

Original Research Article

Integrated Nutrient Management in Rainfed Maize (*Zea mays* L.) under Eastern Ghat High Land Zone of Odisha

ABSTRACT

A field experiment was conducted during *kharif* season of 2016 and 2017 at Regional Research and Technology Transfer Sub-Station, Umerkote of Odisha University of Agriculture and Technology under Eastern Ghat High Zone of Odisha, India to assess the response of integrated nutrient management on yield and economics of rainfed maize. The experiment was laid out in randomized block design with six treatments replicated four times. The experimental soils were strongly acidic, non-saline, loamy sand, low in organic carbon, available N, P, B, Zn and medium in available K contents. The maximum 100 seeds weight (38.86 g), stover yield (9.57 t ha⁻¹), grain yield (7.65 t ha⁻¹), net return (INR 50,711 ha⁻¹) and B:C ratio (1.98) were recorded in soil test based NPKBZn (i.e. N:P₂O₅:K₂O:S:B:Zn @ 150:75:60:1.25:6.25 kg ha⁻¹) + lime @ 0.1 LR + FYM @ 5 t ha⁻¹ (T₆) followed by soil test based NPKZn @ 150:75:60:1.25: 6.25 kg ha⁻¹ + lime @ 0.1 LR (T₅) over control (i.e. Farmers Practice NPKZn @ 160:80:45:0:0 kg ha⁻¹). Hence, it could be concluded that application of soil test based N:P:K:B:Zn @ 150:75:60:1.25:6.25 kg ha⁻¹ + lime 0.1 LR + FYM @ 5 t ha⁻¹ recorded better yield and income as compared to other treatments as well as farmers practice.

Keywords: Maize; INM; lime; yield; economics.

1. INTRODUCTION

Maize (*Zea mays* L.) is the third important cereal crop next to rice and wheat in the world. Maize crop is an important cereal crop because of its high production potential compared to any other cereal crops and better adaptability to wide range of environments. Since the crop has very high genetic yield potential, it is called as the "Queen of cereals". Maize being a C₄ plant has higher yield potential which also depends on nutrient supplying capacity of the soil. However, its potential could not be utilized fully due to lack of proper nutrient management practices [1] (Sahrawat et al. 2008). It is cultivated in all the soil types (except in sandy soil) and agro-climatic conditions. Being a photo insensitive crop, maize has been adopted in different seasons and in different regions, with crop duration ranging from <90-130 days [2] (Humtsoe, 2018). In India, it is cultivated over an area of 92.32 lakh hectares with an annual production of 236.73 lakh tonnes having an average productivity of more than 2564 kg ha⁻¹ [3] (Borase et al., 2018). In Odisha, it occupies an area of 2.80 lakh hectares with total productions of 7.79 lakh tonnes having an average productivity of 2.78 tha⁻¹ in

2013-14 (Odisha Agriculture Statistics, 2013-14, Directorate of Agriculture and Food production, Odisha, www.agriodishanic.in [4]). The state of Odisha covering geographical area of 15.57 m ha lies in the tropical belt in the eastern regions of India between 17^o.47'- 22^o33' N latitude and 81^o31'- 87^o30' E longitudes. The climate is characterized by high temperature and medium rainfall. The average annual rainfall of the state is 1500 mm and the mean annual temperature is 26.20 °C. The soils are deficient in nitrogen, phosphorus and micronutrients like boron, zinc and molybdenum [5] (Sahu and Mishra 2005). About 44 percent of soils of Odisha are deficient in B [6] (Jena et al. 2008). Maize has been previously considered to have a relatively low B requirement compared with other cereals [7] (Marten and Westermann 1991). Deficiency of B in field grown maize was first observed in the 1960s in the United States [8] (Shorrocks and Blaza 1973). Crop yield increases more than 10% was observed in response to B application [9] (Woodruff et al. 1987). In B deficient maize, poor grain setting can result in barren cobs as reported by Vaughan [10] (1977). In Zn deficient soils, Zn application was increased maize grain yield due to increase of kernel numbers and kernel weight. An adequate Zn supply in maize plants maintained high pollen viability and a sufficient carbohydrate source as reported by [11] Liu et al. 2020. Therefore, Zn fertilization can be improved inferior grains, because a positive relationship between kernel number and the maize stem Zn content, whereas the absence of Zn induced barren ear tips [12] (Potarzycki, 2010). Soil acidity and poverty are synonymous in the state of Odisha where 80% of soils are acidic. Low water holding capacity, high bulk density and soil crusting along with chemical constraints like low pH, low CEC, low base saturation (16 to 67%), high Al, Fe and Mn saturation and high P fixing capacity (80 to 91%) are major reasons for low crop productivity in acidic soils of Odisha [13] (Pattanayak et al. 2011). Applications of lime along with other management practices are needed to correct soil acidity. Apart from its manifested role in increasing crop yield, application of lime enhances the efficiency of applied fertilizers, protects the environment and increases the net profit of the farmers [14] (Prochnow 2014). Combined use of organic and inorganic ameliorants simultaneously controls soil acidity, reduces Al and Fe toxicity and increases nutrient availability [13] (Pattanayak et al. 2011) leading to better crop growing conditions in these soils. In Odisha, maize is often grown on marginal lands and is generally supplied with sub-optimal doses of fertilizers in local varieties leading to low productivity of the crop. Balanced and efficient fertilizer application, combining inorganic and organic and also the application of soil ameliorants are essential in realizing the higher yield and reducing cost of production. Therefore, combination of chemical and organic sources and their management have shown promising results not only in sustaining the productivity but also in maintaining soil health.

