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Long term integrated nutrient management in maize (*Zea mays* L.) system under northern hill region of Chhattisgarh

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Abstract
Long term trial was conducted for five years from 2018 to 2022 during the rainy season at Raj Mohini Devi College of Agriculture and Research Station, Ambikapur, Chhattisgarh to examine the effect of INM methods on overall performance of maize. 11 treatments viz., T_1- Unmanured, T_2- 100% RDF, T_3- 75% RDF, T_4- 50% RDF, T_5- FYM 10 t ha^{-1} + Azotobacter, T_6- Maize + legume intercropping with FYM 10 t ha^{-1} + Azotobacter, T_7- 100% RDF + 5 t ha^{-1} FYM, T_8- 75% RDF+ 5 t ha^{-1} FYM, T_9- 50% RDF+ 5 t ha^{-1} FYM, T_{10}- 100% RDF+ 5 kg Zn ha^{-1} and T_{11}- FYM 5 t ha^{-1} were laid out in randomized block design with three replications. The results revealed that significantly higher plant height, number of cobs ha^{-1}, cob length, cob girth, number of grain rows cob^{-1}, number of grains row^{-1}, seed yield (7360 kg ha^{-1}), stover yield (17216 kg ha^{-1}), net return (₹ 77229 ha^{-1}) and B:C ratio (2.00) of maize were recorded under treatment T_7- 100% RDF + 5 t ha^{-1} FYM.

Keywords: Azotobacter, FYM, Integrated nutrient management, legume intercropping

Introduction
Maize (*Zea mays* L.) has been an important cereal because of its great production potential and adoptability to wide range of environmental conditions. Maize occupies an important place in Indian economy also known as the "Queen of Cereals". Rice - rice was dominant cropping system in the Northern hills of Chhattisgarh, which is now shifting towards mono-cropping of rice or maize due to climate change. Maize contributes 24.97% to the total cereal production (MoALD, 2020) [6]. With growing concern about the human health, soil quality and environmental safety, need has been felt to rethink over the prevailing agricultural practices, especially the nutrient management. Thus, organic source of nutrient supply has distinct advantages of sustainability of crop production and judicious combination of organic and inorganic fertilizers helps to sustain soil fertility since the mineral elements contained in it get changed to available forms that could be readily taken up by plants such as nitrates, exchangeable phosphorous, soluble potassium, calcium, manganese *etc* (Rao *et al*., 2002) [10].
Integrated Nutrient Management (INM) - using organic manures with mineral fertilizers is advocated as viable approach not only in maintaining and sustaining proper plant growth, nutrient uptake & productivity, but also in providing stability to crop production. The appropriate & conjunctive application of suitable nutrients through organic and inorganic way by solely or in combined form can provide the solutions to increase in the price of inorganic fertilizers & deterioration effect of soil fertility and productivity. (Bhandari *et al*., 2021) [1]. Application of NPK fertilizers only showed negative impact and reduced organic content of soil by 0.05% in three years. The increase in organic carbon content in the manorial treatment combination is attributed to the direct incorporation of organic matter in the soil. Gundlur *et al*., (2015) [3] stated 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. Therefore, in recent agriculture, the use of chemical fertilizers cannot be ruled completely. However, there is a need for integrated application of alternate sources of nutrient for sustaining the desired crop productivity. Biofertilizers are low-cost and ecofriendly input and have tremendous potential for supplying nutrients which may reduce the chemical fertilizer dose by 25-50%. Hence, an effort was made to achieve the potential yield of maize through adopting long term INM experiment.

