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Performance of maize (*Zea mays* L.) under efficient nutrient management practices for sustainable crop productivity

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Abstract
A field experiment was conducted to optimise the organic, inorganic and biofertiliser needs for sustained productivity of maize (*Zea mays* L.). Seven treatments comprising all possible combinations of chemical fertilizer, organic manure (vermicompost, FYM) with and without biofertilizer (*Azospirillum* and PSB) were laid out in randomized block design with three replications. Different nutrient management practices (organic, inorganic and combined sources of nutrients) significantly influenced the yield attributes, yield and economics of maize crop. Application of 100 % RDF (T_1:180-60-50 kg N, P_2O_5 and K_2O ha^{-1}) resulted in significantly higher cob length, girth (17.7 cm, 16.8 cm), cob weight (225 g), no. of kernel rows cob^{-1} (12.9), no. of kernels row^{-1} (24.2), kernel weight cob^{-1} (5207 kg ha^{-1}), kernel yield (5207 kg ha^{-1}) and stover yield (6751 kg ha^{-1}) which was significantly superior over the rest of the nutrient management practices and it was followed by 50% RDF + Vermicompost @ 1t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} (T_7) and it has given a remarkable yield attributes, kernel (4683 kg ha^{-1}) and stover yield (6394 kg ha^{-1}) which is in turn in parity with 50% RDF + FYM @ 5 t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1} +PSB @ 5 kg ha^{-1} (T_6) and significantly superior to rest of the treatments. The highest net returns (₹ 59920 ha^{-1}) and benefit - cost ratio (2.97) were recorded under 100% RDF (T_1) followed by application of FYM @ 10 t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} (T_6) which has registered a B:C ratio of 2.81 which might be due to comparatively better increase in yield with lesser cost over other treatments. Integration of biofertilizer (T_6 and T_7) has triggered the nutrient uptake mechanism and shown a notable performance in improving yield structures, yield and economics. Long run adoption of combined use of fertilizers and organics expected to match and even excel the sole fertilizer based production strategy.

Keywords: Organic, inorganic, biofertiliser, yield, yield attributes, economics

Introduction

Maize an important food and feed crop of the world and often referred to as "Queen of cereals, back bone of America, miracle crop, king of grain crops". Refineries use maize crop for producing products as corn oil, gluten for animal feed, corn starch, syrup, dextrose (used mainly by pharmaceutical industry as the starting material for manufacturing vitamin C and penicillin), alcohol for beverages, ethanol, high fructose corn syrup (used mainly by soft drink industry), biodegradable chemicals and plastics, ready to eat snack food and breakfast cereals, corn meal, grits, flour and additives in paints and explosives. It is estimated that worldwide maize yields 4000 industrial products (Sprague *et al.*, 1988) [12]. Maize is the third most important food crop after rice and wheat in India, mainly grown during *kharif* season which covers 85% of the total area. In India, it is cultivated on 9.43 million ha area, with production and productivity of 24.35 million tonnes and 2,583 kg/ha respectively (Director's review, IIMR, 2014-15). It accounts for ~9 per cent of total food grain production in the country. India ranks 4th in maize area in the world. Maize grain is mainly used for feed (63%), food (23%) and industrial purpose (13%) in the country. To meet the rising demand, a quantum jump in maize production is the need of the hour. In the previous decade, the maize area expanded by 1.8% and production increased by 4.9% showing productivity growth at 2.6% per annum in India (GoI, 2015).

Maize (*Zea mays* L.) is one of the most versatile crops having wider adaptability and grown in diverse seasons and ecologies for various purposes. It is having special significance as a staple food of the tribal areas, which provides nutritional security due to its high nutritional profile. On account of its quick growth habits, maize is a highly nutrient exhaustive crop. The demand of maize plant for nitrogen and phosphorus is more than any other essential element for the development of all phases. It is absolutely necessary that essential nutrient elements should be supplied in appropriate proportion to maintain soil fertility and to get higher yield.

Now-a-days the escalating cost of chemical fertilizers is considerably resulting in lower net returns. Continuous application of fertilizers alone in a system deteriorates soil health and affects crop productivity (Kannan *et al.,* 2013) [4]. Excessive use of agrochemicals with reduced use of organic source of nutrients for the last several decades resulted in multinutrient deficiencies and decline in fertility and productivity of soil. Although fertilizers supply quick nutrients to the soil, they impede the uptake of other nutrients and there by upset the whole mineral balance pattern. Nutrient management practice that depends lesser on inorganic fertilizers are required to minimize the adverse effects.

