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ROLE OF INTEGRATED NUTRIENT MANAGEMENT ON AVAILABILITY OF MACRO AND MICRO NUTRIENTS IN SOIL AND HYBRID *KHARIF* MAIZE (*Zea mays* L.) GRAINS

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ABSTRACT

Present experiment was conducted at Student's Research Farm, P.G. Department of Agriculture, Khalsa College, Amritsar, Punjab, India in *kharif* season of year 2021-22 to find most efficient organic manure, inorganic sources of nutrients and their integration to enhance the availability of macro and micronutrients in maize (*Zea mays* L.)grains. Experimental design was randomised block design (RBD). Six treatments of integrated nutrient management were tested *viz.,* 100% recommended N through chemical fertilizer (T_1), 100% recommended N through FYM (T_2), 100% recommended N through vermicompost (T_3), 50% recommended N through chemical fertilizer + 50% recommended N through FYM (T_4), 50% recommended N through chemical fertilizer + 25% recommended N through FYM + 25% recommended N through vermicompost (T_5), 50% recommended N through FYM + 50% recommended N through vermicompost (T_6) and was replicated thrice.In soil, among all the treatments, available N was observed significantly higher in treatment T_5 (50% recommended N through chemical fertilizer + 25% recommended N through FYM + 25% recommended N through vermicompost) (200.84 kg ha^{-1}) as compared to treatment T_4(50% recommended N through chemical fertilizer + 50% recommended N through FYM) (175.63 kg ha^{-1}), T_6 (50% recommended N through FYM + 50% recommended N through vermicompost) (164.67 kg ha^{-1}), T_1(100% recommended N through chemical fertilizer)(152.62 kg ha^{-1}), T_3(100% recommended N through vermicompost) (137.92 kg ha^{-1}) and T_2(100% recommended N through FYM) (135.91 kg ha^{-1}), but in case of available P and K treatment T_4 (50% recommended N through chemical fertilizer + 50% recommended N through FYM) was found significantly higher *viz.,* 32.15 kg ha^{-1} and 369.62 kg ha^{-1} respectively when compared with other treatments. Micronutrients were found significant in soil after harvesting maize crop. Macronutrients (N,P and K) in maize grains were also determined significant. In case of micro-nutrient Cu values were found non-significant but Fe was recorded significantly higher in treatment T_4(50% recommended N through chemical fertilizer + 50% recommended N through FYM)(4.27 mg g^{-1}) followed by T_3 (100% recommended N through vermicompost) (3.71 mg g^{-1}). Zn was found significantly higher in treatment T_4 (50% recommended N through chemical fertilizer + 50% recommended N through FYM) (0.27 mg g^{-1}) and lowest in T_6(50% recommended N through FYM + 50% recommended N through vermicompost) (0.14mg g^{-1}).The value of Mn (0.08 mg g^{-1}) in treatment T_1 (100% recommended N through chemical fertilizer) and treatment T_4 (50% recommended N through chemical fertilizer + 50% recommended N through FYM) were similar and significantly higher than all other treatments. The lowest value of Mn was recorded in treatment T_6 (50% recommended N through FYM + 50% recommended N through vermicompost) (0.01 mg g^{-1}).

(Key words: Integrated nutrient management, macronutrients, micronutrients, maize grains, soil)

INTRODUCTION

Maize (*Zea mays* L.), being a C_4 plant, is one of the pulsating food grain crops under diverse agro-climatic conditions. It has yield potential far higher than any other cereal crop.Maize is the third most important cereal crop in the world after wheat and rice with respect to area and production. Maize occupied 107.8 thousand hectares, with a production of 395.1 thousand tonnes in the Punjab state during 2021-22. The average yield was 36.65q ha^{-1} (Anonymous, 2021). Among Indian states Madhya Pradesh and Karnataka has highest area under maize (15% each) followed by Maharashtra (10%), Rajasthan (9%), Uttar Pradesh (8%) and others. India ranks 4th in area and 7th in production, representing around 4 per cent of world's maize area and 2 per cent of total production. Recently, it has become one of the leading food grain crops not only in tropical and subtropical areas but even in the temperate and high hill ecological areas.

