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Effect of INM on nutrient concentration and their uptake of maize (*Zea mays*) crop in central Uttar Pradesh

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Abstract
A field experiment was conducted at field no. 6 Student's Instructural Farm at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur during the *Kharif* season 2017 to find out integrated nutrient management effect on maize with ten treatments i.e. T_1 (125% RDN), T_2 (100% RDN), T_3 (100% RDN + 25% N FYM), T_4 (100% RDN + 25% N FYM + S_{30}), T_5 (100% RDN + 25% N FYM + S_{30} + Zn_5), T_6 (75% RDN), T_7 (75% RDN + 25% N FYM), T_8 (75% RDN + 25% N FYM + S_{30}), T_9 (75% RDN + FYM + S_{30} + Zn_5), T_{10} (Control) in RBD with 3 replications. Maize variety Azad Uttam was taken for study. The results revealed that the N, P, K, S and Zn content in maize grain varies from 1.12 to 1.44%, 0.26-0.37%, 0.32-0.44%, 0.28-0.39% and 22.20-31.80% mg/kg and the N, P, K, S and Zn content of maize stalk varies from 0.34 to 0.55%, 0.110 to 0.142, 1.02 to 1.19%, 0.20 to 0.33% and 14.20-22.80 mg/kg respectively. The total uptake values of N, P, K, S and Zn varied from 43.27 to 107.58 kg/ha, 11.47 to 26.95 kg/ha, 67.19 to 132.11 kg/ha, 17.24 to 46.07 kg/ha and 1268.24 to 3355.10 g/ha. The maximum nutrient concentration and uptakes in case of all treatments was found in T_5 (100% RDN + 25% N FYM + S_{30} + Zn_5) and lowest in T_{10} (Control).

Keywords: *Zea mays*, nutrient concentration, uptake, azad uttam, FYM, grain, stalk

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crop, next to rice and wheat and is used as a food for human and feed for animals. This crop has been developed into a multi dollar business in countries *viz*. Thiland, Tiwan, Singapore, Malaysia, USA, Canada and Germany, because of its potential as a value added product for export and a good food substitute. In India maize is primarily a *kharif* crop which is sown just before monsoon starts. This crop usually grows well under temperatures varying from 22 ºC to 30 ºC, although it can tolerate temperatures as high 35 ºC. This crop is affected by frost, so it is grown where at least 5 frost free months are available in the year. It requires at least 50 to 90 mm of rainfall. It is not recommended to cultivate this crop in the areas where rainfall is more than 100 mm. Maize or corn can be cultivated successfully in variety of soils ranging from clay loam to sandy loam to black cotton soil. For better yield of maize, soils should consider good organic matter content having high water holding capacity. Well drained soils with pH of 5.5 to 7.0 are preferred for maize farming. Maize is grown in an area of 9.76 million hectares with production of 26.14 million tonnes and productivity of 2629.28 kg ha^{-1} (Government of India, 2017). Maize yield is generally higher in high solar intensities, lower night temperature and lower pest infestation. Optimum plant density leads to better utilization of solar radiation resulting into corn dry matter accumulation and biomass production. Uttar Pradesh is the major producing state contributes 60 percent area and 70 percent of maize production in India.

Abbasi *et al.* (2010) [1] reported the highest uptake of N, P and K by maize crop with application of 90 kg N through urea + 30 kg N through PM ha^{-1} as against 52.5 kg N, 33.5 kg P and 11.5 kg ha^{-1} K uptake in control.

Chesti *et al.*, (2015) [2] observed that the three years of conjoint use of 10 t FYM ha^{-1} with 100% NPK significantly higher total NPK uptake by rice 96.3, 20.4 and 109.5 kg ha^{-1}, respectively the application of 100% NPK+10 t FYM ha^{-1} as compared to the total NPK uptake 86.5, 18.1 and 96.8 kg ha^{-1}, respectively with the 100% NPK alone.

Gundlur *et al.*, (2015) [3] state that application of inorganic fertilizers with different sources of organic manures in different proportions has significant role to boost crop productivity, improve nutrient uptake by plants and maintain soil nutrient status in maize based cropping systems.

Kumar (2008) [7] reported that application of 40, 80 and 120 kg N ha^{-1} tended to increase nitrogen uptake by popcorn by 46.5, 78 and 99 percent, respectively over control.

Kumar and Singh (2010) [6] found the DTPA-extractable Zn which was higher in the treatment combination of 100% NPK + 10 kg Zn ha^{-1}. They concluded that integrated application of 100% NPK + green gram + 5.0 t FYM was the most effective treatment in meeting the micronutrient requirements of rice crop.