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Keeping this in view, the present experiment was undertaken to assess the response of integrated nutrient management on yield and economics of maize in an alfisol of Eastern Ghat High Land (EGHL) zone of Odisha.

2. MATERIAL AND METHODS

2.1 Site description and experimental design

The field experiment was conducted for two consecutive years (2016 and 2017) during kharif season at Regional Research and Technology Transfer Sub-Station, Umerkote of Nabarangpur district in

Odisha, India to assess the response of integrated nutrient management on yield and economics of rainfed maize. The field is situated at 19° 39' 10.67" N latitude, 82° 12' 01.39" E longitude, experiencing warm and humid climate during maize growing periods. The average maximum and minimum temperature during the maize growing period varied from 26.4 to 30.3°C and 17.3 to 20.6°C, respectively in 2016; and from 26.3 to 29.8°C and 19.4 to 21.8°C, respectively in 2017. Average maximum and minimum relative humidity (RH) during the experimentation fluctuated from 92 to 94% and 74 to 91%, respectively in 2016; and from 85 to 93% and 77 to 85%, respectively in 2017. Monthly average rainfall during the experimental period varied from 12.4 to 42.1 cm in 2016 and from 9.2 to 47.0 cm, respectively in 2017. The soil was *Typic Haplustalfs* with loamy sand texture (Sand: 85.4%, Silt: 10.4% and Clay: 4.0%) and strongly acidic (pH 4.96) in reaction. The experimental soils were non-saline (EC- 0.007dSm⁻¹), low in organic carbon (2.7 g kg⁻¹), available N (126.0 kg ha⁻¹), available P (5.4 kg ha⁻¹), available B (0.37 mg kg⁻¹), available Zn (0.44 mg kg⁻¹), Ca (1.7 cmol kg⁻¹), Mg (0.6 cmol kg⁻¹) and medium in available K (170.0 kg ha⁻¹) contents, respectively. A composite soil sample analysis was done to know the physico-chemical properties before conducting the experiment. The methods involved in analysis of initial soil samples are depicted in Table 1.

