (2002) and Srivastava *et al*. (2006) reported positive effect of Mg addition on wheat and rice crop, respectively. Zinc mainly functions as metal component of a series of enzymes. Low Zn content in grain and straw results in poor Zn nutrition of human beings and animal, which has recently received considerable attention (Cakmak, 2008) Moreover, the effects of Zn and Mg have not been studied extensively, particularly in wheat crop in light-textured soils of Agra. Keeping in these facts in view, the present study was carried out to assess the effects of Zn and Mg on yield quality and removal of nutrients in wheat on alluvial soil of Agra region, Uttar Pradesh.

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## MATERIALS AND METHODS

The field experiment was conducted during the winter seasons of 2008–09 and 2009–10 at the research farm, Raja Balwant Singh College, Bichpuri, Agra, Uttar Pradesh. The soil was sandy loam, having pH (7.8), electrical conductivity (EC) (0.29 dS/m), organic carbon (0.36%), available N (160 kg/ha), P (9.7 kg/ha), K (110 kg/ha), DTPA-extractable Zn (0.51 ppm) and exchangeable Mg (available) 1.65 cmol (p+)/kg soil. The field trial consisting of 4 levels of Zn (0, 2.5, 5.0 and 10 kg/ha) and 4 levels of Mg (0, 10, 20 and 40 kg/ha) was a factorial experiment laid out in a randomized complete-block design with 3 replications. A common dose of nitrogen, $P_2O_5$ and $K_2O$ @ 150, 60 and 40 kg/ha was applied through urea, diammonium phosphate and muriate of potash respectively. Half of nitrogen and full dose of P and K were applied as basal dressing at sowing and rest half of nitrogen was top-dressed at the time of first irrigation at the crown-root-initiation stage of the crop. Zinc and magnesium were applied through zinc sulphate and magnesium sulphate as per treatments. Wheat 'PBW 343' was sown in rows, 20.0 cm apart using 100 kg seed/ha in first week of November during both the years. Other agronomic management practices were followed as per standard recommendation. The crop was harvested at maturity and grain and straw yields were recorded. Grain and straw samples were digested with diacid mixture of $HNO_3$ and $HClO_4$ in 9:1 ratio. Phosphorus was determined by vanado molybdo phosphoric acid yellow colour method (Jackson, 1973), K by flame photometer, Zn by atomic absorption spectrophotometer and Mg by magnesium ammonium phosphate method (Chapman and Pratt, 1961). Nitrogen in grain and straw was determined by modified micro-Kjeldahl method (Jackson, 1973) and then the N content obtained was multiplied by the factor 6.25 to obtain protein content. The nutrient removal was calculated by multiplying the concentration values with their respective grain and straw yields data.

## RESULTS AND DISCUSSION

### *Grain and straw yield*

Grain and straw yields increased with the increase in Zn level up to 5.0 kg Zn/ha (Table 1). On an average, the highest grain yield at 5.0 kg Zn/ha was 9.6% higher than the lowest grain yield in the control. But reduction in grain yield was recorded at higher levels of Zn (10 kg/ha) compared to 5 kg Zn/ha. Likewise, on an average, the highest straw yield at 5.0 kg Zn/ha was 11.5% higher than the lowest straw yield in the control. The response of crop to applied zinc in present study is obvious, as the soil under study was deficient in DTPA-Zn (0.51 ppm). Singh *et al*. (2004) reported positive response of crop to applied Zn in the Zn-deficient soil. Our finding support the results of Sahay *et al*. (2009) and Khare and Dixit (2011). Magnesium application significantly increased grain and straw yield up to 20 kg Mg/ha, and thereafter the yield decreased at 40.0 kg Mg/ha (Table 1). On an average, the highest and lowest grain yields were recorded under 20 kg Mg/ha and control respectively. Similar trend was recorded for straw yield. Thus, magnitude of crop response to Zn application was higher to Mg. The increase in grain and straw yield because of Mg might be attributed to low availability in experimental soils which responded to the Mg application. Besides, Mg is the chief constituent of chlorophyll which resulted in the formation of carbohydrate in the leaves and thereby ultimately enhancing the yield. Singh and Pathak (2002) reported a significant response of crops to magnesium.