Integrated nutrient management, which includes potential sources like fertilizers, bulky organic manures and biofertilisers in a balanced proportion could help in mitigating the problems and to build an ecologically as well as economically viable farming system. Organic manures particularly FYM and vermicompost, not only supply macronutrients but also meet the requirement of micronutrients, besides improving soil health (Wailare and Kesarwani, 2017) [15]. Biofertilisers are the low cost inputs for supplementing the essential plant nutrients to achieve sustainable agriculture. The presence of different microbes, enzymes and hormones enhance the availability of soil inherent nutrients by the formation of organic acids. Hence, massive efforts are to be adopted with integration of organic, inorganic and biological sources of plant nutrients in the developing countries for improvement of soil fertility and productivity (Hashim *et al.,* 2016) [3].

As heavy feeder of nutrients, maize productivity is largely dependent on nutrient management to express its full potential. Under the present trend of exploitive agriculture in India, inherent soil fertility can no longer be maintained on sustainable basis as the capacity of the soil to supply plant nutrient is steadily declining under intensive cropping systems. Organic manures particularly FYM and vermicompost, not only supply macronutrients but also meet the requirement of micronutrients, besides improving soil health. (Kannan *et al.,* 2013) [4] and biofertilisers play an important role for supplementing the essential plant nutrients for sustainable agriculture (Hashim *et al.,* 2016) [3]. Integrated nutrient management an option arises utilizing the available organic and inorganic sources to build an ecologically sound and economically viable farming system.

Material and Methods

The field experiment was conducted at S.V. Agricultural College Wetland Farm, Tirupati campus of Acharya N. G. Ranga Agricultural University in *kharif,* 2017. Total rainfall received during the crop growth period was 833.6 mm in 42 rainy days. The soil of the experimental field was sandy loam in texture, slightly alkaline in soil reaction (pH 7.9), low in organic carbon (0.25 %) and available N (125 kg ha^{-1}) and medium in available phosphorus (11.7 kg ha^{-1}) and available potassium (223.3 kg ha^{-1}).

The field experiment was laid out in Randomized Block Design (RBD). The seven treatments were replicated thrice and each consisted of a 100% recommended dose of fertiliser @ =180-60-50 kg N, P_2O_5 and K_2O ha^{-1} (T_1), FYM @ 10 t ha^{-1} + *Azospirillum* @ 5 kgha^{-1} + PSB @ 5 kg ha^{-1} **(**T_2), Vermicompost @ 2 t ha^{-1} + *Azospirillum* @ 5 kgha^{-1} + PSB @ 5 kg ha^{-1} **(**T_3), 50% RDF + FYM @ 5 t ha^{-1} **(**T_4), 50% RDF + Vermicompost @ 1 t ha^{-1} (T_5), 50% RDF + FYM @ 5 t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{1} (T_6), 50% RDF + Vermicompost @ 1 t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} **(**T_7). The test hybrid of maize was Kaveri-55. The seed rate for maize is 20 kg ha^{-1}. The seeds were sown on 15th July, 2017 manually at a depth of 5 cm on the ridges which were laid at a spacing of 60 cm between the rows and 20 cm between the plants in each row.

Farm yard manure and Vermicompost were incorporated in marked plots as per treatments and its composition on dry basis was 0.51 % N, 0.25 % P_2O_5, 0.52 % K_2O for FYM and 1.7 % N, 1.1 % P_2O_5, 1.0 % K_2O. Full dose of phosphorus (60 kg ha^{-1}) and potassium (50 kg ha^{-1}) in the form of single super phosphate (SSP) and muriate of potash (MOP) were applied as basal dose at the time of sowing. Nitrogen (180 kg ha^{-1}) in the form of urea was applied as per the treatments in three splits *viz.,* 1/3rd as basal, 1/3rd at knee high stage and the remaining 1/3rd at tasseling stage through band placement. For destructive sampling, five plants were sampled each time from the second border row to record dry matter production. For non-destructive sampling, representative samples of five plants were selected randomly and tagged in net plot area. The biometrical data and post-harvest observations were recorded on the tagged plants. The crop was harvested on 28 October in 2017.

