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Chitra Kashyap
M.Sc. Scholar, Department of Agronomy, ITM University, Gwalior, Madhya Pradesh, India

Phool Singh Hindoriya
Assistant Professor, Department of Agronomy, ITM University, Gwalior, Madhya Pradesh, India

Satish Kumar
Assistant Professor, Department of Agronomy, ITM University, Gwalior, Madhya Pradesh, India

Pushpendra Dhakad
M.Sc. Scholar, Department of Agronomy, ITM University, Gwalior, Madhya Pradesh, India

Corresponding Author:
Chitra Kashyap
M.Sc. Scholar, Department of Agronomy, ITM University, Gwalior, Madhya Pradesh, India

Effect of integrated nutrient management on growth and yield of maize (*Zea mays* L.)

Chitra Kashyap, Phool Singh Hindoriya, Satish Kumar and Pushpendra Dhakad

Abstract
A field study was conducted in *kharif* season during the year 2021-22 at the Crop research centre -1 of Department of Agronomy, School of Agriculture, ITM University, Gwalior (M.P.). Significantly higher values of growth parameters and yield attributes *viz*., Plant height at harvest, number of leaves/plant at harvest, dry matter accumulation at harvest and yield attributes such as number of cobs/plant, number of grain/cob, grain yield and straw yield parameter were observed in the treatments 100% RDF + FYM followed by 100% RDF, 75%RDF + Sulphur + FYM + Azospirillum and 75% RDF + FYM (T_3), However, significantly minimum values of growth parameters and yield attributes such as plant height at harvest, number of leaves/plant at harvest, dry matter accumulation at harvest and yield attributes such as number of cobs/plant, number of grain/cob, grain yield and straw yield parameter are seen in Control (T_0).
The economics point of view, the application of 100% RDF + FYM (T_2) resulted in higher net return (₹ 57931) which was closely followed by (T_1) 100% RDF, (₹ 50497) and lower net return (₹ 22686) was observed in control (T_0). The higher B-C ratio (1.91) was recorded in 100% RDF + FYM (T_2) and followed by (T_1) 100% RDF (1.55) and lower B-C ratio (0.88) was recorded in control T_0.

Keywords: Integrated nutrient, management, maize, yield, *Zea mays* L.

Introduction
As a food, feed, and industrial raw material, maize (*Zea mays* L.) is one of the most significant cereal crops in the global agricultural economy. Among the countries that grow maize, India ranks fourth in area and seventh in production, accounting for about 4% of global maize area and 2% of total production. Around the world, it is grown on roughly 2.60 million hectares, producing 1162 million tonnes with a productivity of 5600 kg/ha and having a broader variety of soil, climate, biodiversity, and management techniques. (Anonymes 2022-23). Consumption of maize is largely influenced by the European Union, which is followed by a number of big producers, including Brazil, Mexico, India, and Canada. It has a global production of 18.9 million tonnes and a total area of 19.65 million hectares. In India, 2.60 lakh hectares of maize were planted in 2022–2023, yielding 35.91 million metric tons at a productivity of 2310 kg ha^{-1}. (Anonymes, 2022-23).
Andhra Pradesh, Karnataka, Rajasthan, Maharashtra, Bihar, Uttar Pradesh, Madhya Pradesh, and Himachal Pradesh are the main states that cultivate maize and account for more than 80% of global production. The main crop in Madhya Pradesh's Chhindwara district in Kharif 2021–2022 is maize. Corn City is the nickname for Chhindwara. Due to the presence of adequate soil and a climate for corn growth, corn is planted throughout the entire district. Chhindwara planted 4.07 lakh hectares of maize in 2022–2023, producing 31 lakh metric tons at a productivity of 3190 kg ha-1 (AICRP on Maize, 2022-23). The utilization of synthetic compost can change the soil pH, upset advantageous microbial environment, increment vermin and even add to the arrival of ozone depleting substances. Accordingly, under this present circumstance, integrated nutrient management is best options for supportable harvest efficiency while keep up with soil ripeness status in maize and other cereal based cropping system (Singh *et al*., 2019) [20]. This ultimately improves crop yield. The amount of animal waste and crop residue on hand is insufficient to meet the nation's crop production needs. As a result, it appears that the best option is to use organic waste as much as possible and combine it with biofertilizers and chemical fertilizers to create integrated manure. (Balemi *et al*., 2019) [4].

