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Physiological parameter of Maize as Influenced by INM Modules under Maize-Chickpea Sequence in a Vertisol of Central India

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A B S T R A C T

A present investigation was conducted at Research Farm, ICAR-Indian Institute of Soil Science, Bhopal during 2017-18 and 2018-19 to study the performance of maize crop under various nutrient management modules in a Vertisol. The field experiment was laid out in RBD consisting of 12 different integrated nutrient management (INM) modules in three replications. The maize (cv. Pro Agro - 4212) and chickpea (cv. JG-315) was grown in *kharif* and *rabi* seasons during 2017 and 2018 with an identified set of treatments. The performance of crops under these treatments was assessed in terms of plant height and seed index. Similarly, the soil physico-chemical properties were also assessed at crop harvest. Finally, the correlation among various studied parameters was worked out. The results revealed that the INM modules positively influenced the performance and productivity of maize crop as compared to the sole inorganic fertilizer application. Besides the superior crop performance, the integrated nutrient management modules significantly (p=0.05) enhanced and improved soil health in terms of soil physico-chemical properties. Among the various modules, (1) application of 75% STCR dose + FYM @ 5t ha^{-1} to maize, (2) application of FYM @ 20t ha^{-1} to maize increased the crop growth and seed index in maize, improved soil health and reflected as a viable technique in improving soil nutrient availability on a sustainable basis.

Introduction

Maize (*Zea mays* L.) is one of the most important crops cultivated throughout the worldas food, feed and industrial raw material which ranked third largest cereals following rice and wheat, respectively (FAO, 2009; Hasan *et al.,* 2018). Long-term fertilizer experiments are played an important role in understanding the complex interaction involving plants, soil and management practices and their effects on crop performance and soil properties (Meena *et al.*, 2019). It also provides opportunities to investigate the crop growth and yield trend, crop productivity, soil health parameters and evaluate the factors are responsible for the sustainable crop production and soil health management (Singh and Wanjari, 2012). Long- term experiments have indicated that imbalanced use of nutrients through chemical fertilizers without addition of organic manures accelerated the degradation of soil quality and declined crop productivity in intensive cropping system (Sharma *et al.*, 2017). India is facing a difficult situation where the human population to feed would continue to increase at an alarming rate while the available cultivated land area is shrinking due to fast urbanization and industrialization. Hence, the adoption of intensive cropping is unavoidable for higher food grain production. Secondly, most of farmers are preferred to apply only nitrogenous fertilizer to crops because of its immediate visual effects either on plants or higher cost of phosphatic and potassic fertilizers, resulting in an imbalance of nutrient consumption leading to exhaustion of nutrients from the soil. Sustenance of high crop yield levels is possible through the judicious use of manures and fertilizers. Inclusion of cereal-legume crop rotation with the addition of organic manures along with optimum NPK application to soil system is essential for sustaining crop productivity and maintaining the soil health (Sharma and Behera, 2009). Maize-chickpea rotation is an important cropping sequence of India. Maize is one of the important cereal crops in the world's agricultural economy both as food for humans and as feed for animals. Of this cropping sequence, maize is considered as the most exhaustive crop after sugarcane and requires both micro and macro-nutrients throughout its growing period to obtain high growth and yield potentials. Long-term sustainability concerns are growing in agriculture owing to over and under the application of fertilizers and poor management of available resources, which are resulting in soil health deterioration and declining crop productivity. Integrated use of organic and inorganic sources of nutrients is the most logical concept for managing and sustaining soil health and crop productivity (Dotaniya *et al.,* 2019). Integrated nutrient management is one of the most important components for enhancing crop production and sustaining soil fertility (Lakaria *et al.*, 2012). Maize is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. It is one of the important cereal crops in the world's agricultural economy both as food for human and as feed for animals. Globally, it is known as queen of cereals due to higher genetic yield potential among cereals. In India, maize is the third most important food crops after rice and wheat. It occupied an area of 9.63 m ha with production of 25.90 mt and yield of 2689 kg ha^{-1} in 2016-17 while in 2017-18 the area and production of maize was recorded 9.47 m ha, and production 28.72 mt and 3032 yield kg ha^{-1} respectively. In India, Madhya Pradesh stands at first position in terms of area and third position in production of maize after Karnataka (Agricultural Statistics, 2018). Keeping in view the above the present study was undertaken to study the performance of maize under various INM modules. Hypothesis elucidated the crop growth performance of maize was carried out to know the effect of organic and inorganic fertilizer on growth parameters of maize.

