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Quality and Productivity enhancement of maize through different doses of nutrient and Zinc

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Abstract
A field experiment was carried out during the kharif season of 2016 and 2017 to study the observed the effect of integrated nutrient management on growth and yield of fodder maize (*Zea mays* L.) under foothill condition of Nagaland. The treatment consists of three factors each of them with three levels. The main plot factors consist three level of organic manures i.e., M_1 (10 t/ha FYM), M_2 (4 t/ha PM) and M_3 (2 t/ha VC); the subplot factor with three level of Recommended dose of fertilizer i.e., F_1 (0% RDF), F_2 (50% RDF) and F_3 (100% RDF); lastly the sub – subplot factors with three level of Zinc i.e., Z_1 (0 kg/ha), Z_2 (15 kg/ha) and Z_3 (30 kg/ha). Among different sources of organic manure M_2 i.e., poultry manure (4t/ha) was found to produce significantly better results in almost all the growth characters and grain yield of maize plant. RDF with higher levels i.e., 100% RDF dominated in producing significantly better results in growth characters and grain yield. Highest levels of Zinc i.e., 30 kg/ha recorded highest value in all the growth characters as well as grain yield. But it was found to be at par with 15 kg ha^{-1} Zinc application in all the characters recorded except for dry matter.
Combine application of poultry manure @4 t/ha with fertilizer @ 100% RDF (M_2F_3) recorded highest dry matter accumulation during all the growth stages. While the interaction between the poultry manure (M_2) and Zinc application @ 30kg/ha (Z_3) produced significantly higher grain yield in the HQPM-1. The interaction between dose of fertilizers and Zinc application showed significant effect on dry matter accumulation (242.16 g), CGR (4.36 g/day) and yield (4104.83 kg/ha). Where, the highest values were recorded with the treatments receiving 100% RDF in combination with 30 kg/ha Zinc application.

Keywords: Productivity, enhancement, maize, nutrient, Zinc, *Zea mays* L.

Introduction
It is a known fact that Agriculture is the back bone of India. One of the most important components of Indian agriculture is Livestock production. As per the 19th livestock census; India has the largest livestock population in the world with the population of 512.06 million (Anonymous, 2018) [8]. With the increase in number of the livestock population there is a requirement in fulfilling the demand of the feeds for the livestock. However, Yadav *et al.* (2017) [46] has reported that the green and dry fodder requirements in India for the livestock is 883.95 and 583.66 Mt against which we are able to produce only 664.73 Mt and 355.93 Mt of green and dry fodder, respectively. Which marks a clear-cut deficit in the fodder supply as compared to the demand. Thus, there is a need to focus on measures to boost the fodder production to meet this deficit of fodder supply.
Maize (*Zea mays* L.) is popularly grown for both human food and animal feeds in India. Maize is considered among the prime source of fodder in cereals as it is a non-legume green fodder with the highest nutritional value free of anti-nutritional components. It's not only rich in protein (8-10%) and high total digestible nutrients (60.0%), but also produces nutritious and rich green fodder that is high in carbohydrates. Maize is a very exhaustive crop and demands relatively high amount of fertilizers Therefore, needs balanced supply of macro and micro-nutrients. Relying solely on the use of chemical fertilizer for increasing production and productivity may results to deleterious effect on soil health. In order to reduce such unwanted effect in the environment there is a need to substitute part of chemical fertilizer by organic sources of nutrients. Integrated nutrient management aims to provide plant nutrients required for sustained crop productivity while keeping the deleterious effects on soil health to minimum. Keeping the facts in views, an experiment was conducted to study.