Vermicompost and farmyard manure are two examples of organic manures that are crucial parts of integrated nutrient management. Micronutrients are provided in trace amounts by organic manures, which are typically not provided by farmers as pure fertilizers. The best plant foods are jeevamrut and panchagavya, which contain nearly all of the essential plant nutrients (nitrogen, phosphorus, potassium, zinc, copper, manganese, etc.), enzymes (acid phosphatise, alkaline phosphatise, dehydrogenase, etc.), and microbes (bacteria, fungi, actinomycetes, free living nitrogen fixers, and phosphorus solubilizing organisms). This improves and directly enhances plant metabolism resulting better growth and development (Ghosh *et al.* 2019) [7]. Therefore, the only solution that should be supported in order to reduce input costs and enhance soil health is organic farming. By enhancing the physico-chemical characteristics of the soil, the use of organic manures like FYM and vermicompost not only helps to sustain soil productivity but also increases the effectiveness of chemical fertilizers that are used. By lowering chemical toxicity to the bacteria and so promoting their proliferation, it mitigates the negative effects of chemical fertilizers applied to the soil. Additionally, organic manure increases the soil's ability to store water and exchange cations, which results in a more efficient supply of nutrients to crop plants and, ultimately, more profitable harvests. (Ariraman *et al.* 2020) [3].

To achieve the highest possible economic output, nitrogen is typically supplied to soil as a base. Nitrogen application to the soil frequently reduces the effectiveness of the relevant nutrients. The nitrogen added to the soil experiences a number of alterations and losses due to leaching and volatilization. In addition, unfavorable soil conditions like acidity, alkalinity, water logging, and insufficient moisture would further prevent crops from accessing nitrogen. Nutrient top dressing or foliar spray is essential to prevent or lessen the severity of such a problem. This application could be used to prevent the depletion of nitrogen in the leaves and the subsequent decline in photosynthetic rate during this time due to inadequate nutrient uptake from the soil and the transfer of nitrogen from the leaves to the growing plant. (Adhikari *et al.* (2021) [2]. After nitrogen, phosphorus, and potassium, sulphur is increasingly becoming acknowledged as the fourth major plant nutrient. Field tests on maize in various agroclimatic regions of the nation revealed that sulphur applications up to 45 kg ha resulted in greater growth, yield, and yield characteristics, as well as protein content in relation to quality indices. However, depending on the initial sulphur condition of the soil, S nutrition absorption by plants rises with the application of sulfur up to 60 kg ha^{-1}. (Stewart *et al.* 2021) [21].

Materials and Methods

The experiment was conducted at the Agriculture Farm, School of Agriculture, Department of Agronomy, ITM University, Gwalior (M.P.). Gwalior is situated in Gird zone at the latitude of 26°.14' North and longitude 78.19' east in Madhya Pradesh. This region has a very hot and dry summer and a cold winter, with a humid subtropical climate. Monsoon season often begins in the final week of June. The soil was sandy clay in texture and slightly alkaline in reaction (*p*H 7.91) with electric conductivity 0.29 dS/m, low in available N (246.25 kg/ha), and medium in available P (11.37 kg/ ha), available K (205.64 kg/ha). A combination of 9 treatments, *viz*., Control (0:0:0) (T_0), 100% RDF (T_1), 100% RDF + FYM (T_2), 75% RDF + FYM (T_3), 50% RDF + Sulphur + FYM (T_4), 75%RDF + Sulphur + FYM + Azospirillum (T_5), 50% RDF + Sulphur + FYM + Azospirillum + PSB (T_6), 50% RDF + FYM + Panchgavya (3%) (3%) (T_7), 50% RDF + Sulphur + FYM + Azospirillum + PSB + Panchgavya (T_8) and 50% RDF + Sulphur + FYM + Azospirillum + PSB + Panchgavya + Jeevaamrut (T_9) were tested in a randomized block design and replicated thrice. Maize 'ZM8' was sown at 60 cm × 25 cm spacing on 2021-22. The recommended dose of fertilizers are RDF: 150:60:60 Kg ha^{-1} (N:P:K), FYM: 10 tonn ha^{-1}, SULPHUR: 50 kg ha^{-1}, PANCHGAVYA: 3%, AZOSPIRILLUM: 10 g kg^{-1} of seed, PSB: 10 ml $kg^{-1}$of seed, JEEVAAMRUT: 200 l ha $^{-1}$ applied as per treatments. Nitrogen and P2O5 were applied through urea and single superphosphate, respectively.

