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Effect of Integrated Nutrient Management on Growth, Productivity and Economics of Hybrid Maize in Odisha State

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Abstract

A field experiment was conducted during *kharif* season (June to September) of 2013 and 2014 at research farm of Regional Research and Technology Transfer Sub-station, Kirei, Sundergarh, Odisha University of Agriculture and Technology of Odisha, India which is located in the geographic parallels of 22^0 4′ N and 84^0 2′ E. The objective of the experiment is to find out the most efficient and economic combination of different organic and inorganic sources of nutrients to increase the growth, productivity and economics of hybrid maize without deteriorating the soil qualities. The experiment comprised of eight treatments, namely 100% Recommended dose of N, P_2O_5 and K_2O, 75% Recommended dose of fertilizer (RDF) nitrogen+25% N through vermicompost, 75% RDF nitrogen+25% N through mustard oil cake, 75% RDF nitrogen+25% N through Farmyard manure, 50% RDF nitrogen+50% N through vermicompost, 50% RDF nitrogen+50% N through mustard oil cake, 50% RDF nitrogen+50% N through Farmyard manure, Control (no manure no nitrogen). Integrated application of 75% Recommended DFN+ 25% N through vermicompost resulted significantly highest plant height (220.8 cm) at harvest, highest leaf area index (5.15) at 60 days after sowing, dry matter accumulation at harvest (1745 g m^{-2}), number of grains cob^{-1} (466.49), Grain weight cob^{-1} (102.67), test weight (220.30 g 1000 grain^{-1}), length of cob (24.25 cm), girth of cob (18.01 cm), number of cobs plant^{-1} (1.07), maize grain yield of 6.79 t ha^{-1}, Stover yield (10.95 t ha^{-1}), harvest index (0.39), gross return (₹ 88,318 ha^{-1}), net return (₹ 52,099 ha^{-1}), return rupee^{-1} invested (₹ 2.44).

Keywords: Maize, integrated nutrient management, growth, yield, economics

1. Introduction

According to a United Nations report, India's population is expected to surpass that of china by 2024 and the demographic pressure is projected to reach 1.5 billion by 2030 (Anonymous, 2017). India needs to produce about 300 million tons of food grains by 2025 to feed its ever-expanding population (Chaudhury and Suresh, 2013). Maize is the third largest cereal crop grown in India and an important cereal crop Worldwide for its diversified use as feed and fodder (Khadtare et al., 2006; Wailer and Kesarwani, 2017). Maize may be defined as the queen of cereals because of its potential in productivity as compared to other cereals. In