Materials and Methods

A field experiment was conducted at the research farm of the ICAR-Indian Institute of Soil Science, Bhopal. The soil of the experimental site is classified as Vertisol (*Typic Haplusterts*) with smectite as the dominant clay mineral. Vertisols are churning heavy clay soils with a high proportion of swelling clays. These soils form deep wide cracks during the summer season. The soil of the experimental site was clayey in texture with 25.2, 18.0 and 56.8 per cent of sand, silt and clay, respectively. The soil was medium in soil organic carbon (0.53%), low in available N (68.8 mg kg^{-1}), medium in available P (12.8 mg kg^{-1}) and high in available K (237 mg kg^{-1}). The soil was normal in reaction (pH 7.76) and electrical conductivity (EC) was 0.48 dS m^{-1}. The performance of maize was evaluated by monitoring crop growth parameters *viz.*, plant height, seed index (100 seed weight). The experiment comprised of 12 treatments (Table 1) laid out in a Randomized Blocks Design (RBD) with 3 replications. All the measurements having the mean value of three separate replicates. Data were subjected to an analysis of variance. The mean values were grouped for comparisons and the least significant differences among them were calculated at $P < 0.05$ confidence level using ANNOVA statistics as outlined by (Gomez and Gomez, 1983).

Results and Discussion

Results

Plant height at 45 DAS

Plant height was found significantly (p=0.05) different at 45 DAS ranged 46.7 - 104.0 cm, 49.7 - 118.3 cm and 48.2 - 111.2 cm during 2017, 2018 and pooled of two years, respectively (Table 2 and Fig. 1). Similarly, average plant height of maize at 45 DAS across the treatments was 86.5 cm, 93.8 cm and 90.1 cm during 2017, 2018 and pooled of two years, respectively. The pooled data of two years with respect to plant height revealed that application of FYM@ 20t ha^{-1} in *kharif* and 5 t ha^{-1} in *rabi* season (T_{11}) and STCR recommended dose of fertilizers (T_3) were significantly superior over rest of the other treatments. These were found statistically at par with each other. Similarly, the treatment receiving general recommended dose (T_2), 75% STCR dose + FYM @ 5t ha^{-1} (T_5), 75% STCR dose + UC@ 5t ha^{-1} (T_7), FYM @ 5t ha^{-1} + *Glyricidia* @ 2t ha^{-1} + incorporation of maize residues (T_{10}) and 75% STCR dose + FYM @ 20t ha^{-1} once in 4 year (T_{12}) found statistically at par with each other. The treatments T_9 (PM @ 1t ha^{-1} + *Glyricidia*@ 2t ha^{-1} + incorporation of maize residues), T_6 (75% STCR dose + PM @ 1 t ha^{-1}) and T_8 (75% STCR dose + incorporation of maize residues) were also found statistically at par with respect to plant height of maize recorded at 45 DAS.

Plant height at 60 DAS

The maize plant height recorded at 60 DAS ranged 98.2 - 182.3 cm, 96.4 - 186.5 cm and 97.3 - 184.4 cm during 2017, 2018 and pooled, respectively (Table 2 and Fig. 1). Similarly, average plant height of maize at 60 DAS across the treatments was found 147.0 cm, 150.0 cm and 148.5 cm during 2017, 2018and pooled data of two years, respectively. The pooled data of two years with respect to plant height of maize recorded at 60 DAS revealed that the treatment receiving FYM@ 20t ha^{-1} (T_{11}) and the treatment receiving STCR recommended dose of fertilizers (T_3) found superior over rest other treatments, whereas found statistically at par with each other. Similarly, treatments receiving GRD (T_2), 75% STCR dose + PM @ 1t ha^{-1} (T_6), 75% STCR dose + UC@ 5t ha^{-1} (T_7), FYM @ 5t ha^{-1} + *Glyricidia* @ 2t ha^{-1} + incorporation of maize residues (T_{10}) and 75% STCR dose + FYM @ 20t ha^{-1} once in 4 year (T_{12}) found statistically at par. The treatment involving the sole application of 75% STCR dose (T_4) showed poorest performance among all the treatments after T_1 (control). The treatmentsT_5 (75% STCR dose + FYM @ 5t ha^{-1}), T_6 (75% STCR dose + PM @ 1t ha^{-1}), T_8 (75% STCR dose + incorporation of maize residues) and T_9 (PM @ 1t ha^{-1} + *Glyricidia*@ 2t ha^{-1} + incorporation of maize residues) were also found statistically at par with respect to plant height of maize recorded at 60 DAS.