Response of crops to plant nutrients like N,P,K can be increased by the application of nutrients through

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organic sources along with chemical fertilizers and thus increased productivity.N and P play a unique role in metabolic, physiological and biochemical functions of plants (Monga and Kumar, 2022).The organic sources besides supplying N, P and K also make unavailable sources of elemental nitrogen, bound phosphates, micronutrients, and decomposed plant residues into an available form to facilitate to plant to absorb the nutrients (Chandrashekara *et al*., 2000). Application of two or more essential nutrients (Nitrogen, phosphorus with or without Potassium) is not adequate to achieve potential yield of crops.

Micronutrient deficiencies are difficult to diagnose and consequently the problem may be termed "hidden hunger" in analogy to the term used in human nutrition. Deficiency of micronutrients during the last three decades has grown in both, magnitude and extent because of increased use of high analysis fertilizers, use of high yielding crop varieties and increase in cropping intensity. This has become a major constraint to production and productivity of agricultural crops. On an average 43.0%, 12.1%, 5.4%, 5.5% and 18.3% of Indian soils are deficient in Zn, Fe, Cu, Mn and B, respectively (Majumdar and Prakash, 2018).Micronutrients are required in small amounts but they directly or indirectly affect photosynthesis and vital processes in plant such as respiration, protein synthesis, reproduction phase. Nutrient demand and acquisition in maize is associated with key vegetative or reproductive growth stages (Bender *et al*., 2013).There is a need to promote balanced fertilization for which use of appropriate multi-micronutrient mixture grades would play a big role to improve nutrients use efficiency and enhance crop productivity for food and nutritional security. So, combined application of organic sources along with inorganic fertilizers assures better nutrients uptake, high crop yield and soil productivity (Kumar *et al.,* 2009). Use of organic manures, green manuring, green leaf manuring, crops residue along with inorganic fertilizers not only reduce demand of inorganic fertilizers, but also increases the efficiency of applied nutrients due to their favourable effect on physical, chemical and biological properties of soil (Meshram *et al*., 2018)

MATERIALS AND METHODS

The present study was carried out during *kharif* season of 2021-22 at Student's Research Farm, P.G. Department of Agriculture, Khalsa College, Amritsar, Punjab, India. The geographical coordinates of the experimental site were 31^0 38'19" N and $74^0$49'50" E and the height above the sea level was 230 m. Amritsar is characterised by semi-arid climate, typical of north-west India and experiences mainly four seasons winter season (December to March), summer season (April to June), monsoon season (July to September) and post-monsoon season (October to November), where both winters and summers are extreme. The monsoon generally starts in the first week of July and mean annual rainfall fluctuate around 75 cm. The experiment was focused on maize hybrid variety NMH-1258, to check the effect of integrated nutrient management on availability of macro and micro nutrient in maize grains and soil. The seed was sown with a distance of 60 cm between rows and 20 cm between plants. The seed rate used was 20 kg ha^{-1}. The soil of experiment field was sandy loam. The soil was neutral in reaction and low in soluble salts, having normal pH (8.3), normal EC (0.21dSm^1), high organic carbon (1.34 g kg^{-1}), before sowing the crop. The field experiment was laid out in randomised block design (RBD) with six treatments of integrated nutrient management, *viz.,*100% recommended N through chemical fertilizer (T_1),100% recommended N through FYM (T_2), 100% recommended N through vermicompost (T_3), 50% recommended N through chemical fertilizer + 50% recommended N through FYM (T_4), 50% recommended N through chemical fertilizer +25% recommended N through FYM + 25% recommended N through vermicompost (T_5), 50% recommended N through FYM + 50% recommended N through vermicompost (T_6) and replicated thrice. The net plot size was 12.25m^2.For mechanical analysis of soil texture International pipette method (Piper, 1966) was used. Bulk density of soil was determined by using scoop sampler method (Blake, 1965). Beckman's glass electrode and solu-bridge conductivity meter was used to obtain pH and EC respectively as described by Jackson (1967). The available nitrogen, phosphorus, potassium status in the soil were determined as per different methods *viz.,* Micro Kjeldahl's method described by Johan Kjeldahl (1883) for N, 0.5M $NaHCO_3$ extractant method described by Olsen *et al*. (1954) for P and Flame photometric method described by Barens *et al*.(1945) for K. The micronutrients were analysed with Atomic emussion spectroscopy described by Walsh (1955).

