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Evaluation of the productivity and profitability of maize (*Zea mays* L.) as influenced by zinc biofortification through integrated nutrient management

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Abstract
Today increasing the yield of maize both in terms of grain and fodder with judicial application of nutrients by means of various sources is key for food security and animal fodder industry. A field experiment was conducted on HQPM1 maize with three types of manures (FYM, poultry manure and vermicompost, three levels of NPK application (0% Recommended dose of fertilizer RDF, 50% RDF and 100% RDF) and three Zn application rate (0 kg/ha, 15 kg/ha and 30 kg/ha). Results showed that among the three sources of manure, poultry manure was the best in terms of reducing the number of days to attain 50% tasselling, 50% silking; and increasing grain yield and stover yield of HQPM1. While for NPK and Zn application their highest levels i.e., 100% RDF and 30kg/ha Zn respectively, resulted in significantly lowest days to 50% tasselling, 50% silking; and highest grain yield (kg/ha) and stover yield (kg/ha). Only fertilizer levels and Zinc application could exert significant influence on nitrogen content and uptake, phosphorus content and uptake; zinc content and uptake; protein and carbohydrate content in the HQPM-1 maize. The treatment combination involving 100% RDF and 30 kg/ha Zinc exerted the best results among all the combinations. Economic analysis of maize production indicated that integrated nutrient management significantly increased the overall profitability of the maize production. $M_2F_3Z_3$ with B:C ratio and net return of 2.22 and ₹60684.83 ha^{-1} respectively, was the best treatment due to significantly higher grain and stover yield of maize plants.

Keywords: HQPM1, zinc application, integrated nutrient management, FYM, poultry manure, vermicompost, profitability

Introduction
Maize (*Zea mays* L.) is the third most important cereal after wheat and rice. The crop is commonly cultivated in the tropics and warm sub-tropics region for food, livestock and industrial uses. In India maize is an important food, fodder and industrial crop grown both commercially and at subsistence level. Maize is used for the production of indigenous and commercial food products that are relished for their unique and distinctive flavours. Maize is considered to be heavy feeder of nutrients hence its productivity is largely dependent on nutrient management. Therefore, there is a need to supply the required amount of nutrients to express its yield potential. In order to meet these demands farmers usually practiced higher dose of inorganic fertilizer which is not sustainable and uneconomical. Promiscuously Relying only on high amount of inorganic source of fertilizer has often led to deterioration of overall soil health of the country leading to a stagnation of food grain production in recent years in spite of consistent increment in fertilizer use. This stagnation in agricultural productivity is often attributed to degradation of soil due to various biotic and abiotic stresses inflicted on soil due to high input agriculture. With a view to sustain the soil health and to maintain thereby the productivity levels of agricultural soils more emphasis is now being paid on integration of organic inputs with mineral sources of nutrition. Use of such organic materials not only increase the nutrient status of the agricultural soils but also help improve various physical, chemical and biological properties of soils leading to betterment of soil quality and also to increased fertilizer use efficiency. Farmyard manure, Vermicompost, Poultry manure, Biofertilizer etc. are some organic manures which are rapidly emerging as an important source of organic inputs produced from various organic wastes and some useful microorganisms.

Integrated use of organic and inorganic sources of plant nutrient not only pushes the production and profitability of the crop but also helps in maintaining the permanent fertility status of the soil. Incorporation of Zinc containing mineral fertilizers along with the organic manure in the nutrient management system of staple cereal crop may contribute towards improved soil health, yields and grain quality as a pathway to enhancing nutrition of smallholder communities in maize-based farming systems. Considering the above points in view the present study was conducted to evaluate the productivity and profitability of maize as influence by Zinc biofortification of maize through Integrated nutrient management.

Material and Methods

Current experiment was planned and conducted at Agronomy experimental farm of School of Agricultural Sciences and Rural Development (SASRD), Nagaland, Medziphema Campus, Nagaland during the season kharif 2016 and kharif 2017. The experimental field had a sandy loam and well-drained soil with medium organic carbon, nitrogen, phosphorus, potassium and zinc content and an acidic pH. Three factors i.e., three different types of manures (Main factor), three levels of recommended dose of fertilizers (Sub plot factor) and three levels of Zinc application (sub-sub plot factor were tested using a Split-Split plot design with three replications. The variety used for the test was HQPM-1 maize hybrid. The seeds were sown in a well-prepared plot at a 30 cm hill spacing and a 60 cm row spacing. All of the normal agronomic practices were performed based on the crop requirement. Five randomly selected plants from each plot were used for recording the various growth characters i.e., days to 50% tasselling, days to 50% silking, grain yield, stover yield. Cost of cultivation was calculated on per hectare basis for each treatment by taking into consideration the cost incurred in different steps separately for each treatment. Gross return was worked out by considering the monetary value of the economic produce of different treatments based on the prevailing market price of the product.