**Table 1.** Effect of zinc and magnesium levels on yield and economics of wheat (mean data of 2 years)

| Treatment | Yield (t/ha) | | Protein in grain (%) | Protein yield (kg/ha) | Net returns (× $10^3$ ₹/ha) | Benefit: cost ratio |
|---|---|---|---|---|---|---|
| | Grain | Straw | | | | |
| *Zinc (kg/ha)* | | | | | | |
| 0 | 4.77 | 5.68 | 13.25 | 633.5 | 63.9 | 2.42 |
| 2.5 | 5.00 | 6.00 | 13.35 | 668.5 | 67.0 | 2.58 |
| 5.0 | 5.23 | 6.33 | 13.45 | 703.3 | 70.2 | 2.74 |
| 10.0 | 5.03 | 5.99 | 13.50 | 680.3 | 67.4 | 2.57 |
| SEm± | 0.04 | 0.05 | 0.05 | 4.93 | | |
| CD (P=0.05) | 0.11 | 0.14 | 0.14 | 14.21 | | |
| *Magnesium (kg/ha)* | | | | | | |
| 0 | 4.92 | 5.93 | 13.05 | 648.0 | 66.3 | 2.67 |
| 10 | 5.02 | 6.01 | 13.30 | 668.6 | 67.2 | 2.56 |
| 20 | 5.11 | 6.13 | 13.45 | 689.4 | 68.5 | 2.70 |
| 40 | 4.96 | 5.94 | 13.70 | 679.6 | 66.4 | 2.37 |
| SEm± | 0.04 | 0.05 | 0.05 | 4.93 | | |
| CD (P=0.05) | 0.11 | 0.14 | 0.14 | 14.21 | | |

### *Interaction*

The interaction of Zn and Mg was significant in grain and straw and highest grain and straw yields were recorded by the treatment combination of 5 kg Zn and 20 kg Mg/ha (Table 2).The highest levels of zinc (10 kg/ha) and Mg (40 kg/ha) could not improve the grain and straw yield of wheat over 5 kg Zn + 20 kg Mg/ha, showing an antagonistic effect of these elements at higher level on wheat production.

### *Economics*

The monetary advantage (Table 1) based on mean of 2 years of experimentation indicated that the maximum net returns and benefit: cost ratio were obtained with higher dose of 20 kg Mg/ha and 5 kg Zn/ha. This was owing to higher grain yield obtained by the application of 20 kg Mg/ha and 5 kg Zn/ha. Singh *et al*. (2004) and Srivastava *et al.* (2006) reported similar results with Zn and Mg application.

### *Quality*

Increasing levels of Zn and Mg significantly increased the protein content in wheat grain from 13.25 to 13.50 and 13.05 to 13.70% with 10 kg Zn and 40 kg Mg/ha respectively. The increase in protein content owing to zinc addition might be attributed to its involvement in the N metabolism. Magnesium serves as a structural component in ribosomes and appears to stabilize the ribosomal particles in the configuration necessary for protein synthesis. It activates the formation of polypeptide chain from amino acids. These factors probably caused an increase in protein content in grain (Desh Bandhu *et al.* 2003; Singh and Pathak 2002). Corresponding application of Zn and Mg also increased the protein yield from 633.5 to 703.3 and 648.0 to 689.4 kg/ha respectively. These increases in protein yield were up to 5 kg Zn and 20 kg Mg/ha and then decreased at higher levels of Zn and Mg. Srivastava *et al*. (2006) and Khare and Dixit (2011) also reported a positive response of Mg and Zn on protein content respectively.