Results and Discussion

Growth parameters: Significantly higher values of growth parameters *viz*., plant height at harvest (Table 1), number of leaves/plant at harvest (Table 1), dry matter accumulation at harvest (Table 1) were observed in the treatments 100% RDF + FYM followed by 100% RDF, 75%RDF + Sulphur + FYM + Azospirillum and 75% RDF + FYM (T_3). The lowest value of plant height at harvest, number of leaves/plant at harvest, dry matter accumulation at harvest under Control (0:0:0) (T_0). This may be due to the expanded accessibility of supplements as the fertilizers were applied by chemical fertilizer, bio fertilizers and farmyard manure. As the use of biofertilizers will build the stockpile or accessibility of essential supplements to the host plant. The consequences of the current examination are likewise in concurrence with the discoveries of Panwar (2008) [17], Wailare *et al*., (2017) [22] and Gunjal and Chitodkar (2017) [9].

Table 1: Effect of different treatments on growth parameters on maize

Tr. No.	Treatments	Growth parameters at harvest		
		Plant height at harvest	No. of leaves at harvest	dry matter accumulation
T_0	Control (0:0:0)	160.73	8.04	198.78
T_1	100% RDF	219.38	9.85	316.66
T_2	100% RDF + FYM	232.08	10.16	335.52
T_3	75% RDF + FYM	216.03	9.43	305.78
T_4	50% RDF + Sulphur + FYM	203.18	8.35	280.51
T_5	75%RDF + Sulphur + FYM + Azospirillum	228.46	9.70	306.22
T_6	50% RDF + Sulphur + FYM + Azospirillum + PSB	205.68	8.83	289.01
T_7	50% RDF + FYM + Panchgavya (3%)	198.71	8.30	277.83
T_8	50% RDF + Sulphur + FYM + Azospirillum + PSB + Panchgavya	208.15	9.25	293.35

T_9	50% RDF + Sulphur + FYM + Azospirillum + PSB + Panchgavya + Jeevaamrut	214.35	9.41	301.03
	S.Em (±)	10.32	0.61	14.08
	C.D. (at 5%)	30.67	1.81	1485

(RDF: 150:60:60 Kg ha^{-1} (N:P:K), FYM: 10 tonn ha^{-1}, SULPHUR: 50 kg ha^{-1}, PANCHGAVYA: 3%, AZOSPIRILLUM: 10 g kg^{-1} of seed, PSB: 10 ml kg^{-1}of seed, JEEVAAMRUT: 200 l ha $^{-1}$**)**

Yield parameters

Significantly higher values of yield attributes such as number of cobs/plant (Table 2), number of grain/cob (Table 2), grain yield (Table 2) and straw yield (Table 2) parameter were observed in the treatments 100% RDF + FYM followed by 100% RDF, 75%RDF + Sulphur + FYM + Azospirillum and 75% RDF + FYM (T_3). The lowest value of number of cobs/plant, number of grain/cob, grain yield and straw yield parameter were observed under Control (0:0:0). In comparison to the other treatments, the combined application of manure and fertilizer, which included 100% RDF NPK, produced significantly greater yield attributes. The increase in yield under these treatments was caused by the beneficial effects of nutrient supplementation on the growth and yield characteristics of maize. The increase in grain yield under treatments using the organic fertilizer vermicompost and FYM could be attributed to the improvement in soil physico-chemical properties (such as pH, bulk density, infiltration rate, and microbial biomass carbon) and the optimal availability of nutrients and organic carbon, which acted as the growth and yield-enhancing characteristics of maize crop. Additionally, the ultimate plant population and yield of each individual plant, which in turn depends on the number of cobs per plant and the weight of grains per cob, are the main factors that affect the amount of grain produced by maize. As a result, higher grain yield in maize. Similar results were also reported by Khadtare *et al*., (2006) [13], Gosavi *et al*., (2009) [8], Keerthi *et al*., (2013) [12].