Material and Methods

The experiment was conducted during the *kharif* season of 2016 and 2017 at Agronomy experimental farm of School of Agricultural Sciences and Rural Development (SASRD), Nagaland, Medziphema Campus, Nagaland. The soil of the experimental field was sandy loam in texture and acidic in reaction. The soil was high in organic carbon (1.25), medium in nitrogen (282.64) and phosphorus (20.52), low potassium (150.47), and Zinc (0.45 mg/kg) content. The experimental field was laid out in Split–Split plot design with three replications. The treatment consists of three different sources of organic manure, *viz*. FYM @10 t/ha, poultry manure @ 4 t/ha and vermicompost @ 2 t/ha in main plot, three level of Recommended dose of fertilizer (RDF), *Viz*. 0% RDF, 50% RDF and 100% RDF in subplots and three level of Zinc *viz*. 0 kg/ha $ZnSO_4$, 15 kg/ha $ZnSO_4$ and 30 kg/ha $ZnSO_4$ in sub-subplot. At the time of sowing, half and full dose of N and P/K, respectively were applied as a basal dose. While the remaining half of N was divided into two equal dose which were applied at Knee height and silking stage of the crop, respectively.

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

Maize variety HQPM-1 was sown maintaining 60 cm spacing from row to row and 30 cm spacing from plant to plant with the seed rate of 20 kg ha^{-1}. Except for the treatment all the normal agronomic practices including irrigation and intercultural practices was carried out as per the recommended package of practice of the crop. The observations were recorded on various growth parameters i.e., Plant height, Number of green leaves/plants, Stem diameter, shoot dry matter, Leaf Area Index and Crop Growth Rate from 5 randomly selected plants from each plot at three growth stages i.e., 30 DAS (Days after sowing), 60 DAS and 90 DAS.

While the grain yield was recorded from the yield obtained from each plot and thereafter grain yield was converted into kg ha^{-1}. The data recorded for each attribute were pooled and subjected to the analysis of variance and significance by "F" test as per the standard procedure mentioned by Gomez and Gomez (1984) [17].

Results and Discussion

Plant height (cm)

The data Revealed that significantly highest plant height at 60 DAS and 90 DAS was recorded where Poultry manure (M_2) was applied. The significantly high plant height resulting due to application of poultry manure was mainly due to the reason of more availability of nutrients by poultry manure throughout the growing season (Farhad *et al*., 2009) [14]. These results are in accordance with the findings of Chandrashekara *et al.* (2000) [13] and Amakinde and Ayoola (2009) [4].

However, it was observed that Recommended dose of fertilizers @ 100% (RDF) recorded significant tallest plant height of the maize at all the growth stages i.e., during 30 DAS, 60 DAS and 90 DAS whereas lowest plant height was recorded in 0% RDF in all the growth stages. The fact that 100% RDF gave maximum plant height in all the growth stages may be due to increased availability of nutrients and more efficient utilization of fertilizer by the plants. Increase in plant height with increasing level of RDF could be attributed to the fact that the nutrients (N, P, K) help in photosynthetic activity, cell and internodal elongation and maintenance of higher auxin levels which ultimately results in obtaining tall plant height than the other treatments. These results are in accordance with the findings of Jaliya *et al.* (2008) [18], Jeet *et al.* (2012) [20] and Khan *et al.* (1999) [23].

Among different levels of Zinc application @ 30 kg ha^{-1} (Z_3) highest plant height at 60 DAS and 90 DAS But it was found to be at par with the response produced by the application of Zn @15 kg ha^{-1}. Positive influence of zinc on plant height might be due to the fact that it plays a vital role in photosynthesis and nitrogen metabolism and it also helps in regulating auxin concentration in plants which ultimately contributes to higher plant height in compared to no zinc application. This result is found to be in line with the findings of Khan *et al.* (2014) [22], Mohsin *et al.* (2014) [31] and Preetha and Stalin (2014) [36].

Number of green leaves/plants

A critical examination of data in table 2. Revealed that significantly highest number of leaves was recorded during 60 DAS and 90 DAS where poultry manure @ 4t/ha was applied as organic manure. However, it was found to be at par with application of FYM @ 10 t/ha. Higher number of leaf due to application of poultry manure might be attributed to its higher and better nutrient content profile both in terms of macro and micro nutrients than the other organic manures (Nahm, 2003) [32]. These micro and macro nutrients enhance the growth and development of the plants hence results in higher numbers of leaf per plant. The result corroborates with the findings of Akongwubel *et al.* (2012) [3], Okonmah (2012) [34] and Ezeibekwe *et al.* (2009) [13].