### *Nutrients uptake*

Increasing levels of Zn progressively enhanced the removal of N by wheat grain and straw from 101.3 to 112.5 kg/ha and from 31.0 to 36.5 kg/ha respectively. This increase in N removal was due to increase in N content and grain and straw yield with Zn application. This increase was noted up to the level of 5 kg Zn/ha and then decreased at higher level (10 kg/ha) of zinc. Magnesium application up to the level of 40 kg/ ha increased the N removal by wheat grain and straw which ranged from 104.0 to 108.5 and 30.9 to 35.1 kg/ha. However, both the higher levels (20 and 40 kg/ ha) of Mg were statistically at par for N removal by wheat grain and straw. Data (Table 3) revealed that the magnesium levels had significant beneficial effect on the removal of P by grain and straw which were increased from 13.6 to 16.4 and 7.2 to 10.1 kg/ha respectively with 40 kg Mg/ ha. The effect of Mg application in improving P removal was associated with increased grain and straw production. The lower level of zinc increased the P removal by the crop over the control. However, a reduction in P removal was noted with 10 kg Zn/ha, indicating an antagonistic effect on P absorption at higher level of zinc. Singh *et al.* (2004) also reported similar results. The removal of K by both grain and straw was in accordance with yield at different Mg and Zn levels and accordingly the highest K removal of 29.9 kg/ha in grain and 120.6 kg/ha in straw was recorded at 5 kg Zn/ha. The highest K removal of 28.4 and 114.8 kg/ha in grain and straw, on an average, were found at 20 kg Mg/ha, respectively. The increase in K uptake with 20 kg Mg/ha corroborated the findings of Singh and Pathak (2002). The removal of Zn in both grain and straw was in accordance with yield of wheat at different Zn levels, and accordingly the highest Zn uptake of 202.5 g Zn/ha in grain and 182.5 g Zn/ha in straw, was recorded at 10.0 kg Zn/ha. Magnesium application decreased the Zn removal by wheat grain and straw from 181.7 to 176.5 and 177.1 to 157.6 g/ha with 40 kg Mg/ha. However, the lower level of Mg could not decrease the Zn removal by wheat crop significantly

**Table 2.** Effect of zinc and magnesium interaction on grain and straw yields of wheat (mean data of 2 years)

| Zinc (kg/ha) | Magnesium (kg/ha) | | | | Magnesium (kg/ha) | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 10 | 20 | 40 | 0 | 10 | 20 | 40 |
| | *Grain yield (t/ha)* | | | | *Straw yield (t/ha)* | | | |
| 0 | 4.64 | 4.90 | 4.81 | 4.73 | 5.52 | 5.83 | 5.73 | 5.63 |
| 2.5 | 4.87 | 5.01 | 5.16 | 4.89 | 5.84 | 6.09 | 6.19 | 5.87 |
| 5.0 | 5.25 | 5.14 | 5.54 | 5.16 | 6.36 | 6.22 | 6.52 | 6.24 |
| 10.0 | 5.04 | 4.95 | 5.08 | 5.06 | 6.00 | 5.90 | 6.04 | 6.02 |
| SEm± | | 0.08 | | | | 0.10 | | |
| CD (P=0.05) | | 0.22 | | | | 0.29 | | |