Kumar *et al.* (2007) [5] reported that application of 100 percent RDF recorded significantly higher dry matter production in leaf, stem, cob, yield and yield attributes and uptake of the nitrogen, phosphorus, potassium and also higher net returns (Rs.20,898 ha^{-1}) and B:C ratio (2.14) over 50% RDF and it was found to be on par with 75% RDF.

Laxminarayana (2006) [8] recorded the maximum total uptake of nitrogen, phosphorus and potassium with the value of 73.27, 21.93 and 87.86 kg ha^{-1}, respectively by rice in treatment where 50% NPK along with 50% N through green manure was applied in *Kharif.*

Laxminarayana and Patiram (2006) [8] revealed that application of optimum doses of NPK in combination with green manure @ 5 t ha^{-1} recorded highest uptake of N, P and K followed by 100 per cent NPK + poultry manure and 100 per cent NPK + FYM. However, the uptake responses were high with the balanced application of NPK in comparison to sub optimal and super optimal doses of NPK an Ultisol.

Makinde and Ayoola (2010) [10] reported significantly higher NPK uptake by maize crop with application of 70 kg N and 13 kg P_2O_5 ha^{-1}.

Meena *et al.* (2006) [12] reported that N uptake by maize significantly increased up to 100 per cent recommended dose of fertilizer which was higher by 18.0 and 19.5 per cent over 75 and 50 per cent dose of fertilizer, respectively.

Ramesh *et al.* (2008) [13] reported that chemical fertilizer treatment recorded significantly the highest total nitrogen and potassium uptake (332.2 and 343.6 kg ha^{-1}) which was on par with poultry manure application (294.1 and 319.7 kg ha^{-1}, respectively) in maize- linseed cropping system.

Roul and Sarawgi (2005) [14] revealed that recommended dose of N (RDN) blended with FYM and 100% RDN + 5 tons of FYM are better in respect of grain yield, straw yield and N-content in grain than other treatments on pooled data basis.

Setia and Sharma (2007) [16] reported that phosphorus uptake by grain (10.4 kg ha^{-1}) and stover (13.0 kg ha^{-1}) in maize was highest when N, P and K were applied @ 180:35:33 kg ha^{-1} as compared to lower doses of fertilizers.

Sujatha *et al.* (2008) [18] reported that maximum uptake of N, P and K by maize crop to the extent of 241.1,35.2 and 234.2 kg ha^{-1}, respectively was observed with application of sunhemp green manure + poultry manure + 100% RDN over control.

Thavaprakash and Velayudham, (2007) [19] conducted on the effect of integrated nutrient management practices on nutrient uptake revealed that the nutrient removal by maize under combined application of FYM, inorganic fertilizers and bio fertilizer as Azospirillum registered higher NPK uptake over (150 + 60 + 40 kg ha^{-1} NPK) recommended dose of fertilizer.

Varalakshmi *et al.* (2005) [20] reported increase in organic carbon content of sandy clay loam soil from 8.1 g kg^{-1} to 8.5 g kg^{-1} after finger millet crop without addition of any fertilizers which was comparatively lower than integrated application of 50 per cent nitrogen through fertilizer and 50 per cent through FYM (9.2 g kg^{-1}).

Materials and Methods

The experiment was conducted on Maize during *kharif* season of 2017 under natural condition at field no. 6 Student's Instructural Farm at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. The soil of the experimental field was alluvial in origin. Soil sample (0-15cm) depths were initially drawn from randomly selected parts of the field before sowing. The quantity of soil sample was reduced to about 500gm through quartering technique. The soil sample was then subjected to mechanical and chemical analysis in order to determine the textural class and fertility status the soils were sampled to a depth of 0-30 cm of the soil, air-dried and sieved (2 mm) for soil analyses. Some physical and chemical properties of soils are given in Table 1.

Table 1: Some properties of the <2mm fraction of the top 30 cm of soil used for the site.

S. No	Particulars	Values
A.	**Mechanical separates**	
1.	Sand (%)	59.6
2.	Silt (%)	17.4
3.	Clay (%)	23.00
4.	Textural Class	Sandy loam
B.	**Physico-chemical properties**	
5.	pH (1:2.5)	8.2
6.	EC (1:2.5) (dS/m at 25 °C)	0.20
7.	Organic Carbon (%)	0.36
8.	Available Nitrogen (kg/ha)	190.00
9.	Available Phosphorus (kg/ha)	13.50
10.	Available Potassium (kg/ha)	182
11.	Available Sulphur (kg/ha)	15.80
12.	Available Zinc (ppm)	0.56
13.	Particle Density (Mg/m^3)	2.54
14.	Bulk Density (Mg/m^3)	1.30
15.	Pore Space (%)	46.0