Plant height at 90 DAS

The data revealed that the plant height of maize recorded at 90 DAS ranged 130.3 - 208.3 cm, 137.5 - 220.2 cm and 133.9 - 214.3 cm during 2017, 2018 and pooled data of two years, respectively presented (Table 2 and Fig. 1). Similarly, the average plant height of maize at 90 DAS across the treatments was found 177.7 cm, 189.0 cm and 183.3 cm during 2017, 2018 and pooled of two years, respectively. The pooled data of two years with respect to plant height of maize at 90 DAS revealed that the treatment receiving FYM@ 20t ha^{-1} (T_{11}) found superior over rest other treatments except treatment T_3 (STCR recommended dose of fertilizers). Similarly, the treatment receiving general recommended dose (T_2), T_3, 75% STCR dose + UC@ 5t ha^{-1} (T_7), FYM @ 5t ha^{-1} + *Glyricidia*@ 2t ha^{-1} + incorporation of maize residues (T_{10}) and 75% STCR dose + FYM @ 20t ha^{-1} once in 4 year (T_{12}) were found statistically at par. The unfertilized control (T_1) recorded lowest plant height among all the treatments under study. The treatmentsT_4 (75% STCR dose), T_5 (75% STCR dose + FYM @ 5t ha^{-1}), T_6 (75% STCR dose + PM @ 1t ha^{-1}), T_8 (75% STCR dose + incorporation of maize residues) and T_9 (PM @ 1t ha^{-1}+ *Glyricidia*@ 2t ha^{-1} + incorporation of maize residues) were also found statistically (p=0.05) at par with respect to plant height of maize recorded at 90 DAS.

Seed index

Seed index (100 seed weight) of maize recorded during 2017, 2018 and pooled of two years is presented in Table 2 and Fig. 2. The seed index of maize ranged between 20.4 - 34.9 g, 19.0 - 32.4 g and 19.7 - 33.7 g during 2017, 2018 and for pooled data of two years, respectively. Similarly, the average seed index of maize across the treatments was found 25.9 g, 23.1 g and 24.5 g during 2017, 2018 and pooled of two years, respectively. The pooled data of two years with respect to seed index revealed that the treatment receiving 75% STCR dose + FYM @ 5 t ha^{-1} (T_5) recorded highest seed index (33.7 g) followed by the treatment T_3 (STCR recommended dose of fertilizers; 28.6 g). The treatments other than T_3 and T_{11}didn't show any significant difference with respect to the seed index of the maize. Even, control and treatments T_4 (75% STCR dose), T_6 (75% STCR dose + PM @ 1t ha^{-1}), T_8 (75% STCR dose + incorporation of maize residues) and T_9 (PM @ 1t ha^{-1} + *Glyricidia*@ 2t ha^{-1} + incorporation of maize residues) were also found statistically at par with each other with respect to seed index of maize.

The performance of the maize and chickpea crop with respect to the growth and yield attributes, grain yield and biomass has been recorded during the experimental period. The growth and yield attributes measured were plant height at various growth stages and seed index. Plant height of maize was recorded at 45 DAS, 60 DAS and 90 DAS respectively during the study years viz., 2017-18 and 2018-19. The results revealed that the plant height of maize recorded at periodic interval during the study period found significantly higher under the treatment receiving FYM @ 20 t ha^{-1} (T_{11}) and the treatment receiving STCR recommended dose of fertilizers (T_3) as compared to the other treatments.

Table.1 Treatment applied in maize-chickpea cropping sequence.

Treatment	Maize	Chickpea
T_1. Control	No Fertilizer/ Manure	No Fertilizer/ Manure
T_2. GRD	120- 60- 30	20-60-20
T_3. STCR	STCR dose for 5 t ha^{-1} maize (135-55-50)	STCR dose for 1.5 t ha^{-1} (0-0-0)
T_4	75% NPK of T_3	100% P only
T_5	75% NPK of T_3 + 5 t ha^{-1} FYM	100% P only
T_6	75% NPK of T_3 + 1 t ha^{-1} PM	100% P only
T_7	75% NPK of T_3 + 5 t ha^{-1} UC	100% P only
T_8	75% NPK of T_3 + MR mulch incorporated	100% P only + MR mulch
T_9	1 t ha^{-1} PM + Gly 2 t ha^{-1} + MR mulch incorporated	100% P only + MR mulch
T_{10}	5 t ha^{-1} FYM + Gly 2 t ha^{-1} + MR mulch incorporated	100% P only + MR mulch
T_{11}	20 t ha^{-1} FYM (every season)	5 t ha^{-1} FYM (Every Season)
T_{12}	75% NPK of T_3 + 20 t ha^{-1} FYM (once in 4 years)	100% P only