Results and Discussion

Yield attributes

The differences among the nutrient management practices could not reach the level of significance with regard to number of cobs plant^{-1}. However, numerically maximum number of cobs plant^{-1} was recorded with 100 per cent recommended dose of nutrients through fertilizers (T_1). The reason for having statistically similar number of cobs plant^{-1} among the nutrient management practices might have been that this character was mainly genetically controlled and was less influenced by environmental factors. Similar results were perceived by Khan *et al.* (1999) [5].

The length and girth of the cob was significantly influenced by different nutrient management practices (Table 1). Application of 100% recommended dose of nutrients through fertilizers (T_1) produced the higher cob length and girth, which was significantly superior to 100 % organic and integrated treatments. It was followed by combined application of 50 % RDF + Vermicompost @ 1 t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} (T_7) which was on par with T_6 (50% RDF + FYM@ 5 t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1}) and these two treatments are significantly superior to rest of the treatments. In general the treatments received combined application of organics, inorganics and biofertlizers ($T_{6,}$ T_7) recorded 23 per cent extra longer cob in maize than the treatments with 100 per cent organics ($T_{2,}$ T_3). The results were in close conformity with Athokpam *et al*. (2017). Nagaral *et al.* (2017) [8] and Meena *et al.* (2013) [7]. Application of 100% RDF directly adds nutrients to soil, needy plants ultimately accrued huge quantity of nutrients and converted to biomass and partitioned a large fraction of assimilates to the sink, resulting in enhanced yield structure as displayed by all the yield attributes. The lower stature of cob length and girth noticed with FYM @ 10 t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} (T_2) might be due to deficiency of nutrients caused by non supply of fertilizers.

Highest cob weight recorded with treatment T_1 (100% recommended dose of nutrients through fertilizers) which was significantly superior to rest of the treatments (Table 1). Maximum cob weight recorded with 100% RDF might be due to a rapid and a large assimilate supply to the sink. Combined application of FYM and Vermicompost each at 50% level recorded significantly higher cob weight (15.36 per cent) than the treatments with 100% organics (T_2 and T_3). Continuous nutrient supplement through integrated nutrient management practice had favourable effect on yield attributes. Increased cob weight was due to enhanced nutrient uptake with higher concentration of macro and micronutrient. This result is in conformity with Umesha *et al*. (2014) [14].

The maximum number of kernel rows cob^{-1}, kernels row^{-1}, kernel weight cob^{-1} and test weight was recorded with T_1 (100% RDF) followed by T_7 (50 % RDF + Vermicompost @ 1t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1}) which was found to be comparable with T_6 (50% RDF + FYM@ 5 t ha^{-1} +*Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} and these two treatments are significantly superior to rest of the treatment (Table 1) whereas lowest performance recorded with FYM @ 10 t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} (T_2). This might be due to enhanced partitioning of photosynthates towards newly formed sink. Moreover the increase in number of kernel rows cob^{-1} and kernels row^{-1} with the above treatment might have resulted in maximum kernel weight cob^{-1}. More number of bigger sized cobs plant^{-1} might have accommodated more kernels providing sufficient space for development at balanced and adequate supply of nutrients (Ramu and Reddy, 2005). Integrating biofertilizer with vermicompost/ FYM + RDF improved the interaction between fertilizer and bacterial growth resulted in number of kernel rows per cob (14.16 per cent) over sole application of organics (T_3 and T_2). Similar result was perceived by Beigzade *et al.*, (2013) [1].

Yield

Adequate nutrient management practices in maize either with organic and inorganic sources or their combined application significantly enhanced kernel and stover yield (Table 2). Application of 100 % nutrients through inorganic sources of fertilizer significantly improved the maize yield (T_1). The maximum kernel yield (5207 kg ha^{-1}) was obtained with T_1 with the application of entire dose of recommended NPK through fertilizers and it was significantly superior to 100% organic and integrated nutrient management practices. It was followed by T_7 (50 % RDF + Vermicompost @ 1t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1}) which was on par with T_6 (50% RDF + FYM@ 5 t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1}). Integrating *Azospirillum* and PSB along with FYM, Vermicompost and RDF produced remarkable yield (52.14 per cent) compared to sole application of organics. Organic manures like FYM and vermicompost also supply nutrients beneficial to crop growth and productivity. Therefore, substitution of 50% inorganic fertilizers with Vermicompost / FYM in combination with bio fertilizer had given the kernel yield which was comparable to 100 % RDF. This is in confirmation with the findings of Shah and Wani (2017).