Maize variety Azad Uttam was taken for study. In the present experiment 10 treatments T_1 (125% RDN), T_2 (100% RDN), T_3 (100% RDN + 25% N FYM), T_4 (100% RDN + 25% N FYM + S_{30}), T_5 (100% RDN + 25% N FYM + S_{30} + Zn_5), T_6 (75% RDN), T_7 (75% RDN + 25% N FYM), T_8 (75% RDN + 25% N FYM + S_{30}), T_9 (75% RDN + FYM + S_{30} + Zn_5), T_{10} (Control)were laid out in Randomized Block Design(RBD) with three replications having plot size 5 x 4 meter square. Doses of fertilizers are applied @ 120 Kg N, 60 Kg P_2O_5, 40 Kg K_2O/ha 30 Kg S/ha, 5 Kg Zn/ha and Organic manure 60 tonne/ha through Urea, D.A.P and Murate of Potash, Elemental sulphur, Zinc oxide and Farm Yard Manure. Sowing is done @ 20 kg seed ha^{-1} maize variety Azad Uttam was used and sown on 22 June 2017. Row to row and plant to plant distance remain 60 and 20 respectively. Seed were sown about 5-6 cm depth.

Field Preparation: The experimental field was ploughed once with soil turning plough fallowed by two cross harrowing. After each operation, planking was done to level the field and to obtain the fine tilth. Finally layout was done and plots were demarked with small sticks and rope with the help of mannual labour in each block.

Application of fertilizers: The crop was fertilized as per treatment. The recommended dose of nutrient i.e. N, P, and K was applied @ 120: 60: 40 kg ha^{-1} respectively.

Time and method of fertilizer: Half does N_2 and total phosphorus, potash, zinc and sulphur were applied as basal dressing. Remaining dose of nitrogen was applied through top dressing after knee-high stage. Well decompose FYM applied @ 60 t ha^{-1} 15 day after sowing.

Seed Treatment: To ensure the seeds free from seed borne diseases, seeds were treated with thiram 75% WDP (1.5g/kg of seed).

Seed and sowing: 20 kg seed ha^{-1} maize variety Azad Uttam was used and sown on 22 June 2017. Row to row and plant to plant distance remain 60 and 20 respectively. Seed were sown about 5-6 cm depth.

Intercultural operations: Weeding and hoeing were done with khurpi and hand hoe after germination.

Irrigation: Tube-well was the source of irrigation. Irrigation was provided in the crop as and when required.

Harvesting: The crop was harvested at proper stage of maturity as determined by visual observations. Half meter length on either end of each plot and two border rose from each side as border were first removed from the field to avoid error. The crop in net plot was harvested for calculation on yield data. Produce was tied in bundles and weighted for biomass yield. Threshing of produce of each net crop was done by manually.

Soil Analysis

Mechanical Separates: Soil separates analyzed by International pipette method as described by the Piper (1966).

pH: pH of the soil determined by using soil water suspension (1:2.5) with the help of digital pH meter.

EC: EC also determined using soil water suspension (1:2.5) with help of conductivity meter (Jackson, 1967).

Organic Carbon: Organic Carbon was determined by Walkley and Black's rapid titration method as described by Jackson (1967).

Available Nitrogen: It was determined by Alkaline Potassium Permagnate Method described by Subbiah and Asija (1956).

Available Phosphorus: It is determined by Olsen's method using 0.5 M NaHCO3 (Olsen *et al*. 1954).

Available Potassium: Potassium is determined by using Neutral Normal Ammonium Acetate (pH 7.0) by Flame Photometer.

Available Sulphur: Available Sulphur was determined by turbidimetric method (Chesnin and Yien, 1950) after extraction with 0.15% $CaCl_2$ solution.

Available Zinc: Available Zn is determined by Atomic Absorption Spectrophotometer with the help of DTPA extractant (Lindsey and Norvell, 1978).

Plant Analysis

Plant samples were dried first in air then kept in oven at 70 °C for 8hr to make the sample free from excess moisture. The samples were grounded in a Wiley mill having stainless parts and stored in polythene bags.

Preparation of extract: Fine ground plant samples were digested in triacid mixture of conc. Nitric acid, sulphuric acid and perchloric acid for P and K determination in 10:4:1 ratio. Diacids (9:4mixture of HNO3 and $HClO_4$) digesion method is adopted for Zn extraction.

Determination of N, P, K, S and Zn in plant:

I. **Nitrogen:** N is determined by Kjeldahl method given by Jackson (1967).
II. **Phosphorus:** P is determined colorimetrically by vanadate-molybdate yellow colour method as advocated by Chapman and Pratt (1961).
III. **Potassium:** K determination has been done using flame photometric method (Chapman and Pratt, 1961) outlined by Jackson (1967).
IV. **Sulphur:** S is determined through turbidimetric method (Chesnin and Yien, 1956).
V. **Zinc:** Zn is extracted from plant with the help of atomic absorption spectrophotometer (Lindasey and Norwell, 1978).