Gross return (₹/ha) = Yield x selling price

Net return of each treatment was estimated by subtracting the total cost of cultivation from the gross return.

Net return = Gross return – Cost of cultivation

Benefit cost ratio was calculated by the following formula:

Benefit cost ratio = (Net return)/ (Cost of cultivation)

The data recorded for each of the observations from both the season were pooled and subjected to the analysis of significance test using "F" test (Gomez and Gomez, 1984).

Table 1: Details of the treatment combinations

Treatment notations	Treatment combination
$T_1(M_1F_1Z_1)$	10 t/ha FYM +0% RDF + 0 kg/ha Zn
$T_2(M_1F_1Z_2)$	10 t/ha FYM + 0% RDF + 15 kg/ha Zn
$T_3(M_1F_1Z_3)$	10 t/ha FYM + 0% RDF + 30 kg/ha Zn
$T_4(M_1F_2Z_1)$	4 t/ha PM + 0% RDF + 0 kg/ha Zn
$T_5(M_1F_2Z_2)$	4 t/ha PM + 0% RDF + 15 kg/ha Zn
$T_6(M_1F_2Z_3)$	4 t/ha PM + 0% RDF + 30 kg/ha Zn
$T_7(M_1F_3Z_1)$	2 t/ha VC + 0% RDF + 0 kg/ha Zn
$T_8(M_1F_3Z_1)$	2 t/ha VC + 0% RDF + 15 kg/ha Zn
$T_9(M_1F_3Z_2)$	2 t/ha VC+ 0% RDF + 30 kg/ha Zn
$T_{10}(M_2F_1Z_3)$	10 t/ha FYM + 50% RDF + 0 kg/ha Zn
$T_{11}(M_2F_1Z_1)$	10 t/ha FYM + 50% RDF + 15 kg/ha Zn
$T_{12}(M_2F_1Z_2)$	10 t/ha FYM + 50% RDF + 30 kg/ha Zn
$T_{13}(M_2F_2Z_3)$	4 t/ha PM + 50% RDF + 0 kg/ha Zn
$T_{14}(M_2F_2Z_1)$	4 t/ha PM + 50% RDF + 15 kg/ha Zn
$T_{15}(M_2F_2Z_1)$	4 t/ha PM + 50% RDF + 30 kg/ha Zn
$T_{16}(M_2F_3Z_2)$	2 t/ha VC + 50% RDF + 0 kg/ha Zn
$T_{17}(M_2F_3Z_3)$	2 t/ha VC + 50% RDF + 15 kg/ha Zn
$T_{18}(M_2F_3Z_1)$	2 t/ha VC+ 50% RDF + 30 kg/ha Zn
$T_{19}(M_3F_1Z_2)$	10 t/ha FYM + 100% RDF + 0 kg/ha Zn
$T_{20}(M_3F_1Z_3)$	10 t/ha FYM + 100% RDF + 15 kg/ha Zn
$T_{21}(M_3F_1Z_1)$	10 t/ha FYM + 100% RDF + 30 kg/ha Zn
$T_{22}(M_3F_2Z_1)$	4 t/ha PM + 100% RDF + 0 kg/ha Zn
$T_{23}(M_3F_2Z_2)$	4 t/ha PM + 100% RDF + 15 kg/ha Zn
$T_{24}(M_3F_2Z_3)$	4 t/ha PM + 100% RDF + 30 kg/ha Zn
$T_{25}(M_3F_3Z_1)$	2 t/ha VC + 100% RDF + 0 kg/ha Zn
$T_{26}(M_3F_3Z_2)$	2 t/ha VC + 100% RDF + 15 kg/ha Zn
$T_{27}(M_3F_3Z_3)$	2 t/ha VC + 100% RDF + 30 kg/ha Zn

Results and Discussion

The result from the experiment is presented (table 2 and 3) and their implications are discussed in this section.

Days to 50% Tasselling:

The appraisal of result presented in table 2 revealed the presence of significant effect (p<0.05) of manure, RDF and Zn levels. Among the different types of organic manure tested treatments receiving poultry manure took significantly minimum days to tasselling. This is due to the high nutrient content, particularly phosphorus which is responsible for early tasselling when compared to other treatment. The result is in conformity with the findings of Ezeibekwe *et al*. (2009) [6], Boochi and Tano (1994) and Amakinde and Ayoola (2009) [2].