Integration of biofertilizer in treatment T_7 (50 % RDF + vermicompost @ 1t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1}) and T_6 (50% RDF + FYM@ 5 t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1}) recorded 19 and 23 per cent more yield compared to T_4 (50% RDF + FYM@ 5 t ha^{-1}) and T_5(50 % RDF + Vermicompost @ 1t ha^{-1}) which did not include biofertilizer. It indicates the role of biofertilizer in enhancing the easy uptake of nutrients. These results are in accordance with the findings of Beigzade *et al*. (2013) [1] Hashim *et al.* (2015) [2]. and Rasool *et al.* (2015) [9].

Economics

The economics is the main bone of contention in making the sound recommendations of any package of practices for adoption by the farmers. Gross and net returns as well as benefit-cost ratio were altered to a noticeable extent due to varied nutrient management practices in maize (Table 2 and Fig. 1).

The highest net returns (₹ 59920 ha^{-1}) were recorded 100% RDF (T_1), which was significantly superior over the rest of the nutrient management practices (Table 2 and Fig. 1). The increase in net returns might be due to increased kernel yield coupled with reduced cost of fertilizer application. The net return was recorded in the order of T_6, T_7, T_4 and T_5. The net returns indicated the fact that application of vermicompost was not much economical compared to FYM application. The negative net returns (₹ 11760 ha^{-1}) were recorded with application of Vermicompost @ 2 t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} (T_3) might be due to high cost of vermicompost (₹ 15 kg^{-1}) and lower yields as reported by Jinjala *et al.* (2016). The highest gross and net returns as well as benefit - cost ratio (2.97) was realized with 100 per cent recommended dose of nutrients through inorganic fertilizers (T_1). It might be due to the higher kernel and straw yields as well as lesser production costs in comparison to organic and integrated sources. These findings lend to support of Tomar *et al.* (2017) [13].

Among the various organic and integrated nutrient management practices, application of FYM @ 10 t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} (T_6) registered a B:C ratio of 2.81 which might be due to comparatively better increase in yield with lesser cost over other treatments. This result was in accordance with the findings of Makwana *et al*. (2015) [6].

Monetary returns play a key role, for adapting the refined agro techniques. In the present study, higher yields coupled with higher monetary returns were obtained with application of 100% RDF but integration of different sources of nutrients through chemical, organic and biofertiliser not only improves the total crop productivity but also maintains and sustains soil health for future generation as well as improving the economic stability of the farmers.

Conclusion

In the present study, higher yields coupled with higher monetary returns were obtained with application of 100% RDF but integration of different sources of nutrients either from chemical, organic and biofertilizer sources not only improves the total crop productivity but it also maintain and sustains soil health for future generation as well as improving the economic stability of the farmers. Hence, adoption of a balanced nutrient management approach will safeguard the higher crop productivity and economic returns. Long run adoption of combined use of fertilizers and organics expected to match and even excel the sole fertilizer based production strategy.

Table 1: Yield attributes of maize as influenced by various nutrient management practices

Treatments	Cob length (cm)	Cob girth (cm)	Number of kernel rows cob^{-1}	Number of kernels row^{-1}	Cob weight (g)	Kernel weight Cob^{-1} (g)	Test weight (100 kernels) (g)
T_1 : 100% RDF (180 - 60 -50 kg N, P_2O_5, and K_2O ha^{-1})	17.7	16.8	12.9	24.4	225	70.1	24.5
T_2 : FYM @ 10t ha^{-1} + *Azospirillum*@ 5 kgha^{-1}+ PSB @ 5 kg ha^{-1}	11.9	11.5	10.2	20.1	178	41.9	20.6
T_3 : Vermicompost @ 2t ha^{-1} + *Azospirillum*@ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1}	12.5	12.1	10.3	20.5	180	42.4	20.8
T_4 : 50% RDF + FYM @ 5 t ha^{-1}	13.9	13.3	11	21.4	192	52.1	22.3
T_5 : 50% RDF + Vermicompost @ 1t ha^{-1}	14.2	13.5	11	21.7	196	52.4	22.6
T_6 : 50% RDF + FYM@ 5 t ha^{-1} + *Azospirillum*@ 5 kg ha^{-1}+ PSB @ 5 kg ha^{-1}	15.7	15.0	11.9	22.9	210	63.8	23.7
T_7 : 50% RDF + Vermicompost @ 1t ha^{-1} + *Azospirillum*@ 5 kg ha^{-1}+ PSB @ 5 kg ha^{-1}	16.1	15.2	12	23.6	213	65.6	24.1
SEm±	0.42	0.33	0.21	0.23	3.3	1.38	0.07
CD (P=0.05)	1.3	1.01	0.65	0.71	10.1	4.3	0.20