Uptake

To calculate the uptake of N, P, K and S in grain as well as in straw, the following formula is used-

$$\text{Uptake of Nutrients (kg/ha)} = \frac{\text{Nutrient content(\%)} \times \text{Yield(kg/ha)}}{100}$$

Statistical Analysis: The data on various characters studied during the course of investigation were statistically analyzed for randomized block design. Wherever treatment differences were significant ("F" test), critical differences were worked out at five per cent probability level. The data obtained during the study were subjected to statistical analysis using the methods advocated by Chandel (1990).

Results

Effect of INM on Nutrient Concentration

Nitrogen concentration

Grain

Data pertaining to N concentration in grain given in table 4.6 and figure 4.6 showed significant increase in all the treatment in comparison to it respective control. N concentration in grain varied from 1.22% (control) to 1.44% in T_5 (100% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}). Variation in N concentration within 75% RDN, 100% RDN and 125% RDN was noted significant. Integration of S, FYM and Zn influenced N concentration when applied with 75% RDN and 100% RDN treatment. It was also observed that integration of S showed higher increase in N concentration over Zn and FYM at 75% RDN and 100% RDN levels.

Table 4.6: Effect of Integrated Nutrient Management on N content (%) in grain and stalk.

S. No	Treatments	N content (%) in grain	N content (%) in stalk
1.	T_1	1.34	0.46
2.	T_2	1.30	0.42
3.	T_3	1.32	0.45
4.	T_4	1.38	0.51
5.	T_5	1.44	0.58
6.	T_6	1.26	0.38
7.	T_7	1.28	0.40
8.	T_8	1.36	0.49
9.	T_9	1.40	0.54
10.	T_{10}	1.22	0.34
S.E ±		0.018	0.026
C. D. (at 5%)		0.052	0.077

Stalk

The data in regard to N concentration in stalk given in table 4.6 and figure 4.6 showed linear and significant increase in all the treatments over control. Maximum N concentration in stalk was (0.58%) was noted with T_5 (100% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) followed by (0.54%) with T_9 (75% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) and minimum (0.34%) at control (T_{10}). Variation in N concentration within 75% RDN, 100% RDN and 125% RDN was recorded non-significant. Integration of S influenced N concentration higher in comparison to FYM and Zn when applied with 75% RDN and 100% RDN treatments.

Phosphorus concentration

Grain

Data pertaining to P concentration in grain given in table 4.7 and figure 4.7 revealed that P accumulation in grain influenced significantly in all the treatment over control. P concentration in grain varied from 0.25% to 0.37% lowest at control (T_{10}) and maximum at T_5 (100% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) respectively. Integration of S, Zn and FYM showed slight increase when applied with 100% RDN and 75% RDN treatments. Variation in P concentration within 75% RDN, 100% RDN and 125% RDN was noted narrower and non-significant.

Table 4.7: Impact of Integrated Nutrient Management on P (%) content in grain and stalk

S. No	Treatments	P content (%) in grain	P content (%) in stalk
1.	T_1	0.32	0.128
2.	T_2	0.30	0.122
3.	T_3	0.31	0.126
4.	T_4	0.34	0.134
5.	T_5	0.37	0.142
6.	T_6	0.28	0.116
7.	T_7	0.29	0.120
8.	T_8	0.33	0.130
9.	T_9	0.31	0.136
10.	T_{10}	0.26	0.110
S. E. ±		0.018	0.
C. D. (at 5%)		0.053	0.077

Stalk

P concentration in stalk depicted in table 4.7 and figure 4.7 showed linear and non-significant variation within all the treatments. Maximum absorption of P in stalk (0.142%) was noted with T_5 (100% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) and minimum (0.110%) at control (T_{10}). Addition of FYM, S and Zn also showed slight increase in P concentration in stalk when applied with 75% RDN and 100% RDN but the increase in P concentration in stalk was noted non-significant. Variation in P accumulation in stalk within 75% RDN, 100% RDN and 125% RDN was also found non-significant.

Potassium concentration in maize

Grain

The data presented in table 4.8 and figure 4.8 showed significant influenced of K concentration in grain in all the treatments over control. Maximum K concentration 0.44% was recorded with T_5 (100% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) followed by 0.42% with T_9 (75% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) and minimum 0.32% at control (T_{10}). Addition of FYM, sulphur and zinc showed significant influenced in K accumulation at 75% RDN and 100% RDN treatments. Variation in K accumulation in grain within 75% RDN, 100% RDN and 125% RDN was noted non-significant.