The experiment was laid out in randomized block design (RBD) with six treatments viz. T₁: Farmers practice NPKBZn (N:P₂O₅:K₂O:B:Zn @ 160:80:45:0:0 kg ha⁻¹ i.e. control), T₂: Farmers practice + lime @ 0.1 lime requirement (LR), T₃: Farmers practice + lime @ 0.1 LR + FYM @ 5 t ha⁻¹, T₄: Soil test based NPKBZn (N:P₂O₅:K₂O:B:Zn @ 150:75:60:1.25:6.25 kg ha⁻¹), T₅: Soil test based NPKBZn + lime @ 0.1 LR, T₆: Soil test based NPKBZn + lime @ 0.1 LR + FYM @ 5 t ha⁻¹] replicated four times taking maize (cv. Kaveri, 25K55) as test crop. Crop was sown with a spacing of 60 cm x 30 cm in the last week of June during both years of experimentation. Lime was applied at 0.1 LR in the form of paper mill sludge (PMS) locally available liming material (60% calcium carbonate equivalent) below the seed zone at the time of sowing. The farmers' practice was considered as control treatment and it was widely adopted in the locality of rainfed upland maize ecosystems under Eastern Ghat High Land Zone of Odisha. Urea, Diammonium Phosphate (DAP), Muriate of Potash (MOP), Borax and Zinc sulphate were used as source of N, P, K, B and Zn respectively. The entire amount of P and K were applied as basal during final land preparation (before sowing of maize seeds). Nitrogen was applied in three split doses i.e. 25% as basal, 50% at first hoeing (three weeks after sowing) and 25% at second hoeing (six to seven weeks after sowing). Top dressings of fertilizers were applied at the time of hoeing/intercultural and earthing up operations to incorporate fertilizer into the soil. Borax fertilizer was applied as basal soil application before sowing in each respective treatment except T₁, T₂ and T₃, respectively. Zinc sulphate fertilizer was also applied as basal soil application before sowing in respective treatment except T₁, T₂ and T₃, respectively. Well decomposed FYM (containing 0.45% N, 0.21% P₂O₅ and 0.32% K₂O on a dry-weight basis) @ 5 t ha⁻¹ was applied 10 days prior to sowing in respective treatments (i.e. T₃ and T₆). All the other cultural practices were followed uniformly throughout the growing period of crop. The yield attributes were recorded at harvest and grain yield at 14% moisture content. Hundred seed weight was recorded after sun drying of seeds. Net return (INR ha⁻¹) and benefit:cost (B:C) ratio of maize were calculated based upon the prevailing local market prices.

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2.2 Statistical analysis

The data on growth and yield attributes were subjected to an analysis of variance (ANOVA) using randomized block design and statistical analysis was carried out using the SPSS statistical package (version 18.0, Chicago, USA). Probabilities of significance ($p= 0.05$) was used to test the significance of nutrient effects.

3. RESULTS AND DISCUSSION

3.1 Yield and yield attributes of maize

The experimental results of two years (2016 and 2017) on maize (Table-2) revealed that 100 seeds weight, grain yield and stover yield were significantly increased in soil test based NPKBZn (i.e. $N:P_2O_5:K_2O:S:B:Zn @ 150:75:60:1.25:6.25 \text{ kg ha}^{-1}$) + lime @ 0.1 LR + FYM @ 5 t ha^{-1} as compared with all other treatments. The maximum 100 seeds weight (38.86 g), grain yield (7.65 t ha^{-1}) and stover yield (9.57 t ha^{-1}) were obtained in soil test based NPKBZn + lime @ 0.1 LR + FYM @ 5 t ha^{-1} followed by soil test based NPKBZn + lime @ 0.1 LR (T_5), where farmers practice showed the lowest 100 seeds weight (35.50 g), grain yield (4.61 t ha^{-1}) and stover yield (7.19 t ha^{-1}), respectively (Table-2). This result also corroborated with the findings of Borase et al. [3]; Phonglosa et al. [23]; Thinghujam et al. [24]. Combined application of inorganic, organic and lime i.e. soil test based NPKBZn + lime @ 0.1 LR + FYM @ 5 t ha^{-1} increased 65.94% (Fig. 1) grain yield of maize over control (i.e. Farmers practice NPKBZn). Similar results were reported by Borase et al. [3]; Phonglosa et al. [23]. The improvement in grain, stover and biological yield of maize is mainly attributed to complementary role of boron in the reproduction and vegetative stage of plants as reported by Tahir et al. (2012) [25]. The present investigation confirmed that significantly lowest values of yield attributes were recorded in control (farmers practice) plots. The favourable effect of integrated application of inorganic fertilizers, FYM and lime on yield attributes might be due to better absorption and availability of nutrients to the crop. Samantaray et al. [26] reported that integrated application of 75% soil test-based fertilizer recommendation (STBFR) + FYM @ 5 t ha^{-1} + lime @ 0.2 LR + sulphur @ 20 kg ha^{-1} recorded maximum yield attributes and yield in pigeon pea crop.