Application of recommended dose of fertilizer had a positive effect on the maize plants in terms of the tasselling. Here 100% RDF (F_3) took 69.81 days to attain 50% tasselling which is significantly lower than the other two levels of the RDF. Similar observations were made by Kanton *et al.* (2016) [11]. The treatment Z_3 (30 kg/ha $ZnSO_4$) with an average 69.99 days recorded significantly lesser days to tassel which was on par with the treatment Z_2 (15 kg/ha Zn) with the value of 53.71 day. The application of Zinc produced vigorous and faster growth and development in the maize plants allowing them to complete their vegetative growth phase faster. This was the reason for it to attain tasselling in significantly lesser days. The above finding is in consonance with the findings of Rasheed *et al.* (2004) where it was reported that high level of Zn application reduced number of days to tasselling and silking.

Table 2: Effect of manure, fertilizer and zinc application on days to 50% tasseling, 50% silking, grain yield (kg/ha) and stover yield (kg/ha) of maize

Treatment	Days to 50% Tasseling	Days to 50% Silking	Grain Yield (kg/ha)	Stover Yield (kg/ha)
Manures				
M1 - FYM	71.26	76.90	3115.13	5018.18
M2 - Poultry	69.81	75.66	3288.98	5148.18
M3 - Vermicompost	73.06	79.50	3026.72	4967.59
Sed ±	0.42	0.36	56.68	89.09
CD (P=0.05)	0.96	0.85	130.7	NS
Recommended Dose of Fertilizers				
F1 - 0% RDF	73.37	79.78	2177.09	4119.12
F2 - 50% RDF	70.70	76.44	3309.17	5253.69
F3 - 100% RDF	68.05	73.80	3944.57	5761.13
Sed ±	0.41	1.33	51.16	75.48
CD (P=0.05)	0.84	2.75	105.59	155.78
Zinc Level				
Z1- 0 kg/ha Zn	71.43	77.33	2986.5	4957.38
Z2- 15 kg/ha Zn	70.71	76.65	3199.57	5076.49
Z3- 30 kg/ha Zn	69.99	76.04	3244.76	5100.07
Sed ±	0.48	0.47	49.7	71.843
CD (P=0.05)	0.96	0.94	99.08	NS

Days to 50% Silking

Careful examination of the results obtained analysis of the variance showed significant (p<0.05) effect of manures, RDF and Zinc application on the days taken to 50% silking. Poultry manure (M_2) has resulted in significantly shortest days to 50% silking (75.33) while the maize plants receiving vermicompost as the source of manure took the longest time to produce silking. Higher concentration of phosphorus and other micronutrients supplied by poultry manure which is responsible for early tasselling and silking. The result is in harmony with the findings of Ezeibekwe *et al.* (2009) [6], Boochi and Tano (1994) and Amakinde and Ayoola (2009) [2]. Application of 100% RDF (F_3) with 73.80 days was found to result in significantly lesser days to silking while maximum number of days to 50% silking was recorded where 0% RDF (F_1) was given. This may be ascribed to the role of N, P and K which help in attaining faster growth and development stage than the plot where the nutrient is deprived for their growth and development. Similar observations were made by Kanton *et al.* (2016) [11]. Application of Zinc had a positive effect on the maize plants flowering where it significantly reduced days taken to obtain 50% silking as per the data presented in table 2. Z_3 (30 kg/ha Zn) reduced days to 50% silking significantly compared to Z_1 (0 kg/ha Zn) while the treatment Z_2 (15 kg/ha Zn) was at par with the Z_3. The above finding is in consonance with the findings of Rasheed *et al.* (2004).

Yield (kg ha^{-1})

A critical evaluation of the data presented in table 2 revealed that the grain yield of maize was positively influenced by integrated nutrient management. Where a significant effect was evident for manure, RDF and Zn levels while a significant interaction of manure with Zn levels and interaction of RDF with Zinc levels was also observed. Among the different types of organic manure poultry manure (M_2) produced significantly higher grain yield (3288.98 kg ha^{-1}). This impact of poultry manure may be not only due to the balanced and adequate supply of the nutrients but also their major role in nutrient availability of soil to plant. It helps to create balance source sink relationship. Okoroafor *et al.* (2013) [16] and Obi and Ebo (1995) [15] also reported a similar finding. With the increase in the levels of RDF a subsequent increase in the grain yield of maize plants was clearly evident. 100% RDF on average recorded the highest grain yield. RDF application enhanced the growth and development of the maize plant by better nitrogen use efficiency and better availability of macro nutrients helping them to produce increased number of grains per cob, grain weight per cob, test weight per cob and cob length, all of these culminated in the increased grain yield. The current findings are in complete agreement with the findings of Sharma and Gupta (1998) [21], Maqsood *et al.* (2001) [13] and Kogbe and Adediran (2003) [12]. Application of Zinc produced a positive and significant jump in the yielding ability of the maize plants. The application of zinc @ 30 kg/ha (Z_3) to maize significantly increased the yield when compared with no Zinc or 0 kg/ha (Z_1) application. Zinc increases the activity of meristematic cell in terms of division and elongation resulting in improved vegetative growth of the maize plant. This insures a better and efficient source which can later ensure the efficient supply to the sink. All of this culminates in to the higher yield of the maize. The result, generally are in harmony with the finding of Khan *et al.* (2014), Mohsin *et al.* (2014) [14], Arya and Singh (2000) [3], Kakar *et al.* (2006) [10], Raskar *et al.* (2012) [17] and Hossain *et al.* (2008) [9].