GRD - General recommended dose (kg ha^{-1}), STCR - Soil test crop response dose, MR - Maize residues, FYM - Farm yard manure, PM - Poultry manure, UC - Urban compost, Gly - *Glyricidia*

Table.2 Crop growth performance by maize under different INM modules

Treatments	Plant height (cm)									Seed Index (g)		
	45 DAS			60 DAS			90 DAS					
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T_1	46.7	49.7	48.2	98.2	96.4	97.3	130.3	137.5	133.9	20.4	19.0	19.7
T_2	93.7	97.0	95.3	160.7	160.2	160.4	183.0	196.4	189.7	25.5	23.4	24.5
T_3	100.0	112.7	106.3	182.0	186.5	184.3	201.0	209.9	205.5	29.7	27.4	28.6
T_4	78.0	82.3	80.2	116.7	118.2	117.4	168.0	169.5	168.7	22.8	20.7	21.8
T_5	90.0	95.0	92.5	128.3	136.5	132.4	175.7	194.9	185.3	34.9	32.4	33.7
T_6	80.7	94.3	87.5	149.0	153.2	151.1	174.7	187.0	180.8	23.5	19.9	21.7
T_7	95.0	97.7	96.3	153.0	160.1	156.5	182.7	195.1	188.9	26.2	23.0	24.6
T_8	77.0	91.3	84.2	136.7	144.9	140.8	167.3	179.5	173.4	24.4	20.5	22.5
T_9	87.0	90.0	88.5	138.3	140.2	139.3	172.0	184.2	178.1	24.7	20.7	22.7
T_{10}	92.0	98.0	95.0	164.7	156.2	160.4	184.0	196.0	190.0	25.3	22.5	23.9
T_{11}	104.0	118.3	111.2	182.3	186.5	184.4	208.3	220.2	214.3	26.9	23.5	25.2
T_{12}	93.7	98.7	96.2	154.0	161.4	157.7	185.0	197.3	191.1	26.0	23.7	24.9
SEm±	3.5	1.7	1.2	7.8	6.5	6.6	6.9	5.4	5.7	1.6	0.8	1.2
CD (p=*0.05*)	10.2	4.85	5.85	22.8	18.8	19.4	20.3	15.8	16.6	4.7	2.3	3.5

Table.3 Correlation matrix of crop growth performances by maize under different INM modules

Parameters	Maize plant height			Seed index
	45 DAS	60 DAS	90 DAS	
45 DAS	1.000			
60 DAS	0.921**	1.000		
90 DAS	0.993**	0.944**	1.000	
Seed Index	0.553	0.370	0.547	1.000