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developing countries maize is a major source of income to many farmers (Tagne et al., 2008). Diversified uses of maize for corn starch industry, corn oil production, baby corns, pop corns and its potential for exports has added to the demand of maize all over the world besides other commercial avenues (Shivran et al., 2015). It is well known that maize is a heavy feeder of nutrients and continuous application of only chemical fertilizers in intensive cropping system leads to imbalance of nutrients in soil, which has an adverse effect on soil health and also on crop yield (Bhatt et al., 2020). Over reliance on use of chemical fertilizers has been associated with decline in soil physical, chemical conditions and yield of crop (Hepperly et al., 2009). Excess use of chemical nitrogen fertilizer reported to be the cause of soil and environmental pollution (Biswas and Tewatia, 1991). Maize productivity is a function of genetic potential of crop varieties, soil productivity and environmental condition through its internal, physiological and biological processes. Highest productivity of crops in a sustainable manner without deteriorating the soil and other natural resources could be achieved only by applying appropriate combination of different organic manures and inorganic fertilizers (Chandrashekara et al., 2000). It is important to identify the best type of available organic resources which can be used as nutrients and their best suitable combination with appropriate proportion of inorganic fertilizers. Application of organic manures in general improves the availability of micronutrients besides improving soil health and environment (Shilpashree et al., 2012; Garg et al., 2005). Adopting integrated nutrient management practices improves significantly organic carbon content in soils and increases the availability of nutrients and also improves the soil properties and pollution (Gundlur et al., 2015; Chandrashekara et al., 2000). Most of the crops respond quickly to chemical fertilizers and give higher yield and maize is more responsive to nitrogen fertilizer (Kholoud et al., 2019). But, continuous application of chemical fertilizers alone had been reported to deteriorate soil health (Yadav, 2003) and causes decline in soil and food quality due to loss of organic matter (Singh, 2000; Melero et al., 2008; Jiang et al., 2020). Dependency on chemical fertilizers alone may not provide a viable economic option (Priya et al., 2014). Vermicompost application accelerates the ripening process of the crop upto 1-2 weeks with improving the quality parameters of cultivated plants (Kovacik, 2014) and increases the population of beneficial microorganism (Kumar and Singh, 2001; Srivastava et al., 2002). Among several factors, soil productivity assumes paramount importance. For maintenance of soil fertility and productivity, nourishing the soil by addition of organic manures along with chemical fertilizers in right amount and proper balance is necessary to get higher production on sustainable basis (Inderjeet et al., 2014; Mahmood et al., 2017; Kalaiyarasan, 2011; Saha et al., 2008). The vermitech complex is efficient in raising the productivity of crops and increasingly becoming famous among farmers (More et al., 2013). According to Roychowdhury et al., 2017, vermicompost are safe for environment. Furthermore, Nanjappa et al. (2001) and Jayanthi et al. (2002) suggested that application of vermicompost and manure together showed a positive improvement in maize seed functioning. Vanlauwe and Giller, 2006, reported that farmers apply organic wastes like swine and farm yard manure.

Therefore, in the present context, information on judicious combination of organics and chemical fertilizers are required which maintains soil and crop productivity. Integrated nutrient management aims at maintenance of soil fertility and plant nutrient supply by integration of nutrients from all possible sources for the desired crop productivity. The lack of sufficient information in this aspects under rainfed condition made an impetus to undertake the present study.

2. Materials and Methods

A field experiment was conducted during the *kharif* season (June to September) of 2013 and 2014 at the research farm of Regional Research and Technology Transfer Sub Station , Kirei, Sundergarh, OUAT of Odisha state (22° 4' N and 84° 2' E), India and placed at 225 meter above mean sea level having sub-tropical climate. The total amount of rainfall received during the cropping seasons were 930.7 and 999.4 mm during the year 2013 and 2014 respectively. The mean maximum and minimum temperatures of both years were 32.5 and 24.7°C. The experiment consisting of eight treatments with three replications and was laid in randomized block design. The soil of the experimental site was found to be sandy loam with pH of 6.74, Electrical conductivity 0.86 dSm^{-1}, low in organic carbon (4.2 g kg^{-1}), low in available nitrogen (216 kg ha^{-1}), medium in phosphorus (14 kg ha^{-1}) and medium in potassium (187 kg ha^{-1}), Jackson, 1973. The bulk density of the soil was 1.68 mg m^{-3}. The experimental plot was ploughed followed by clod breaking, hoeing and levelling. The field was divided into three blocks and in each block there were eight unit plots and in altogether there were 24 number of unit plots. Then individual gross plots of 6.0×5.0 m^2 were formed. The required quantity of vermicompost, Mustard oil cake and FYM was applied as per treatment schedule. Then lines were formed at 60 cm spacing within each plot. The Maize hybrid cv. PMH-3 was sown by dibbling on 10th June and 12th June at plant spacing of 30 cm distance and harvested on 15th September and 17th September in the year 2013 and 2014 respectively. All the farm operations were conducted as per recommendations of the crops. The eight treatments consist of 100% RDF, 75% RDFN+25% N by vermicompost, 75% RDFN+25% RDFN by MOC, 75% RDFN+25% N by FYM, 50% RDFN+50% N by VC, 50% RDFN+50% RDFN by MOC, 50% RDFN+50% N by FYM and Control for hybrid maize crop. Fertilizer doses were calculated as per treatment and applied to each plot using urea, SSP and MOP as source of nitrogen phosphorus and potash. The soil test based RDF as recommended in treatment was 120-60-60 kg NPK ha^{-1}, out of which whole P and K were applied at the time of