Materials and Methods

Field experiment was conducted for five successive years from 2018 to 2022 during rainy (*kharif*) season at Raj Mohini Devi College of Agriculture and Research Station, Ambikapur, Chhattisgarh situated in Northern hill zone of Chhattisgarh. The soil of experimental field was sandy loam in texture slightly acidic, low in available nitrogen (234.72 kg ha^{-1}), and medium in organic carbon (0.56%), phosphorus (8.4 kg ha^{-1}) and potassium (268 kg ha^{-1}). The experiment was laid out in randomized block design with 3 repetitions. The treatment comprised 11 treatments *i.e.*, T_1- Unmanured, T_2- 100% RDF (150:80:60 kg NPK ha^{-1}), T_3- 75% RDF (112:60:45 kg NPK ha^{-1}), T_4- 50% RDF (75:40:30 kg NPK ha^{-1}), T_5- FYM 10 t ha^{-1} + Azotobacter, T_6- Maize + legume intercropping with FYM 10 t ha^{-1} + Azotobacter, T_7- 100% RDF + 5 t ha^{-1} FYM, T_8- 75% RDF+ 5 t ha^{-1} FYM, T_9- 50% RDF+ 5 t ha^{-1} FYM, T_{10}- 100% RDF+ 5 kg Zn ha^{-1}, T_{11}- FYM 5 t ha^{-1} (state practice: 120:60:40 kg NPK ha^{-1}). Maize variety NK-30 was sown in plots of 15 m^2 by maintaining the spacing of 60 x 20 cm. Nutrients were applied as per treatments. Recommended dose of fertilizer was 150: 80: 60 kg NPK ha^{-1}. Nutrients were applied through inorganic fertilizers viz. Iffco (12:32:16), urea (46% N) and MOP (60% K) integrated with organic manure *viz.*, 5t FYM and biofertilizer *viz.*, Azotobactor. In treatment T_6, cowpea was sown as intercrop with maize. Based on nutrient content the quantity of fertilizers to be applied were computed for a hectare and then for a plot of 15 m^2.The data recorded related to various parameters were preliminary tabulated and subjected to statistical analysis. The influence of different treatments were tested with ‘F’ test, wherever ‘F’ test shown their significance, the treatments were compared by critical difference at 5% level of significance according to the procedure given by Gomez and Gomez (1984) [2].

Results and Discussion

Growth attributes

Plant population of maize was found to be differed non-significantly due to various integrated nutrient management practices. Data regarding growth attributes *viz.*, plant height, days to 50% tasseling and silking (Table 1) indicate that significantly taller plants were recorded under treatment, T_7- 100% RDF + 5 t ha^{-1} FYM as compared to others, but it was at par to T_2- 100% RDF,T_{10}- 100% RDF+ 5 kg Zn ha^{-1} and T_8- 75% RDF+ 5 t ha^{-1} FYM. Data revealed that days to 50% tasseling and silking did not varied significantly among treatments, however it was recorded minimum under treatments, T_7- 100% RDF + 5 t ha^{-1} FYM and T_{10}- 100% RDF+ 5 kg Zn ha^{-1}. Application of 100% RDF with FYM may increased the availability of essential nutrients to crop there by increased growth components. Higher plant height in FYM combined plots might be due to the continuous steady release of nutrients, might have enabled the leaf area duration to expand, which favouring the plants to increment the photosynthetic rate which in turn, could have led to higher accumulation of dry matter. FYM serve as a reservoir of macro, secondary and micro nutrients, many hormones, antibiotics and organic matter content etc. Organic matter content is the major natural source of microbial energy (Painkra *et al.*, 2018) [7]. These results were in the agreement with the findings of Painkra *et al.* (2018) [7] and Patel *et al.* (2021) [8].

Yield attributes and yield

Among INM practices, number of cobs ha^{-1} was recorded significantly higher under treatment T_7- 100% RDF + 5 t ha^{-1} FYM as compared to others, but it was at par to T_{10}- 100% RDF+ 5 kg Zn ha^{-1}, T_8- 75% RDF+ 5 t ha^{-1} FYM, T_2- 100% RDF, T_{11}- FYM 5 t ha^{-1} (state practice: 120:60:40 kg NPK ha^{-1}), T_9- 50% RDF+ 5 t ha^{-1} FYM and T_3- 75% RDF. Further, yield attributes viz., cob length, cob girth, number of grain rows cob^{-1} and number of grains row^{-1} were recorded significantly maximum under treatment, T_7- 100% RDF + 5 t ha^{-1} FYM, which was at par to treatments, T_2- 100% RDF, T_{10}- 100% RDF + 5 kg Zn ha^{-1} and T_8- 75% RDF+ 5 t ha^{-1} FYM. Further, cob girth and number of grain rows cob^{-1} was also at par to T_3- 75% RDF, however, number of grain rows cob^{-1} was also at par to treatment T_9- 50% RDF+ 5 t ha^{-1} FYM. Treatment T_7- 100% RDF + 5 t ha^{-1} FYM had significantly higher seed yield (7360 kg ha^{-1}) and stover yield (17216 kg ha^{-1}) over others which was 68.57 and 68.22% higher that the yield obtained under unmanured control (Table 1). The increase in seed yield can be traced back to the significant increase in the yield components like cob length, cob girth, number of grain rows cob^{-1} and number of grains row^{-1}, which were more pronounced due to the application FYM with recommended dose of fertilizer might be associated to better amelioration, enhanced mobilization and more supply of nutrients from the soil and soil microbial activities through the production of organic acids and improved soil physical conditions consequently led to the increased crop productivity. Results are in accordance to Kaleeswari *et al.* (2012) [4], Raman and Suganya (2018) [9] and Patel *et al.* (2021) [8].