Table 4.8: Impact of Integrated Nutrient Management on K (%) Content in grain and stalk.

S. No	Treatments	K. content in (%) grain	K. content (%) in stalk
1.	T_1	0.38	1.12
2.	T_2	0.36	1.09
3.	T_3	0.37	1.11
4.	T_4	0.41	1.15
5.	T_5	0.44	1.19
6.	T_6	0.34	1.05
7.	T_7	0.35	1.07
8.	T_8	0.38	1.13
9.	T_9	0.42	1.16
10.	T_{10}	0.32	1.02
S. E. ±		0.021	0.003
C. D. (at 5%)		0.062	0.010

Stalk

Data in respect to K concentration in stalk was given in table 4.8 and figure 4.8 showed significant increase in K absorption in all the treatment in comparison to control. Maximum value of K concentration was noted 1.19% in T_5 (100% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) and minimum 1.02% at control (T_{10}). Variation in P accumulation within 75% RDN, 100% RDN and 125% RDN was noted non-significant. Integration of S, Zn and FYM showed positive influenced in K concentration when applied with 75% RDN and 100% RDN treatments.

Sulphur concentration in maize

Grain

It is apparent from the data given in table 4.9 and figure 4.9 showed that S concentration in all the treatments influenced significantly in over to control. Higher accumulation of S in grain was recorded 0.390% with T_5 (100% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) and minimum 0.20% with T_{10} (control). Integration of sulphur, Zn and FYM influenced significantly S concentration in grain when applied with 75% RDN and 100% RDN. It was also observed that addition of S showed higher increase in its accumulation when applied with 75% RDN and 100% RDN. Variation in S concentration within 75% RDN, 100% RDN and 125% RDN was also noted significant.

Table 4.9: Impact of Integrated Nutrient Management on S (%) content in grain and stalk

S. No	Treatments	S content (%) in grain	S content (%) in stalk
1.	T_1	0.34	0.27
2.	T_2	0.32	0.24
3.	T_3	0.33	0.26
4.	T_4	0.36	0.30
5.	T_5	0.39	0.33
6.	T_6	0.30	0.22
7.	T_7	0.31	0.23
8.	T_8	0.35	0.28
9.	T_9	0.37	0.31
10.	T_{10}	0.28	0.20
S. E. ±		0.018	0.016
C. D. (at 5%)		0.055	0.047

Stalk

Data in regard to S concentration in stalk given in table 4.9 and figure 4.9 showed that accumulation of sulphur in all the treatments influenced significantly over control. Addition of S, Zn and FYM also increase the S concentration when applied with 100% RDN and 75% RDN treatments. Maximum S concentration 0.33% was recorded with T_5 (100% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) and minimum 0.20% at control (T_{10}). Significant variation in S accumulation was also noted within 75% RDN, 100% RDN and 125% RDN treatments.

Zinc concentration in maize

Grain

A critical perusal of the data given in table 4.10 and figure 4.10 showed that zinc absorption in grain increase significantly in all the treatments over its control (T_{10}). Highest zinc concentration in grain was noted 31.8 ppm with T_5 (100% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) and lowest 22.2 ppm with T_{10} (control). Integration of sulphur, zinc and FYM also showed significant increase when added with 75% RDN and 100% RDN treatments. It was also observed that integration of zinc showed increase in its concentration when applied with 100% RDN and 75% RDN treatments. Variation in zinc concentration within 75% RDN and 100% RDN was found non-significant while variation with 100% RDN and 125% RDN was noted significant.

Stalk

Data presented in table 4.10 and figure 4.10 showed significance influenced in Zn concentration in stalk in all the treatments over its respective control. Maximum zinc concentration 23.8 ppm was noted with T_5 (100% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) and minimum 14.2 ppm at control (T_{10}). Addition of sulphur, Zn and FYM also influenced zinc accumulation significant when applied with 75% RDN and 100% RDN treatments. Like-wise sulphur addition of zinc also showed higher increase in its concentration in stalk when applied with 75% RDN and 100% RDN treatments. Non-significant accumulation of zinc was noted within 75% RDN, 100% RDN and 125% RDN treatments.