RESULTS AND DISCUSSION

Status of soil before sowing of maize crop

The data given in Table 1 indicated the physical, chemical and mechanical properties of soil before sowing the maize crop. The amount of macronutrients (N, P and K) and micronutrients (Fe, Zn, Cu and Mn) are also presented in Table 1.

Table 1.Physical, chemical and mechanical characterstics of the soil before sowing

Mechanical	
Sand (%)	72
Silt (%)	19
Clay (%)	9
Textural class	Sandy loam
Physical	
Bulk density (mg m^{-3})	1.24
Partical density (mg m^{-3})	2.61
Chemical	
pH	8.3
EC (ds m^{-1})	0.21
Organic carbon (g kg^{-1})	1.34
Available N (kg ha^{-1})	163

Available P (kg ha^{-1})	22
Available K (kg ha^{-1})	263
Available Zn (µg g^{-1})	0.90
Available Cu (µg g^{-1})	0.66
Available Mn (µg g^{-1})	12.57
Available Fe (µg g^{-1})	13.43

Effect of integrated nutrient management on chemical properties of Soil

Available nitrogen

Data in Table 2 revealed that treatment T_5 (50% recommended N through chemical fertilizer + 25% recommended N through FYM + 25% recommended N through vermicompost) (200.84 kg ha^{-1}) was recorded significantly higher available nitrogen as compared to treatment T_4 (50% recommended N through chemical fertilizer + 50% recommended N through FYM) (175.63 kg ha^{-1}), T_6 (50% recommended N through FYM + 50% recommended N through vermicompost) (164.67 kg ha^{-1}), T_1(100% recommended N through chemical fertilizer) (152.62 kg ha^{-1}), T_3 (100% recommended N through vermicompost) (137.92 kg ha^{-1}) and T_2 (100% recommended N through FYM) (135.91 kg ha^{-1}).The results suggested that organic manures in combination with chemical fertilizers registered a considerable increase in available nitrogen. Significantly higher values of available N (246.4 kg ha^{-1}), available P (30.5kg ha^{-1}) and available K (140.9 kg ha^{-1}) with application of 50% recommended NPK dose through fertilizers (60:65:12.5) + 50% N through FYM (6 ton ha^{-1}) were found in wheat by Sandhu *et al.*(2020).

Available phosphorus

There was significantly higher accumulation of phosphorus found in the soil with treatment T_4 (50% recommended N through chemical fertilizer + 50% recommended N through FYM) (32.15 kg ha^{-1}) than other treatments (shown in Table 2). The reason behind this was the complexing of cations like Ca and Mg with organic manures which were responsible for fixation of phosphorus.Tana and Woldesenbet (2017) found that combining organic and inorganic fertilizers, such as 5 t ha^{-1} FYM, in conjunction with 50 and 75 per cent inorganic NP fertilizers, significantly improved accessible soil P (14.50 mg kg^{-1})in barley crop.

Available potassium

In this experiment treatment T_4(50% recommended N through chemical fertilizer + 50% recommended N through FYM)(369.62 kg ha^{-1}) observed significantly higher value of potassium compared to T_5 (50% recommended N through chemical fertilizer +25% recommended N through FYM + 25% recommended N through vermicompost) (331.24 kg ha^{-1}), T_6(50% recommended N through FYM + 50% recommended N through vermicompost) (336.01 kg ha^{-1}), T_3 (100% recommended N through vermicompost) (291.01 kg ha^{-1}), T_2 (100% recommendedN through FYM) (285.43 kg ha^{-1}) and T_1 (100% recommended N through chemical fertilizer) (263.21 kg ha^{-1}). Availability of potassium was increasing as a result of the use of chemical fertilizers in combination with FYM.The value of P (606 kg ha^{-1}) was evaluated significantly higher with 100% NPK+ FYM (2.45) under intensive cropping system by Kharche *et al.*(2013).