Economics

Significantly higher net return (₹ 77229 ha^{-1}) and B:C (2.00) ratio was computed for the treatment, T_7- 100% RDF + 5 t ha^{-1} FYM than rest of the treatments. However, in case of B:C ratio, it was at par to treatment T_2- 100% RDF (Table 1). The higher net return and B: C ratio under above treatments was due to the fact that higher seed and stover yields associated with lower cost of cultivation. Similar results were also found by Mathukia *et al.* (2014), Painkra *et al.* (2018) [7] and Patel *et al.* (2021) [8]

Table 1: Effect of integrated nutrient management on overall performance of maize (pooled data of 5 years)

Treatment		Plants ('000/ha)	Plant height (cm)	Day to 50% tasseling	Day to 50% silking	Cobs ('000/ha)	Cobs Length (cm)	Cobs Girth (cm)	Grain rows/ cob	Grains/ row	Grain yield (kg/ha)	Stover yield (kg/ha)	Net returns (Rs./ha)	B:C ratio
T_1	Unmanured	59.7	131.9	55	56	41.2	10.3	10.2	9	21	2313	5471	9114	0.33
T_2	100% RDF	64.9	236.2	53	55	64.2	18.9	14.5	15	37	6836	15803	71795	1.99
T_3	75% RDF	64.5	225.4	53	55	63.3	17.6	14.1	13	33	5926	13897	59528	1.73
T_4	50% RDF	64.9	204.9	54	55	62.3	14.3	13.1	13	29	4963	11725	45502	1.46
T_5	FYM 10 t ha^{-1} + Azotobacter	64.2	160.0	54	56	46.9	10.2	12.1	11	22	3291	7154	18368	0.60
T_6	Maize + legume intercropping with FYM 10 t ha^{-1} + Azotobacter	64.3	171.8	54	56	49.1	11.9	12.2	11	23	4162	7701	28079	0.78
T_7	100% RDF + 5 t ha^{-1} FYM	65.3	246.4	52	54	65.0	19.3	14.7	15	38	7360	17216	77229	2.00
T_8	75% RDF+ 5 t ha^{-1} FYM	64.9	231.2	53	55	64.6	18.3	14.1	14	36	6036	14161	58564	1.58
T_9	50% RDF+ 5 t ha^{-1} FYM	64.6	214.2	53	56	63.5	15.3	13.5	13	30	5441	13105	50514	1.48
T_{10}	100% RDF+ 5 kg Zn ha^{-1}	65.2	232.4	52	54	64.8	18.7	14.5	14	37	6595	15394	67136	1.82
T_{11}	FYM 5 t ha^{-1} (state practice: 120:60:40 kg NPK ha^{-1})	66.4	206.2	53	55	64.0	15.1	13.1	13	30	5163	11730	44783	1.17
SEm±		1.76	5.68	1.45	1.50	1.62	0.43	0.36	0.63	0.86	150.44	346.91	1449.72	0.04
CD (P=0.05)		NS	16.77	NS	NS	4.78	1.28	1.08	1.87	2.54	443.79	1023.38	4276.66	0.12

Conclusion

Salient findings of five year investigation on maize system concluded that the combined sources of nutrient i.e., 100% RDF + 5 t ha^{-1} FYM was most suitable for increasing growth, yield and profitability of maize.

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