Table 4.10: Impact of Integrated Nutrient Management on Zn (ppm) content in grain and stalk

S. No	Treatments	Zn content (ppm) in grain	Zn content (ppm) in stalk
1.	T_1	27.00	18.80
2.	T_2	24.80	16.80
3.	T_3	26.20	18.20
4.	T_4	29.80	20.80
5.	T_5	31.8	22.80
6.	T_6	23.50	15.40
7.	T_7	24.20	16.20
8.	T_8	28.60	19.40
9.	T_9	30.60	21.20
10.	T_{10}	22.20	14.20
S. E ±		1.509	1.053
C. D. (at 5%)		4.519	3.153

Effect of INM on nutrient uptake

Nitrogen uptake

Grain

Data in regard to N uptake in grain presented in table 4.11 and figure 4.11 revealed that N uptake increased significantly in all the treatment in comparison to its respective control. Variation in N uptake within all the treatment was noted narrower and non-significant. Maximum N uptake 50.75 kg ha^{-1} was recorded with T_5 (100% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) followed by 45.63 kg ha^{-1} with T_9 (75% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) and minimum 22.87 kg ha^{-1} at control (T_{10}). Addition of FYM, S and Zn with 100% RDN and 75% RDN also influenced N accumulation. Addition of S with 100% RDN and 75% RDN showed significant accumulation of N uptake while addition of Zn influenced significantly N uptake when applied with 100% RDN. Variation in N uptake within 75% RDN, 100% RDN and 125% RDN was found non-significant.

Table 4.11: Impact of Integrated Nutrient Management on N uptake in grain and stalk

S. No	Treatments	N uptake (kg ha^{-1}) in grain	N uptake (kg ha^{-1}) in stalk	Total uptake (kg ha^{-1})
1.	T_1	39.12	39.35	78.47
2.	T_2	34.96	34.11	69.07
3.	T_3	38.24	38.55	76.79
4.	T_4	44.84	46.73	91.57
5.	T_5	50.75	56.83	107.58
6.	T_6	30.76	28.67	59.43
7.	T_7	33.91	32.32	66.23
8.	T_8	40.72	41.96	82.68
9.	T_9	45.63	49.28	94.91
10.	T_{10}	22.87	20.40	43.27
S.E. ±		2.14	2.215	4.355
C. D. (at 5%)		6.42	6.632	13.052

Stalk

The data of N uptake in stalk are given in table 4.11 and figure 4.11 It varied from 20.40 to 56.83 kg ha^{-1}. All the treatment showed significant increase N uptake in stalk over control. Integration of S and Zn with 100% RDN and 75% RDN showed significant increase in N uptake in stalk.

Integration of FYM with 100% RDN and 75% RDN also influenced N uptake in stalk but increase in N uptake in stalk was found non-significant. It was also observed from the data that N uptake in stalk was recorded higher in stalk in comparison to grain but increase N uptake in stalk in comparison to grain was found nominal.

Phosphorus uptake

Grain

It is visualized from the data given in table 4.12 and fig 4.12 revealed significant increases in P uptake in grain in all the treatment in comparison to control. P uptake in grain was varied from 4.87 to 13.04 kg ha^{-1} in all the treatments. Addition of FYM, S and Zn showed significant increase in P uptake in grain when applied with 100% RDN and 75% RDN. Increase in P uptake with 75% RDN and 100% RDN was found significant while increase in P accumulation within 100% RDN and 125% RDN was found non- significant.

Table 4.12: Impact of Integrated Nutrient Management on P uptake grain and stalk

S. No	Treatments	P uptake (kg ha^{-1}) Grain	P uptake (kg ha^{-1}) stalk	Total uptake (kg ha^{-1})
1.	T_1	9.34	10.94	20.28
2.	T_2	8.06	9.91	17.97
3.	T_3	9.00	10.79	19.79
4.	T_4	11.04	12.28	23.32
5.	T_5	13.04	13.91	26.95
6.	T_6	6.81	8.75	15.56
7.	T_7	7.68	9.69	17.37
8.	T_8	9.88	11.13	21.01
9.	T_9	11.40	12.41	23.81
10.	T_{10}	4.87	6.60	11.47
S. E. ±		0.515	0.600	1.115
C. D. (at 5%)		1.543	1.795	3.338

Stalk

It is appraisal from the data given in table 4.12 and figure 4.12 revealed that P uptake in stalk increased significantly in all the treatment over control. Maximum P uptake 13.91 kg ha^{-1} was noted with T_5 (100% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) followed by 12.41 kg ha^{-1} with T_9 (75% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) and minimum 6.60 kg ha^{-1} at control (T_{10}). Integration of FYM, S and Zn also increased P accumulation when applied with 75% RDN and 100% RDN. P accumulation in stalk within 75%, 100% RDN and 125% RDN was found non-significant. It was also observed that P accumulation in stalk was higher over grain.

Potassium uptake

Grain

It is obvious from the data given in table 4.13 and fig 4.13 revealed significant increases in K uptake in all the treatments over control. T_5 (100% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) showed maximum accumulation in 15.51 kg ha^{-1} followed by T_9 (75% RDN + 25% N FYM + 30 kg S + 5 kg Zn) 13.68 kg ha^{-1} and minimum in 5.99 kg ha^{-1} in grain was noted with control (T_{10}). Integration of S and Zn showed significant increase in K uptake in grain when applied with 75% RDN and 100% RDN. Addition of FYM also influenced K accumulation in grain but the increase was found non-significant. Variation in K uptake within 75% RDN, 100% RDN and 125% RDN was noted non-significant.