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3.2 Economics of maize cultivation

The cost of cultivation of maize varied from INR 51,664 ha^{-1} to INR 43,391 ha^{-1} (Table 3). Average data of economics of maize showed that maximum gross return (INR 43,391 ha^{-1}), net return (INR 50,711 ha^{-1}) and B:C ratio (1.98) were recorded from the treatments with soil test based NPKBZn (i.e. $N:P_2O_5:K_2O:S:B:Zn @ 150:75:60:1.25:6.25 \text{ kg ha}^{-1}$) + lime @ 0.1 LR + FYM @ 5 t ha^{-1} followed by T_5 (soil test based NPKBZn + lime @ 0.1 LR) over control (i.e. farmers practice NPKBZn).

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4. CONCLUSION

The results of the investigation revealed that integrated nutrient management i.e. soil test based $N:P_2O_5:K_2O:S:B:Zn @ 150:75:60:1.25:6.25 \text{ kg ha}^{-1}$ + lime @ 0.1 LR + FYM @ 5 t ha^{-1} could be effective in maximizing the productivity and economics of maize crop in acidic soils under continuous

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maize growing areas of Eastern Ghat High Land zone of Odisha. Application of FYM and lime amelioration of the acidic soils had strong economic impact when applied in combination with soil test based fertilizer (N, P, K, B and Zn) recommendation.

REFERENCES

1. Sahrawat KL, Rego TJ, Wani SP, Pardhasaradhi G. Sulphur, boron and zinc fertilization effects on grain and straw quality of maize and sorghum grown on farmers' fields in the semi-arid tropical region of India. *Journal of Plant Nutrition*. 2008; 31(9): 1578-1584.
2. Humtsoe BM, Dawson J, Rajana P. Effect of nitrogen, boron and zinc as basal and foliar application on growth and yield of maize (*Zea mays* L.). *Journal of Pharmacognosy and Phytochemistry*, 2018; 7(6): 01-04.
3. Borase CL, Lomte DM, Thorat SD, Dhonde AS. Response of Kharif maize (*Zea mays* L.) to micronutrients. *Journal of Pharmacognosy and Phytochemistry*. 2018; 7(3): 482-484.
4. Odisha Agriculture Statistics, 2013-14, Directorate of Agriculture and Food production, Odisha, www.agriodishanic.in
5. Sahu GC, Mishra A. Soil of Orissa and Its Management. *Orissa Review*, LXII (4). 2005; 56-60.
6. Jena D, Singh MV, Pattnaik, MR, Nayak SC. Scenario of Micro and Secondary nutrient deficiencies in soils of Orissa and management. Department of Soil Science and Agricultural Chemistry, OUAT, Bhubaneswar, Technical Bulletin 1. 2008;1-42.
7. Marten JM, Westermann DT. Fertilizer applications for correcting micronutrient deficiencies. In: Mortvedt JJ, Cox FR, Shuman LM, Welch RM (eds) *Micronutrients in agriculture*, SSSA Book Series No. 4. Soil Science Society of America, Wisconsin. 1991; 549-592.
8. Shorrocks VM, Blaza AJ. The boron nutrition of maize. *Field Crop*. 1973; 25:25-27.
9. Woodruff JR, Moore FW, Musen HL. Potassium, boron, nitrogen and lime effects on corn yield and ear leaf nutrients concentration. *Agronomy Journal*. 1987; 79:520-524.
10. Vaughan AKF. The relation between the concentration of boron in the reproductive and vegetative organ of maize plants and their development. *Rhodesian Journal Agricultural Research*. 1977; 15:163-170.
11. Liu DY, Zhang W, Liu YM, Chen XP, Zou CQ. Soil application of zinc fertilizer increases maize yield by enhancing the kernel number and kernel weight of inferior grains. *Frontiers in Plant Science*. 2020; 11:188. doi: 10.3389/fpls.2020.00188
12. Potarzycki J. The impact of fertilization systems on zinc management by grain maize. *Fertilizers Fertilization*. 2010; 39:78-89.