It is also evident from the data presented in Table 2. That successive increase in the levels of fertilizer application significantly affected the number of leaves per plant in maize. Application of 100% RDF recorded maximum number of green leaves per plant in 30 DAS (7.07 cm), 60 DAS (13.52

cm) and 90 DAS (14.54 cm). Whereas lowest number of leaves was recorded where no recommended dose of fertilizer was given. Higher number of leaves with increase in fertilizer level may be due to the fact that application of nitrogen increases the plant height which resulted in more node and internode which subsequently increase the number of leaves per plant (Amin, 2011) [6].

Application of different levels of Zinc shows increasing levels of zinc up to 30 kg ha^{-1} Zn significantly increases numbers of leaf per plant during 60 DAS (12.38) and 90 DAS (13.06) growth stages (Table 2). It is noteworthy that in all the above cited stages treatment Z_2 (15 kg ha^{-1} Zn) was found to be at par with that of Z_3 (30 kg ha^{-1} Zn). Significantly higher numbers of leaf in zinc applied treatment might be due to the positive stimulatory effect of zinc on most of physiological as well as metabolic process of plant. The findings are in line with the results of Kumar *et al.* (2017) [26] and Marngar and Dawson (2017) [29].

Shoot dry matter (g plant^{-1})

A critical examination of data presented in table 2 revealed that, application of poultry manure resulted in significantly highest dry mater accumulation in maize plant at all the growth stages of maize plants i.e., 30 DAS, 60 DAS and 90 DAS. However, during 90 DAS application of FYM @ 10 t/ha produced statistically par effect as that of poultry manure @4 t/ha on dry matter accumulation of maize plant. The exceptional higher performance of poultry manure at all the growth stages of crop regarding dry matter accumulation can be credited to its higher content of phosphorus and other beneficial micronutrient, which encourages early root development required for better growth ultimately resulting in increased accumulation of dry matter in plants. The findings are similar to Madhavi *et al.* (1995) [27] and Ezeibekwe *et al.* (2009) [13].

Application of recommended dose of fertilizer (RDF) up to 100% RDF significantly increases dry matter accumulation at all the growth stages. Higher rate of growth and dry matter accumulation with increase in level of RDF was due to more plant height, greater size of photosynthetic system as evident by leaf area and possibly higher rate of photosynthesis due to balance nutrition. The result, generally, are in harmony with the findings of Madhavi *et al.* (1995) [27] and Ezeibekwe *et al.* (2009) [13].

Increasing levels of Zinc application @ of 30 kg ha^{-1} Zn recorded maximum value of dry matter accumulation at all the growth stages i.e. 30 DAS, 60 DAS and 90 DAS. The dry matter of maize was found to be increasing with application of zinc at almost every stage of growth this response can be attributed to stimulatory effect of zinc on the synthesis of tryptophan in plant which is a precursor for the production of growth regulators like auxin, indole acetic acid and cytokinin which in turn increases cell division, cell elongation and root growth, finally promotes the dry matter production. The above findings are in harmony with the findings of Kumar and Bohra (2014) [25], Meena *et al.* (2013) [30] and Tariq *et al.* (2014) [43].

Application poultry in combination with 100% recommended dose of fertilizer (M_2F_3) was found to accumulate highest dry matter in maize plants during 30 DAS and 60 DAS with the value of 13.48 g plant^{-1} and 100.44 g plant^{-1}, respectively which was at par with M_2F_2 (poultry manure with 50% RDF). The positive effect of the combination of M_2F_3 (poultry manure and 100% RDF) on dry matter at almost all the stages of growth can be realized from the fact that crop under this treatment has comparatively more extractable and more nutrient available in the field in compared to other treatment combination. This have ultimately resulted in higher dry matter accumulation. The results are in line with the findings of Unagwu *et al.* (2012) [44].