Table 2: Kernel yield, stover yield (kg ha^{-1}) and harvest index of maize as influenced by various nutrient management practices

Treatments	Kernel yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Gross returns	Net returns	B : C ratio
T_1 : 100% RDF (180 - 60 -50 kg N, P_2O_5, and K_2O ha^{-1})	5207	6751	90063	59821	2.97
T_2 : FYM @ 10t ha^{-1} + *Azospirillum*@ 5 kg ha^{-1}+ PSB @ 5 kg ha^{-1}	2059	4937	37881	8547	1.29
T_3 : Vermicompost @ 2t ha^{-1} + *Azospirillum*@ 5 kg ha^{-1}+ PSB @ 5 kg ha^{-1}	2352	4950	42576	-11760	0.78
T_4 : 50% RDF + FYM @ 5 t ha^{-1}	3660	5790	64350	37044	2.36
T_5 : 50% RDF + Vermicompost @ 1t ha^{-1}	3949	5815	69004	29198	1.73
T_6 : 50% RDF + FYM@ 5 t ha^{-1} + *Azospirillum*@ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1}	4534	6206	78742	50738	2.81
T_7 : 50% RDF + Vermicompost @ 1t ha^{-1} + *Azospirillum*@ 5 kg ha^{-1}+ PSB @ 5 kg ha^{-1}	4683	6394	81314	40810	2.02
SEm±	88	114	1454	1454	0.04
CD (P=0.05)	271	317	4479	4479	0.13

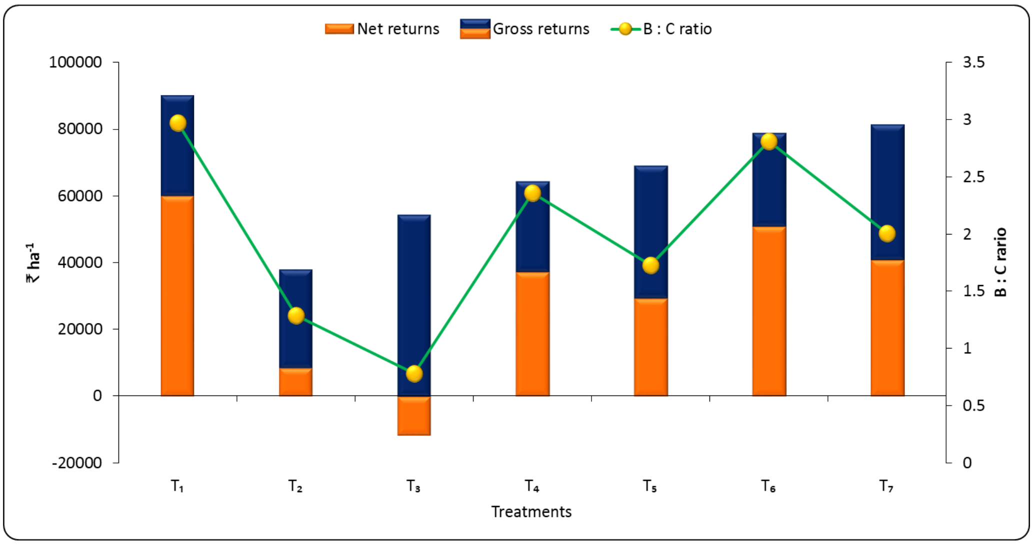

Fig 1: Gross returns, net returns (₹ ha^{-1}) and B:C ratio of maize as influenced by various nutrient management practices

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