Available iron

DTPA extractable Fe was observed significantly higher in treatment T_4(50% recommended N through chemical fertilizer + 50% recommended N through FYM) (20.73 µg g^{-1}) followed by T_5(50% recommended N through chemical fertilizer +25% recommended N through FYM + 25% recommended N through vermicompost) (20.33 µg g^{-1}) and T_6(50% recommended N through FYM + 50% recommended N through vermicompost) (19.50 µg g^{-1}). The application of FYM with inorganic fertilizers increased iron content of the soil. It could be attributed to the organic chelation, which prevents iron absorption, immobilisation, and precipitation, increasing iron availability in the soil.The DTPA extractable Fe (5.34 mg kg^{-1}) level was observed significantly higher in soybean with application of 100% NPK+FYM by Meshram *et al.*(2016).

Available zinc

The level of Zn was found significantly higher in treatment T_5(50% recommended N through chemical fertilizer +25% recommended N through FYM + 25% recommended N through vermicompost) (1.37 µg g^{-1}) as compared to all other treatments. Availability of zinc increases, due to the ability of organic matter to form complexes with zinc through its functional groups. The significantly higher level of Zn (3.55 mg kg^{-1}) by application of 3/4 chemical fertilizer: 1/4 biofertilizer was also observed in mustard by Banerjee *et al.*(2011).

Available copper

There was significant value recorded in DTPA extractable copper content in soil with treatment T_5 (50% recommended N through chemical fertilizer +25% recommended N through FYM + 25% recommended N through vermicompost) (0.87 µg g^{-1}). The value of copper was recorded same in treatment T_4 (50% recommended N through chemical fertilizer + 50% recommended N through FYM) and T_6 (50% recommended N through FYM + 50% recommended N through vermicompost) *i.e.* 0.84 µg g^{-1}.The increase in available copper may be attributed to the reduction of the soil redox potential after the addition of organic sources and the chelating action of organic sources due to its decomposition which also prevents some important processes like fixation, precipitation, leaching and oxidation of micronutrients. The highest amount of available copper (0.86 ì g g^{-1}) was recorded in maize with application of 50% RDF of N,P,K through chemicals + 50% RD of N through FYM by Singh (2021).

Available manganese

In this experiment, value of available manganese was recorded significantly higher in treatment T_5 (50% recommended N through chemical fertilizer +25% recommended N through FYM + 25% recommended N through vermicompost) (23.37 µ g g^{-1}).This might be due to the FYM chelating action during its decomposition which also prevents the fixation of Mn and other micronutrients. The higher value of availability of DTPA extractable Mn (5.60 mg kg^{1}) was recorded with treatment RDF through CDU + Polymer coated DAP + Bentonite sulphur in soybean by Todmal *et al.*(2022)

Organic carbon

The level of organic carbon evaluated significantly higher in treatment T_4(50% recommended N through chemical fertilizer + 50% recommended N through FYM) (4.43 g kg^{-1}). The treatment T_5(50% recommended N through chemical fertilizer +25% recommended N through FYM + 25% recommended N through vermicompost) and T_6(50% recommended N through FYM + 50% recommended N through vermicompost) recorded less variation in organic carbon content *i.e.* 4.18 g kg^{-1} and 4.07 g kg^{-1} respectively.The lowest organic carbon was found in treatment T_1(100% recommended N through chemical fertilizer)(3.74 g kg^{-1}), because of the inclusion of carbon sources such as FYM, root biomass, and crop wastes. The organic carbon content (5.20 g kg^{-1}) was recorded significantly higher in maize with the application of 100% NPK + FYM by Brar *et al.* (2015).

Table 2.Impact of INM on macro and micronutrients in soil

Treatments	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Organic Carbon (g kg^{-1})	Fe (µg g^{-1})	Zn (µg g^{-1})	Cu (µg g^{-1})	Mn (µg g^{-1})
T_1	152.62	26.91	263.21	3.74	15.70	0.97	0.66	17.33
T_2	135.91	16.52	285.43	3.96	17.70	1.16	0.73	20.20
T_3	137.92	18.64	291.01	3.82	18.50	1.21	0.80	19.76
T_4	175.63	32.15	369.62	4.43	20.73	1.24	0.84	22.40
T_5	200.84	31.82	331.24	4.18	20.33	1.37	0.87	23.37
T_6	164.67	30.01	336.01	4.07	19.50	1.25	0.84	22.17
SE(m)±	4.38	0.79	4.58	0.28	0.04	0.02	0.02	0.02
CD at 5%	12.74	2.23	12.83	0.84	0.12	0.06	0.07	0.06