There was significant interaction between RDF and Zinc application when it came for dry matter accumulation in maize plants. At every growth stage i.e., 30 DAS, 60 DAS and 90 DAS the combination of 100% RDF and Zinc application @ 30 kg ha^{-1} produced the highest dry matter in maize plants. The positive effect of RDF and Zinc may be due to the fact that the combination is providing optimum nutrition involving combination of all the beneficial nutrients. Increasing available fertility level could be providing the right amount of nutrients at critical growth stages. Higher level of RDF also improved protein synthesis leading there by to rapid cell division and enlargement which ultimately resulted to vigorous plant growth. The above finding is in consistent with the findings of Ashoka *et al.* (2009) [10] and Azab (2015) [11].

Leaf area index

The data revealed revealed maximum leaf area index (LAI) at 60 DAS and 90 DAS was found with application of poultry manure @ 4 t/ha. Better performance of poultry manure could be attributed to the essential nutrient present in the poultry manure which must have increased the photosynthetic efficiency and promote more vigorous growth. The finding corroborates with the report of Amakinde and Ayoola (2009) [4], Okonmah (2012) [34] and Ezeibekwe *et al.* (2009) [13].

A significantly higher LAI was recorded where 100% RDF was applied at all the growth stages of crop (Table 2). Second highest LAI value was recorded in the plot where 50% RDF was applied and the lowest LAI was recorded where no fertilizer (0% RDF) was given. The higher values of LAI due to increase level of RDF might be associated with increased availability of Nitrogen, Phosphorus and Potassium providing balanced nutrition which plays important role in rapid cell division and elongation in meristematic plant tissue. The present results are in agreement with the findings of Jeet *et al.* (2012) [20] and Singh and Nepalia (2009) [41].

Application of higher level of Zinc up to 30 kg/ha Zinc recorded maximum LAI during 60 DAS and 90 DAS stages. However, the response from Z_3 was at par with those of Z_2 and the lowest value was recorded in the plot where no Zinc was applied. LAI being the growth parameter must have increased with the application of Zinc as application of Zinc increase the cell division, cell elongation, chlorophyll and photosynthesis of the leaf or the plant. Same result was recorded by Sawar *et al.* (2012), Arya and Singh (2001) and Amanullah *et al.* (2016) [5].

Crop growth rate (g day^{-1})

Crop growth rate at different growth stages was significantly affected by application of RDF and Zinc (Table 2). Significantly higher value of crop growth rate was recorded in all growth stages at 30 DAS, 60 DAS and 90 DAS where 100% RDF was incorporated. This may be attributed to better nutrient availability and nitrogen use efficiency which might enhance the rate of cell division and elongation thereby providing better overall growth of plant resulting in increased CGR. Similar findings were also reported by Kumar and

Bohra (2014) [25] and Sobhana *et al.* (2012) [42]. Similar beneficial effect on CGR with increasing application of Zn was evident from the data. However, Z_3 (30 kg ha^{-1} $ZnSO_4$) produced significantly highest CGR at all growth stages of maize plants but during early growth stages i.e., 30 DAS and 60 DAS it was statistically at par with that of the Z_2 (30 kg ha^{-1} $ZnSO_4$). The above result might be due to the involvement of Zinc in auxin metabolism which ultimately led to higher hormonal activity and growth of the plant. Kumar and Bohra (2014) [25], Tariq *et al.* (2014) [43], Meena *et al.* (2013) [30] also reported finding which are similar to the above result. Interaction of RDF and Zn treatments was also significant for CGR only at 90 DAS. The highest CGR (4.36 g day^{-1}) was evident in the maize plants of the treatment where 100% RDF and Zinc @ 30 kg/ha (F_3Z_3) was incorporated. However it was at par with 100% RDF and Zinc @ 15 kg/ha (F_3Z_2) i.e., 4.15 g day^{-1}. Lowest value of CGR was recorded where combination of 0% RDF and 0 kg/ha Zinc (F_1Z_1) was given. Combination of the nutrient elements attributed to the favourable nutritional status of the soil making it more extractable and more nutrient available for the plant. Apart from providing nutrients, application of RDF must have also showed synergistic effects by enhancing micronutrient uptake and utilization which resulted in better crop growth rate. The findings are in line with the finding of Kumar and Bohra (2014) [25].