* Significant at 5 %; ** Significant at 1%

Fig.1 Plant height by maize under various INM Modules

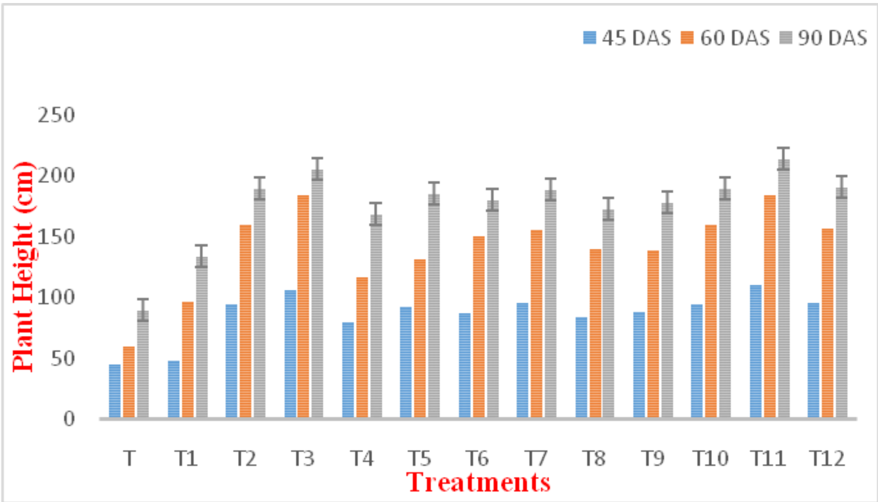
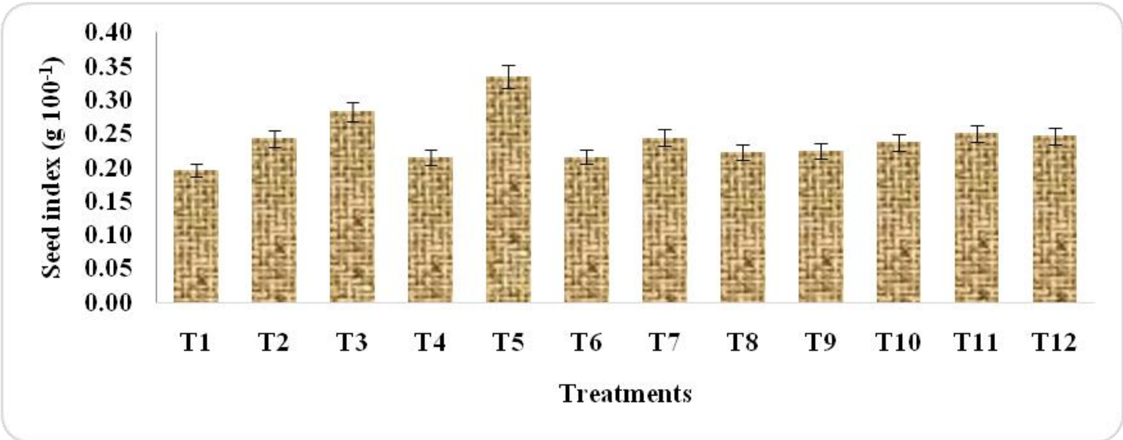


Fig.2 Seed Index by maize under different nutrient management practices



The seed index of maize and chickpea found significantly influenced under the integrated nutrient application (Table 2; Fig. 1 and 2). The pooled data of two years were indicated highest seed index under the treatment (T_5) receiving 75% STCR dose + FYM @ 5 t ha^{-1} followed by the treatment with STCR recommended dose of fertilizers. Addition of organic manure improves soil physico-chemical properties by mediating rhizospheric effect and nutrient dynamics that help improve crop performance (Pingoliya *et al.*, 2014; Mohbe *et al.,* 2015 & 2018; Selim, 2020; Dotaniya, *et al.*, 2020). Incorporation of organic sources during the crop production; it mediated the soil- plant nutrient dynamics by mineralization kinetics. It secreted different type of organic acids during the microbial decomposition and enhanced soil aggregates and most of the crops yield potential (Dotaniya *et al.*, 2016). Decomposition of organic matter act as source of energy to soil biota and enhance microbial population and diversity. Gathala *et al.,* (2013) reported that incorporation of maize residue every year enhanced wheat crop yield by 0.5 to 1.2 tonnes ha^{-1} over farmer's practices. The above finding was supported by (Dotaniya *et al.*, 2013; Aher *et al.*, 2015; Meena *et al.*, 2015; Dharwe *et al.,* 2019; Salame *et al.*, 2020).

Correlations

The correlation between crop performance *viz.,* 45, 60, and 90 DAS with crop seed index of maize are presented in Table 3. Plant height of maize was found highly significant and positively correlated with maize seed index. The correlations between plant height of maize at 60 and 90 DAS was significant and positively correlated with seed index (*r=0.921*, *0.993 & 0.944*). The higher height of plants might be produce bold size of seed due to more photosynthetic activities and utilization of higher sink source of the plants. These results are agreement with Gautam *et al.,* (2018).

In conclusion, the INM modules positively influenced the performance and productivity of maize crop as compared to the sole inorganic fertilizer application. Besides the superior crop performance, the INM modules significantly enhanced and improved soil health in terms of soil physical and chemical properties. Among the various modules, (1) application of 75% STCR dose + FYM @ 5 t ha^{-1} and (2) application of FYM @ 20 t ha^{-1} to maize increased the crop growth performance and seed index in maize, improved soil physico-chemical properties and reflected as a viable technique in improving soil nutrient availability on a sustainable basis in maize cultivation.

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