The interaction between manure and Zinc levels showed a synergistic effect on grain yield. In our experiment poultry manure in combination with Zn @ 30 kg/ha $ZnSO_4$ (M_2F_3) was found to be producing highest grain yield (3537.89 kg/ha) among all the of the treatment combinations. High concentration of NPK and other mineral nutrients of poultry manure when combined with Zn was able to increase the availability of a balanced nutrient profile for the growing maize plants. This helped the plants to boost their growth and development. The result is in line with the finds of Sarwar *et al.* (2012) [20] and Saleem *et al.* (2017) [19]. On the other hand, when 100% RDF was applied with 30 kg/ha Zn (F_3Z_3) it produced the highest significant gain in the grain yield of the maize plants. This positive interaction between RDF and Zn application can be attributed to the fact that they improve the overall nutrient status of the soil by increasing the availability of the nutrients and thereby increases the uptake.

Better uptake of Zn and NPK and their translocation to growing tissues and reproductive parts results to the higher dry matter production and higher yield attributing traits. Similar result was recorded by Abrol *et al.* (2007) [1], and Ashoka and Sunitha (2011) [4].

Stover Yield (kg/ha)

The data presented in the table 2 revealed significant differences in the response of varying RDF levels in terms of the stover yield of the maize plants. The application of 100% RDF (F3) on an average was able to produce highest significant stover yield 5761.13 kg/ha. Singh *et al.* (2005) [22] reported a similar trend of increase in stover yield with the increasing levels of RDF application.

Economics

Economic analysis of maize production indicated that integrated nutrient management significantly increased the overall profitability of the maize production. In the present experiment treatment T_{18} ($M_2F_3Z_3$) produced highest gross return (₹110908.33 ha^{-1}) and net return (₹60684.83 ha^{-1}). M1F3Z2 produced the highest B:C ratio despite of the medium net returns owing to its lower cost of cultivation. From the analysis of the data, it is clear that $M_2F_3Z_3$ with B:C ratio and net return of 2.22 and ₹60684.83 ha^{-1} respectively, was the best treatment due to significantly higher grain and stover yield of maize plants. Singh *et al.*, (2005) [22] and Gohawale and Dahipale (2007) reported a similar finding.

Table 3: Effect of integrated nutrient management on economics of maize

Treatment	Gross Income	Net Income	B:C ratio
M1F1Z1	52787.50	25572.50	1.94
M1F1Z2	54870.83	26256.11	1.92
M1F1Z3	54420.83	24406.11	1.81
M1F2Z1	78287.50	45967.94	2.42
M1F2Z2	85779.17	52059.89	2.52
M1F2Z3	84995.83	49876.55	2.42
M1F3Z1	90787.50	53363.72	2.43
M1F3Z2	98762.50	59939.00	2.54
M1F3Z3	100212.50	59989.00	2.49
M2F1Z1	54287.50	17072.50	1.46
M2F1Z2	55437.50	16822.78	1.43
M2F1Z3	58487.50	18472.78	1.46
M2F2Z1	79912.50	37592.94	1.89
M2F2Z2	85537.50	41818.22	1.96
M2F2Z3	91337.50	46218.22	2.02
M2F3Z1	96412.50	48988.72	2.03
M2F3Z2	106954.17	58130.67	2.19
M2F3Z3	111654.17	61430.67	2.22
M3F1Z1	52787.50	11572.50	1.28
M3F1Z2	54362.50	11747.78	1.28
M3F1Z3	52404.17	11389.45	1.19
M3F2Z1	76537.50	30217.94	1.65
M3F2Z2	81612.50	33893.22	1.71
M3F2Z3	80562.50	31443.22	1.64
M3F3Z1	90162.50	38738.72	1.75
M3F3Z2	96587.50	43764.00	1.83
M3F3Z3	95995.83	41772.33	1.77

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