sowing and N was applied in 3 split doses as 50% at the time of sowing, 25% at 20 days after sowing (DAS), and remaining 25% at the time of tasseling (i.e. at 60 DAS). The NPK content of vermicompost were 2%, 0.5%, 0.5% and for mustard oil cake were 5%, 1.8% and 1.2% and of FYM were 0.75%, 0.5% and 0.5% in 2013 and for the year 2014 the NPK contents of vermicompost were 1.6%, 0.3%, 0.65%, mustard oil cake contained 4.9% N, 2.3% P and 3.7% K and farm yard manure contained 0.6% N, 0.32 % P and 0.6% K which were used as source of nutrients in the experiment. Accordingly, the quantity was calculated equivalent to 25 and 50% of recommended fertilizer nitrogen. Regular biometric observations were recorded at specific time intervals by selecting randomly 5 plants in each treatment from the second row for the measurement of plant height, dry matter accumulation and leaf area index. The leaf area index was measured by using leaf-area meter (LICOR Ltd, USA). Leaf area index was computed by dividing the leaf area to the ground area. The plants were dried in the hot air oven which were kept for 72 hours. The dry matter was measured when the plants attain constant weight. After harvesting, threshing, cleaning and drying, the grain yield was recorded. Stover yield was obtained by subtracting grain yield from the total biomass yield. Maize was harvested on 15th September and on 17th September in the year 2013 and 2014 respectively. Yield attributes and yield were recorded after harvesting of crops. Gross return, Net return and return rupee^{-1} invested of each of the treatment were calculated consecutively for two years as well as pooled data taking into account of all the components of cost of cultivation and cost of produce involved in the treatments and only the pooled data is presented. The return per rupee invested was calculated by dividing the gross return by total cost of cultivation. The statistical analysis of the data was carried out using standard analysis of variance (Panse and Sukhatme, 1989). The results were presented at 5% level of significance (p=0.05) for making comparison between treatments.

3. Results and Discussion

3.1. Growth attributes

Plant height of hybrid maize was influenced by different treatments of organic and inorganic fertilizers combinations. The pooled analysis over two years data (Table 1) showed that plant height increased gradually as the growth stages of plant advances. Application of 75% RDFN+25% N through vermicompost resulted significantly the tallest plant height of 220.8 cm at harvest followed by the application of (100% RDF) which resulted 204.6 cm. The lowest plant height was recorded by control where no manure nor fertilizer were applied (159.6 cm). The tallest plants due to conjunctive application of vermicompost and chemical nitrogen fertilizer might be due to the more availability of plant nutrients, enzymes, vitamins and congenial soil characters which helped the plant to uptake more soil nutrient along with water. This result was corroborated by Canellus et al. (2000). Mahapatra et al. (2018) also found similar result in baby corn. Dhiman (2014) also reported that application of farmyard manure along with vermicompost and forest litter resulted in tallest plants in comparison to application of chemical fertilizer only.

Leaf area index of hybrid maize was influenced by different

Table 1: Effect of integrated nutrient management on growth, yield and economics of hybrid maize (pooled data of 2013 and 2014)