Table 3.Impact of INM on the macro and micronutrients of maize grain

Treatments	Available N (%)	Available P (%)	Available K (%)	Fe (mg g^{-1})	Zn (mg g^{-1})	Cu (mg g^{-1})	Mn (mg g^{-1})
T_1	1.50	0.26	0.42	0.85	0.20	0.03	0.08
T_2	1.32	0.20	0.40	0.69	0.16	0.03	0.06
T_3	1.35	0.23	0.42	3.71	0.16	0.03	0.07
T_4	1.60	0.29	0.49	4.27	0.27	0.04	0.08
T_5	1.48	0.27	0.44	0.82	0.15	0.03	0.07
T_6	1.48	0.25	0.45	0.49	0.14	0.02	0.01
SE(m)±	0.04	0.02	0.03	0.04	0.02	0.002	0.02
CD at 5%	0.12	0.07	0.09	0.13	0.06	-	0.06

Effect of INM on macronutrients of maize grain

An appraisal of data given in Table 3 revealed that significant difference was observed in nitrogen, phosphorus and potassium content in grains. The highest N content was recorded in treatment T_4 (50% recommended N through chemical fertilizer + 50% recommended N through FYM) (1.60%) and lowest value of nitrogen was found in treatment N_2 (100% recommended N through FYM) (1.32%).Among all the treatments,value of P was recorded significantly higher in treatment T_4 (50% recommended N through chemical fertilizer + 50% recommended N through FYM)(0.29%) as compared to other treatments. All treatments recorded variation in phosphorus. The lowest P content was found in treatment T_2 (100% recommended N through FYM) (0.20%). Available N, P and K were found at par after harvest of the crop. This might be due to adequate nutrient supply through fertilizer application and continuous transformation of nutrient from soil reserve.The K content was recorded significantly higher in treatment T_4(50% recommended N through chemical fertilizer + 50% recommended N through FYM) (0.49%) and lowest in treatment T_2(100% recommended N through FYM) (0.40%).

These results of N, P and K were in line with the findings of Priyanka (2018). They recorded significantly higher values of N (1.62%), P (0.33%) and K (0.50%) by application of 150% NPK in maize.

Effect of INM on micronutrients of maize grain

The available Fe content was recorded significantly higher in treatment T_4 (50% recommended N through chemical fertilizer + 50% recommended N through FYM) (4.27 mg g^{-1}) followed by T_3 (100% recommended N through vermicompost) (3.71 mg g^{-1}). The treatment T_1(100% recommended N through chemical fertilizer) and T_5(50% recommended N through chemical fertilizer +25% recommended N through FYM + 25% recommended N through vermicompost) were at par with values of iron 0.85 mg g^{-1} and 0.82 mg g^{-1} respectively.The Zn content found significantly higher in treatment T_4 (50% recommended N through chemical fertilizer + 50% recommended N through FYM)(0.27 mg g^{-1}) and lower in treatment T_6 (50% recommended N through FYM + 50% recommended N through vermicompost) (0.14 mg g^{-1}). Among all the treatments, result of Cu content in grains was recorded non-significant. The highest value was found in treatment T_4 (50% recommended N through chemical fertilizer + 50% recommended N through FYM) (0.04 mg g^{-1}) and lowest in T_6(50% recommended N through FYM + 50% recommended N through vermicompost) (0.02 mg g^{-1}). In case of Mn, the results were significant.The values of Mn (0.08 mg g^{-1}) in treatment T_1 (100% recommended N through chemical fertilizer) and treatment T_4 (50% recommended N through chemical fertilizer + 50% recommended N through FYM) were similar and significantly higher than all other treatments.The lowest value of Mn was recorded in treatment T_6 (50% recommended N through FYM + 50% recommended N through vermicompost) (0.01 mg g^{-1}). Similar content of micronutrients Fe (108 mg kg^{-1}), Zn (22.40 mg kg^{-1}), Cu (12.54 mg kg^{-1}) and Mn (66.57 mg kg^{-1}) was also recorded in maize with application of 100% NPK + FYM 10 t ha^{-1} by Priyanka (2018).

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