**Table 3.** Effect of zinc and magnesium levels on removal of nutrients by wheat (mean data of 2 years)

| Treatment | Nitrogen(kg/ha) | | Phosphorus(kg/ha) | | Potassium(kg/ha) | | Zinc(g/ha) | | Magnesium(kg/ha) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Grain | Straw | Grain | Straw | Grain | Straw | Grain | Straw | Grain | Straw |
| *Zinc (kg/ha)* | | | | | | | | | | |
| 0 | 101.3 | 31.0 | 14.8 | 8.7 | 26.3 | 106.5 | 152.8 | 129.5 | 13.8 | 10.4 |
| 2.5 | 107.0 | 33.2 | 15.2 | 8.6 | 27.9 | 113.4 | 171.2 | 180.0 | 13.9 | 10.6 |
| 5.0 | 112.5 | 36.5 | 15.5 | 8.7 | 29.9 | 120.6 | 197.1 | 180.0 | 14.0 | 10.5 |
| 10.0 | 108.9 | 34.0 | 14.8 | 8.2 | 27.7 | 112.2 | 202.5 | 182.5 | 13.3 | 9.5 |
| SEm± | 1.01 | 0.57 | 0.66 | 0.41 | 0.28 | 0.36 | 1.18 | 0.99 | 0.29 | 0.33 |
| CD (P=0.05) | 2.94 | 1.65 | NS | NS | 0.81 | 1.01 | 3.43 | 2.87 | NS | NS |
| *Magnesium (kg/ha)* | | | | | | | | | | |
| 0 | 104.0 | 30.9 | 13.6 | 7.2 | 28.2 | 112.9 | 181.7 | 177.1 | 11.4 | 7.8 |
| 10 | 108.6 | 33.2 | 14.4 | 7.7 | 28.4 | 114.0 | 184.2 | 172.3 | 13.0 | 9.6 |
| 20 | 108.2 | 34.5 | 15.9 | 9.4 | 28.2 | 114.8 | 180.9 | 165.0 | 14.8 | 11.6 |
| 40 | 108.5 | 35.1 | 16.4 | 10.1 | 26.8 | 110.5 | 176.5 | 157.6 | 15.6 | 12.1 |
| SEm± | 1.01 | 0.57 | 0.66 | 0.41 | 0.28 | 0.36 | 1.18 | 0.99 | 0.29 | 0.33 |
| CD (P=0.05) | 2.94 | 1.65 | 1.91 | 1.91 | 0.81 | 1.01 | 3.43 | 2.87 | 0.83 | 0.96 |

over the control. The reduction in Zn removal at higher levels of Mg might be due to antagonism between Mg and Zn. The values of Mg removal at different levels of Mg in grain as well as straw resembled with the yield and Mg content. The lowest Mg removal of 11.4 kg/ha in grain and 7.8 kg/ha in straw were reported in control. On the other hand, the highest Mg removal of 15.6 kg/ha in grain and 12.1 kg/ha in straw was recorded at 40 kg Mg/ha. Singh and Pathak (2002) also reported an increase in Mg removal with its addition. Magnesium removal by wheat grain and straw slightly increased up to 5 kg/ha followed by a reduction at higher level (10 kg/ha) of zinc. This decrease in Mg removal at higher dose of Zn might be attributed to restricted translocation of Mg from roots, as both the ions compete for the same absorption sites due to same charge and ionic radii (Shukla, 1986).

**Table 4.** Effect of magnesium and zinc levels on apparent recovery and agronomic efficiency in wheat (mean data of 2 years)

| Treatment | Apparent Mg recovery (%) | Apparent Zn recovery (%) | Agronomic efficiency (kg grain/ kg nutrient) |
|---|---|---|---|
| *Zinc (kg/ha)* | | | |
| 0 | – | – | – |
| 2.5 | 4.0 | 0.74 | 90.0 |
| 5.0 | 4.0 | 0.88 | 92.2 |
| 10.0 | 0.1 | 0.50 | 26.3 |
| *Magnesium (kg/ha)* | | | |
| 0 | – | – | – |
| 10 | 16.0 | 0.03 | 9.8 |
| 20 | 17.0 | 0.02 | 9.5 |
| 40 | 10.5 | 0.01 | 1.0 |

### *Agronomic efficiency*

Agronomic-use efficiency of Zn and Mg were highest at 2.5 kg Zn and 10 kg Mg/ha respectively, and progressively decreased with increasing levels of Zn and Mg. Agronomic efficiency of Zn in wheat declined from 90.0 to 26.3 when the levels of Zn increased from 2.5 to 10 kg Zn/ha. Similarly, agronomic efficiency of Mg fertilization decreased from 9.8 to 1.0 when the level of Mg fertilization was increased from 10 to 40 kg Mg/ha. Recovery efficiency of Zn in wheat was the highest with 5 kg Zn/ha and 10 kg Mg/ha, respectively and lowest at 10 kg Zn/ha and 40 kg Mg/ ha. Apparent Mg recovery was highest at 20 kg Mg/ha and 2.5 kg Zn /ha.

It may be concluded that in light textured soils deficient in Zn and Mg, Zn and Mg fertilization are required to harvest optimum crop yield, quality and nutrient removal by wheat. Application of 5 kg Zn and 20 kg Mg/ha would be required for maintaining higher wheat yields. This also helps in improving grain quality (protein content) and removal of nutrients in wheat crop.

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