13. Pattanayak SK, Misra UK, Sarkar AK, Majumdar K. Integrated nutrient management for groundnut and redgram on acid soils in Odisha. *Better crops-South Asia*. 2011; 8-10.
14. Prochnow BL. Soil acidity evaluation and management. *Better Crops*. 2014; 98 (1): 22–25.
15. Bouyoucos GJ. Hydrometer method improved for making particle size analysis of soils. *Agronomy Journal*. 1962; 54: 464-465.
16. Jackson ML. *Soil Chemical Analysis*, Prentice Hall of India Pvt. Ltd., New Delhi, India. 1967.
17. Jackson ML. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi, India, 1973; pp. 48-302.
18. Subbiah B, Asija GL. A rapid procedure for the estimation of available N in soils. *Current Sciences*. 1956; 25, 259-260.
19. Bray RH, Kurtz LT. Determinations of total, organic and available forms of phosphorus in soils. *Soil Science*. 1945; 59: 39-45.
20. Brown AJ, Warncke D. In W. C. Dahnke (ed.) Recommended chemical soil test procedures for the North Carolina Region. North Dakota Agricultural Experimental Station Bull 499. 1988;15-16.
21. Berger KC, Truog E. Boron determination in soils and plants. *Industrial and Engineering Chemistry, Analytical Edition*. 1939; 11: 540- 545.
22. Lindsay WL, Norvell WA. Development of DTPA soil test for Zn, Fe, Mn and Cu. *Soil Science Society of the America Journal*. 1978; 42: 421-428.
23. Phonglosa A, Dalei BB, Nayak RK, Pattanayak SK, Kropi J, Saren S. Response of boron on yield and economics of maize under Eastern Ghat High Land Zone of Odisha. *International Journal of Agriculture, Environment and Biotechnology*. 2019; 12(1): 33-37.
24. Thingujam U, Bhattacharyya K, Ray K, Phonglosa A, Pari A, Banerjee H, Dutta S, Majumdar K. Integrated Nutrient Management for Eggplant: Yield and Quality Models through Artificial Neural Network. *Communications in Soil Science and Plant Analysis*. 2020; 51 (1): 70-85.
25. Tahir M, Ali A, Khalid F, Naeem M, Fiaz N, Waseem M. Effect of Foliar Applied Boron Application on Growth, Yield and Quality of Maize (*Zea mays* L.). *Pakistan Journal of Scientific and Industrial Research Series B: Biological Sciences*. 2012; 55(3):117-121.
26. Samantaray SK, Satapathy M, Jena S. Effect of Nutrient Management Practices on Yield Attributes, Yield, Nutrient uptake and Economics of Pigeonpea (*Cajanus cajan* L.) Cultivars during Rabi Season. *International Journal of Current Microbiology and Applied Sciences*. 2020; 9(3): 1709-1715.

Table 1. Analytical methodologies for different soil parameters

Parameter	Methodology	Citation	Equipment used
Soil analyses			
Sand-Silt-Clay	Hydrometer method	Bouyoucos (1962) [15]	Hydrometer
pH	(in 1:2.5:: Soil : Water)	Jackson (1967) [16]	m-processor based pH-
EC	(in 1:2.5:: Soil : Water)	Jackson (1967) [16]	EC-Ion meter
Organic carbon	Wet oxidation method	Jackson (1973) [17]	
Available N	Hot alkaline KMnO ₄ Method	Subbiah and Asija (1956) [18]	Kjeldahl apparatus
Available P	0.03 N NH ₄ F + 0.025 N HCl (pH 3.5)	Bray and Kurtz (1945) [19]	Spectrophotometer
Available K	Neutral N NH ₄ OAc extraction	Brown and Warncke (1988) [20]	Flame photometer
Available B	Hot water extraction	Berger and Truog (1939) [21]	Spectrophotometer
Available Zn	DTPA extraction	Lindsay and Norvell (1978) [22]	Atomic Absorption Spectrophotometer

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Table 2. Effect of integrated nutrient management on yield and yield attributes of maize (mean data of 2 years)