Table 2: Effect of different treatments on yield parameters on maize

Tr. No.	Treatments	Yield parameters			
		No. of cob/plant	No. of grain/cob	Grain yield	Straw yield
T_0	Control (0:0:0)	1.02	307.41	18.73	60.51
T_1	100% RDF	1.56	509.53	31.97	90.83
T_2	100% RDF + FYM	1.60	515.71	32.72	91.36
T_3	75% RDF + FYM	1.41	503.41	30.91	86.83
T_4	50% RDF + Sulphur + FYM	1.17	460.42	27.17	80.70
T_5	75%RDF + Sulphur + FYM + Azospirillum	1.49	506.63	31.13	88.83
T_6	50% RDF + Sulphur + FYM + Azospirillum + PSB	1.26	468.07	28.42	81.42
T_7	50% RDF + FYM + Panchgavya (3%)	1.12	454.83	26.76	79.09
T_8	50% RDF + Sulphur + FYM + Azospirillum + PSB + Panchgavya	1.34	481.33	29.43	83.85
T_9	50% RDF + Sulphur + FYM + Azospirillum + PSB + Panchgavya + Jeevaamrut	1.39	499.36	30.03	85.37
	S.Em (±)	0.06	22.17	1.84	4.99
	C.D. (at 5%)	0.41	65.87	5.47	14.84

(RDF: 150:60:60 Kg ha^{-1} (N:P:K), FYM: 10 tonn ha^{-1}, SULPHUR: 50 kg ha^{-1}, PANCHGAVYA: 3%, AZOSPIRILLUM: 10 g kg^{-1} of seed, PSB: 10 ml kg^{-1}of seed, JEEVAAMRUT: 200 l ha $^{-1}$**)**

Economics parameters

The economics point of view, (Table 3) the application of 100% RDF + FYM (T_2) resulted in higher net return (₹ 57931) which was closely followed by (T_1) 100% RDF, (₹ 50497) and lower net return (₹ 22686) was observed in control (T_0). The higher B-C ratio (1.91) was recorded in 100% RDF + FYM (T_2) and followed by (T_1) 100% RDF (1.55) and lower B-C ratio (0.88) was recorded in control T_0. This is because this treatment produces a greater economic yield. The control therapy, however, provided a minimal gross and net return. This is a result of the treatment's minimal economic yield. These results are in close conformity with the findings reported by Sujatha *et al*. (2008).

Table 3: Effect of different treatments on economics of maize

Treatment	Gross return	Net return	B:C ratio
Control (0:0:0)	48591	22686	0.88
100% RDF	88236	50497	1.55
100% RDF + FYM	83002	57931	1.91
75% RDF + FYM	73717	42312	1.35
50% RDF + Sulphur + FYM	69355	37950	1.21
75%RDF + Sulphur + FYM + Azospirillum	76860	43805	1.33
50% RDF + Sulphur + FYM + Azospirillum + PSB	63088	32233	1.04
50% RDF + FYM + Panchgavya (3%)	67050	36195	1.17
50% RDF + Sulphur + FYM + Azospirillum + PSB + Panchgavya	76860	44355	1.36
50% RDF + Sulphur + FYM + Azospirillum + PSB + Panchgavya + Jeevaamrut	78822	45767	1.38

(RDF: 150:60:60 Kg ha^{-1} (N:P:K), FYM: 10 tonn ha^{-1}, SULPHUR: 50 kg ha^{-1}, PANCHGAVYA: 3%, AZOSPIRILLUM: 10 g kg^{-1} of seed, PSB: 10 ml kg^{-1}of seed, JEEVAAMRUT: 200 l ha $^{-1}$**)**

Conclusion

Based on the one year experimentation, it is concluded that higher and economical production along with efficient nutrient management in kharif maize under Gwalior region can be achieved by 100% RDF + FYM followed by 100% RDF, 75%RDF + Sulphur + FYM + Azospirillum and 75% RDF + FYM, which suggests that the 100% RDF + FYM application is more scientific management of nutrients in crop management of maize in Gwalior region of Madhya Pradesh.

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