TR	PHH	LAI	DMAH	NGC	GW	LC	GC	NCP	TW	GY	SY	HI	GR	NR	RRI
T_1	204.6	4.55	1608.4	402.15	87.89	19.77	15.05	1.03	218.55	5.33	10.92	0.35	69225	44732	2.83
T_2	220.8	5.15	1745.0	466.49	102.67	24.25	18.01	1.07	220.30	6.79	10.95	0.39	88318	52099	2.44
T_3	181.4	4.21	1595.5	406.01	82.91	17.02	13.45	1.03	208.40	5.48	10.57	0.34	71236	36498	2.05
T_4	200.8	4.47	1593.1	408.65	88.80	20.88	16.03	1.03	217.83	5.92	10.31	0.35	76934	45879	2.48
T_5	185.4	4.27	1582.0	441.84	89.74	21.63	16.55	1.02	209.54	5.99	10.63	0.36	77840	29901	1.63
T_6	178.6	4.07	1471.1	368.74	76.50	16.53	12.95	1.02	209.12	5.10	9.33	0.35	66337	21361	1.47
T_7	179.3	4.05	1617.4	404.84	86.36	18.48	9.97	1.01	213.34	5.75	10.54	0.35	74798	37186	1.99
T_8	159.6	3.05	850.4	217.81	45.06	11.72	9.63	1.02	209.18	2.97	5.47	0.35	38660	15061	1.64
SEm±	4.73	0.15	42.46	13.95	2.37	0.47	0.85	0.01	4.15	0.19	0.24	0.01	2462	2462	0.08
CD	14.46	0.47	128.79	42.33	7.2	1.41	2.59	0.04	NS	0.57	0.72	0.03	7469	7469	0.24

PHH: Plant height at harvest (cm); LAI: LAI at 60 DAS; DMAH: Dry matter accumulation at harvest (g m^{-2}); NGC: Number of grains cob^{-1}; GW: Grain weight (g cob^{-1}); LC: Length of cob (cm); GC: Girth of cob (cm); NCP: Number of cobs plant^{-1}; TW: Test weight (g); GY: Grain yield (t ha^{-1}); SY: Stover yield (t ha^{-1}); HI: Harvest index; GR: Gross return (₹ ha^{-1}); NR: Net return (₹ ha^{-1}); RRI: Return rupe^{-1} invested; NB: Market price of maize ₹ 1300 q-1 (1 US$=₹ 63.47 and ₹ 61.99) in September 2013 & 2014, respectively); TR: Treatments; T_1: 100% RDF, T_2: 75% RDFN+25% N by VC, T_3: 75% RDFN+25% N by MOC, T_4: 75% RDFN+25% N by FYM, T_5: 50% RDFN+50% N by VC, T_6: 50% RDFN+50% N by MOC, T_7: 50% RDFN+50% N by FYM, T_8: Control: (No manure and no nitrogen fertilizer); CD: CD (p=0.05)

treatments of organic and inorganic fertilizers combinations. It was revealed in Table 1 that combined application of organic and inorganic sources of nutrient recorded higher values of leaf area index in comparison with the sole application of chemical fertilizers. Treatment receiving 75% RDFN+25% N through vermicompost recorded significantly highest value of LAI (5.15) at 60 days after sowing followed by the application of 100% RDF (4.55). The highest leaf area index might be due to greater availability of soil nutrient throughout the growth period from the combined application of organic and inorganic sources of nutrient. Similar result was confirmed by the findings of Tollenaar et al. (2006). Choudhary et al. (2006) reported that vermicompost supplies micronutrients like Mg^{2+}, which helped in synthesis of chlorophyll constituents. Higher solar radiation interception by applying vermicompost might have caused more dense leaves and higher leaf area index.

The data pertaining to the dry matter accumulation presented in Table 1 showed that the treatment receiving 75% RDFN+25% N through vermicompost recorded the highest (1745 g m^{-2}) dry matter accumulation which was at par with i.e 50% RDFN+50% N through FYM (1617.4 g m^{-2}). The highest dry matter accumulation due to application of 75% RDFN+25% N by vermicompost might be attributed to the greater availability of applied nutrients and higher uptake of primary nutrients by maize from the combined application of organic and inorganic sources of nutrients. This result was in agreement with the findings of and Tollenaar et al. (2006). Kumawat (2010) also found that vermicompost along with chemical fertilizer increased the dry matter of blackgram due to major release and availability of major nutrients and micronutrients by vermicompost.