Table 4.13: Impact of Integrated Nutrient Management on K uptake in grain and stalk

S. No	Treatments	K uptake (kg ha^{-1}) grain	K uptake (kg ha^{-1}) stalk	Total uptake (kg ha^{-1})
1.	T_1	11.09	95.82	106.91
2.	T_2	9.68	88.53	98.21
3.	T_3	10.74	95.11	105.85
4.	T_4	13.42	105.39	118.81
5.	T_5	15.51	116.60	132.11
6.	T_6	8.27	79.25	87.52
7.	T_7	9.27	86.49	95.76
8.	T_8	11.37	96.77	108.14
9.	T_9	13.68	105.88	119.56
10.	T_{10}	5.99	61.20	67.19
S. E. ±		0.62	5.191	5.811
C. D. (at 5%)		1.855	15.543	17.398

Stalk

It is apparent from the data given in table 4.13 and fig 4.13 showed that K uptake in stalk was significantly increase in all the treatment over control. Highest K uptake 116.60 kg ha^{-1} was noted with T_5 (100% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) followed by 105.88 kg ha^{-1} T_9 (75% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) and minimum 61.20 kg ha^{-1} at control. Addition of sulphur, Zn and FYM also influenced K accumulation in stalk when applied with 100% RDN and 75% RDN but the increase in K uptake in stalk was found non-significant. Increase in K uptake within 75% RDN, 100% RDN and 125% RDN was also found non-significant. It is also obvious from the data that stalk showed more than 7 times higher accumulation of K in comparison to grain.

Sulphur uptake

Grain

Data in respect to S uptake in grain are given in table 4.14 and fig. 4.14 showed significant increase in S uptake in grain in all the treatments over control. Addition of sulphur and zinc showed significant increase in S uptake in grain when applied with 75% RDN and 100% RDN. Integration of FYM showed non-significant increase in S accumulation in grain when applied with 75% RDN and 100% RDN. Sulphur accumulation in grain with 75% RDN and 100% RDN was noted non-significant while absorption of S in grain within 100% RDN and 125% RDN was observed significant. Maximum S uptake in grain 13.74 kg ha^{-1} with T_5 (100% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) and minimum S uptake 5.24 kg ha^{-1} with control (T_{10}).

Table 4.14: Impact of Integrated Nutrient Management on S uptake in grain and stalk

S. No	Treatments	S uptake (kg ha^{-1}) grain	S uptake (kg ha^{-1}) stalk	Total uptake (kg ha^{-1})
1.	T_1	10.92	23.09	33.01
2.	T_2	8.60	19.49	28.09
3.	T_3	9.58	22.27	31.85
4.	T_4	11.69	27.49	39.18
5.	T_5	13.74	32.33	46.07
6.	T_6	7.30	16.60	23.90
7.	T_7	8.21	18.58	26.79
8.	T_8	10.48	23.97	34.45
9.	T_9	12.06	28.29	40.35
10.	T_{10}	5.24	12	17.24
S. E. $\pm$		0.535	1.357	1.892
C. D. (at 5%)		1.602	4.64	6.242

Stalk

The uptake data of sulphur in stalk given in table 4.14 and fig. 4.14 showed significant increase in S uptake in all treatment over control. Higher absorption of S in stalk 32.33 kg ha^{-1} was noted with T_5 (100% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) followed by 28.29 kg ha^{-1} with T_9 (75% RDN + 25% N FYM + 30 kg S + 5 kg Zn) 28.29 kg ha^{-1} and minimum 12 kg ha^{-1} at control. Integration of sulphur and zinc with 75% RDN and 100% RDN showed significant increase in S uptake while integration of FYM showed non-significant increase in S uptake when applied with 75% RDN and 100% RDN. Variation in S uptake in stalk within 75% RDN, 100% RDN and 125% RDN was also noted non-significant. It is also obvious from the data that S accumulation in stalk was recorded more than 2 times higher in over grain.

Zinc uptake

Grain

Data in regard to zinc uptake in grain depicted in table 4.15 and fig. 4.15 revealed that Zn uptake increased significantly in all the treatments over control. Highest Zn uptake 1120.95 gm ha^{-1} was noted with T_5 (100% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) and minimum 415.24 gm ha^{-1} with control (T_{10}). Addition of S and Zn influenced significantly Zn accumulation when applied with 100% RDN and 75% RDN but the increase in Zn uptake in grain was found non-significant. Addition of FYM also influenced Zn accumulation in grain but the increase in Zn uptake in grain was found non- significant. Variation in Zn uptake within 75% RDN 100% RDN and 125% RDN was also noted non-significant.