Treatments	100 seeds wt. (g)	Grain yield (t ha ⁻¹)	Stover yield (t ha ⁻¹)	Percent increase in grain yield over control
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	(T ₁ : farmers practice)			
T ₁ : Farmers practice NPKBZn [#]	35.50	4.61	7.19	-
T ₂ : Farmers practice NPKBZn + lime @ 0.1 LR	37.37	5.46	7.78	18.44
T ₃ : Farmers practice NPKBZn + lime @ 0.1 LR + FYM 5 t ha ⁻¹	37.77	5.84	7.86	26.68
T ₄ : Soil test based NPKBZn ^{##}	38.54	6.49	8.66	40.78
T ₅ : Soil test based NPKBZn + lime @ 0.1 LR	38.65	6.82	9.44	47.94
T ₆ : Soil test based NPKBZn + lime @ 0.1 LR + FYM @ 5 t ha ⁻¹	38.86	7.65	9.57	65.94
SEm (±)	0.701	0.083	0.068	-
CD (=0.05)	2.111	0.250	0.206	-

[#]Farmers practice NPKBZn i.e. N:P₂O₅:K₂O:S:B:Zn @ 160:80:45:0:0 kg ha⁻¹;

^{##}Soil test based NPKBZn i.e. N:P₂O₅:K₂O:S:B:Zn @ 150:75:60:1.25:6.25 kg ha⁻¹

Table 3. Effect of integrated nutrient management on economics of maize cultivation (mean data of 2 years)

Treatments	Cost of cultivation (INR ha ⁻¹)	Gross Return (INR ha ⁻¹)	Net Return (INR ha ⁻¹)	B:C ratio
T ₁ : Farmers practice NPKBZn [#]	43391	61640	18249	1.42
T ₂ : Farmers practice NPKBZn + lime @ 0.1 LR	43657	72981	29324	1.67
T ₃ : Farmers practice NPKBZn + lime @ 0.1 LR + FYM 5 t ha ⁻¹	48657	78115	29457	1.61
T ₄ : Soil test based NPKBZn ^{##}	46398	86869	40471	1.87
T ₅ : Soil test based NPKBZn + lime @ 0.1 LR	46664	91163	44499	1.95
T ₆ : Soil test based NPKBZn + lime @ 0.1 LR + FYM @ 5 t ha ⁻¹	51664	102375	50711	1.98

[#]Farmers practice NPKBZn i.e. N:P₂O₅:K₂O:S:B:Zn @ 160:80:45:0:0 kg ha⁻¹;

^{##}Soil test based NPKBZn i.e. N:P₂O₅:K₂O:S:B:Zn @ 150:75:60:1.25:6.25 kg ha⁻¹;

INR: Indian Rupee; B:C ratio:: Benefit: Cost ratio.

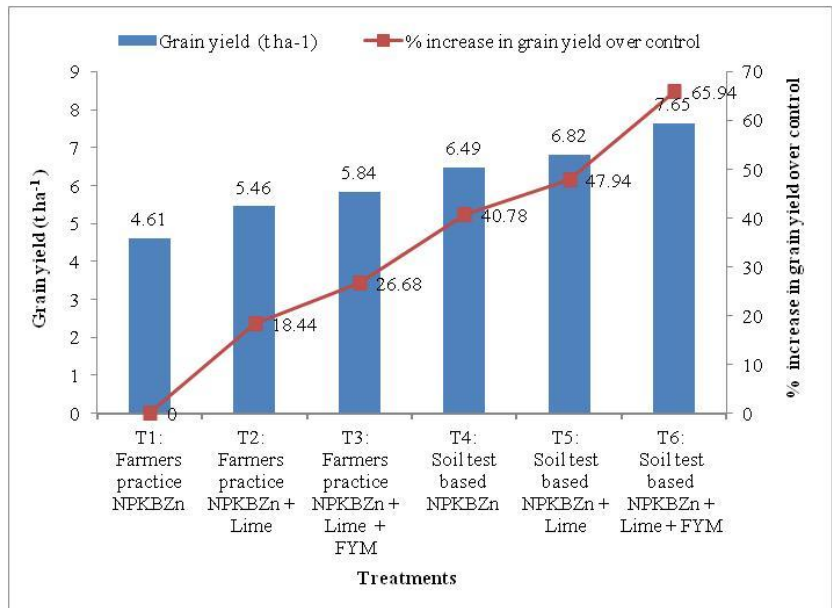


Fig. 1. Effect of integrated nutrient management on grain yield and percent increase over control (i.e. farmers practice NPKBZn only)

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