Stover yield (kg ha^{-1})

The data presented in table 2 revealed that higher level of recommended dose of fertilizers @100% RDF results in significantly higher stover yield as compared to 0%RDF and 50% RDF. Singh *et al*. (2000), Sanjeev *et al*. (1997) reported that stover yield increased with the increase in levels of RDF application. Similar improvement in stover yield was also recorded with increase in RDF levels by Krishnamurthy *et al*. (1974).

Yield (kg ha^{-1})

Significant effect of manure, RDF, Zn levels, interaction of manure with Zn levels and interaction of RDF with Zinc levels on grain yield are evident as presented in table 2. Incorporation of poultry manure @4 t/ha resulted in significantly higher grain yield of 3288.98 kg ha^{-1} followed by FYM (3115.13 kg ha^{-1}) and vermicompost (3026.72 kg ha^{-1}). The marked increase in yield with the application of poultry manure can be ascribed not only to adequate supply of nutrients but also to their major role in nutrient availability of soil to plant. High yield due to poultry manure and FYM can also be ascribed to their positive influence on maintaining balance source sink relationship. Similar result was reported by Okoroafor *et al.* (2013) [35] and Obi and Ebo (1995) [33]. In case of RDF application an increase in yield was evident with subsequent increase in the levels of RDF where highest yield was recorded from F_3 (100% RDF). This may be the implications of the better nitrogen use efficiency and better availability of macro nutrients in the treatments receiving RDF. And the present treatment provides the most favourable condition as compare to 50% or 0% RDF. The current findings are in complete agreement with the findings of Sharma and Gupta (1998) [40], Maqsood *et al.* (2001) [28]; Kogbe and Adediran (2003) [24]; and Sharar *et al*. (2003).

Similarly, the effect of Zn on yield showed significant increase in yield. It is observed that 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. Significantly higher yield of the crop due to application of Zinc could be due to availability of Zinc which increased activity of meristematic cell and cell elongation which in turn improved the vegetative growth which eventually contributed to better dry matter production further reflected in yield attributing character ultimately the yield of the crop under the present treatment was recorded significantly high. The result, generally are in harmony with the finding of Khan *et al.* (2014) [22], Mohsin *et al.* (2014) [31] Arya and Singh (2000) [8], Kakar *et al.* (2006) [21], Raskar *et al.* (2012) [37] and Hossain *et al.* (2008) [17].

Among the interaction of manure with Zn level, highest grain yield, *viz*., 3537.89 kg ha^{-1} from application of poultry manure with 30 kg ha^{-1} $ZnSO_4$ (M_2Z_3). Poultry manure, which content high concentration of nitrogen, phosphorus potassium and other essential mineral nutrients, in combination with zinc enhanced the growth and yield of the crop Abdelmawgoud *et al.* (2005) [1]. The result is in line with the finds of Sawar *et al.* (2012) and Saleem *et al.* (2017) [38]. The critical examination of the data revealed that yield of maize was found to be significantly affected by combined application of Zinc and fertilizer. Among the treatment combination maximum yield was recorded in F_3Z_3 (4104.83 kg ha^{-1}) treatment combination. Positive interaction effect of RDF and Zinc on yield of maize can be attributed to increased total dry matter production as a result of better uptake of Zn and NPK and their translocation to reproductive parts. Better or higher yield attributing character was the main cause of increased maize yield in combined application of Zn @30 Kg Zn and RDF@ 100%. Similar result was recorded by Abrol *et al.* (2007) [2], and Ashoka and Sunitha (2011) [9].

Economics

The perusal study of table2 revealed that The Total cost of cultivation in production of Maize was found to be highest (₹54223.5 ha-1) in T27 (M3F3Z3) while the lowest was observed in T1 (M1F1Z1). And highest gross return of ₹112400.00 ha-1 was recorded in T18 (M2F3Z3). Net Income Close observation of the provided data on Table2. Revealed that maximum net return was recorded in T18 (M2F3Z3) with the value of ₹61430.67 ha-1. B: C Ratio the Pooled maximum benefit cost ratio (B: C) was recorded in T5 (M1F2Z2) and T8 (M1F3Z2) with the value of 2.54 each.

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