Table 4.15: Impact of Integrated Nutrient Management on Zn uptake in grain and stalk

S. No	Treatments	Zn uptake (gm ha^{-1}) grain	Zn uptake (gm ha^{-1}) stalk	Total uptake (gm ha^{-1})
1.	T_1	788.39	1608.33	2396.73
2.	T_2	661.73	1364.66	2026.39
3.	T_3	761.10	1559.88	2320.98
4.	T_4	968.49	1906.31	2874.80
5.	T_5	1120.94	2234.16	3355.10
6.	T_6	572.22	1162.38	1734.60
7.	T_7	641.30	1309.28	1950.58
8.	T_8	856.56	1661.60	2518.16
9.	T_9	997.55	1935.10	2932.65
10.	T_{10}	416.24	852.00	1268.24
S. E. $\pm$		45.24	91.065	136.30
C. D. (at 5%)		135.399	272.663	408.062

Stalk

It is visualised from the data given in table 4.15 and fig. 4.15 showed that all the treatment significantly influenced Zn uptake in stalk over control. Highest Zn uptake in stalk was noted 224 gm ha^{-1} with T_5 (100 % RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) and minimum 852 gm ha^{-1} at control (T_{10}). Addition of S and Zn showed significance increased in Zn uptake when applied with 100% RDN and 75% RDN while integration of FYM showed non-significant increase in Zn accumulation when added with 100% RDN and 75% RDN. Variation in Zn uptake within 100% RDN and 125% RDN was found significant. It is also obvious from the data that stalk showed more than 2 times higher Zn accumulation over the grain.

Discussion

Impact of INM on nutrient content and uptake

Concentration of nutrient *i.e.* N, P, K, S and Zn were analyzed at harvest in grain and stalk. Based on yield and nutrient concentration their uptake values were also calculated to obtained definite amount of nutrient taken by crop to attain the observed yield level.

Nutrient content

Impact of INM on nutrient content at harvest in grain and stalk presented in table 4.6 to table 4.10 and fig. 4.6 to fig. 4.10 that contents of N, P, K, S and Zn in grain and stalk increased significantly in all the treatments over control. Variation in N, P, K, S and Zn content in grain and stalk within all the treatments were noted narrower and non-significant. Addition of S and Zn and FYM with 100% RDN and 75% RDN treatments also influenced N, P, K, S and Zn content in grain and stalk. It was also observed that integration of S and Zn showed higher increase in its concentration and also increase the concentration of other nutrient. The higher concentration of N, P, K, S and Zn to be attributed to higher availability and synergistic effects of these nutrients to each other at all the stage of crop growth. It was also observed that concentration of the nutrient bearing potash was higher in grain than stalk which ascribed to the translocation of N, P, S and Zn from vegetative part of crop plant to grain at the time of maturity. Unlike the higher concentration of N, P, S and Zn in grain content of K reported higher in stalk, this may be due to the fibrous cells which are usually in sclerenchyma cells and they tend to respond to potassium supply. K supply results in relatively high turgidity and high content of cellulose and hemicelluloses associated with high content of K in stalk. Similar results are also reported by other workers Karki *et al*. (2005) [4], Shashidhar *et al*. (2009) [17], Mann *et al*. (2006) [11], Mahala *et al.* (2006) [9] and Vikas *et al.* (2007) [21].

Nutrient uptake

Impact of INM on nutrient uptake at harvest in grain and stalk were computed and presented in table 4.11 to table 4.15 and fig 4.11 fig. 4.15 it is clearly revealed that all the treatment showed significant increase in N, P, K, S and Zn uptake in grain and stalk over control. Maximum accumulation of N, P, K, S and Zn were noted with T_5 (100% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) followed by T_9 (75% RDN + 25% N FYM + 30 kg S + 5 kg Zn ha^{-1}) and minimum at control (T_{10}). Addition of S, Zn and FYM also influenced N, P, K, S and Zn accumulation in grain and stalk when applied with 100% RDN and 75% RDN.

It was also observed that uptake of N, P, S and Zn was in general higher in stalk, while N, P, S and Zn content was recorded higher in grain. It may be due to the more than 3 times more stalk yield over grain yield. It was also observed that K uptake in stalk was more than 6 times over than grain. It may be due to higher concentration of K in stalk and more than 3 times over stalk yield than grain. These results are in close conformity with the findings of Sujatha *et al.* (2008) [18], Makinde and Ayoola (2010) [10], Kumar (2008) [7], Thavaprakash and Velayudham (2007) [19], and Sarwar *et al.* (2012) [15].

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