3.2. Yield attributes

The data presented in Table 1 showed that the length of cob was significantly highest with 75% RDFN+25% N through vermicompost which resulted 24.25 cm in the pooled data of year 2013 and 2014 followed by application of 50% RDFN+50% N through vermicompost (21.63 cm). The control treatment resulted the least length of 11. 72 cm only which is 106% less than the lengthiest cob of 24.25 cm. Yadav et al., 2016 also reported similar result. An introspection of pooled data presented in Table 2 reflected that the girth of cob was significantly highest with application of 75% RDFN+25% N through vermicompost (18.01 cm) which was statistically at par with application of 50% RDFN+50% N through vermicompost (16.55 cm). The highest number of cobs $plant^{-1}$ were recorded by the application of 75% RDFN+25% N through vermicompost (1.07). The lowest number of cobs $plant^{-1}$ was recorded in the application of 50% RDFN+50% N through Farm yard manure (1.01). The length of cob, girth of cob and number of cob are primarily attributed due to better growth of plants in terms of plant height and dry matter accumulation due to integration application of vermicompost and chemical fertilizer. The yield attributing characters (Table 1) like number of grains cob^{-1} (466.49) was highest with application of (75% RDFN+25% N by VC) which was significantly highest among all other treatments. The conjunctive application of chemical nitrogen and vermicompost has been reported to increase in the plant greenery level causing increase in the production of photosynthesis materials, duration of flowering and flowers fertility and therefore increase in number of grains cob^{-1} (Esmaeil et al., 2015). This improvement in yield components of maize with integral application of organic and inorganics might be because of higher availability of macro and micronutrients with the combined application of inorganic and organic sources of nutrients (Chandrashekara et al., 2000).

The perusal of data on the grain weight cob^{-1} presented indicated that the highest grain weight cob^{-1} was 102.67 g cob^{-1} which was exhibited by application of 75% RDFN+25% N by vermicompost followed by the treatment of 50% RDFN+50% N through VC (89.74 g cob^{-1}). The lowest grain weight per cob of 45.06 g cob^{-1} was recorded by the control treatment in the mean data of two years. Manyuchi et al., 2013 found that the increase in grain weight cob^{-1} might be due to increase availability of Zinc and phosphorous like nutrients. Sujatha et al., 2008 also observed similar beneficial effect of organic manures on different growth and yield attributes.

The perusal of pooled data of 2013 and 2014 presented in Table 1 indicated that the test weight of maize was not influenced significantly by different treatments. However, numerically highest 1000-grain weight/Test weight of 220.30 g 1000-$grain^{-1}$ was recorded with the plot which received application of 75% RDFN+25% N by vermicompost. Nasrolahzadeh et al., 2017 also reported no significant 1000 grain weight when they used 6 t ha^{-1} vermicompost and 50% chemical fertilizer in maize.

3.3. Grain and stover yield

The data presented in Table 1 showed that significantly highest grain yield (6.79 t ha^{-1}) in maize was obtained with the application of 75% RDFN+25% N by vermicompost to hybrid maize. On the other hand the least grain yield of 2.97 t ha^{-1} was registered with no manure and no nitrogen treatment. The percent increase of highest grain yield over the control is 56.3%. Increase in maize grain yield owing to integration application of chemical fertilizer and vermicompost might be attributed to steady release of nutrients to soil for longer duration after decomposition resulting in better plant growth and yield attributing characters. Zaremanesh et al., 2017 also found that the application of vermicompost resulted higher grain yield of maize. Gupta et al., 2014 also reported the higher yield in maize due to integrated application of organics and inorganics source of fertilizer. The higher grain yield with integrated nutrient management treatments might be due to remarkable increase in yield components such

as number of grains and grain weight. This is also due to adequate supply of photosynthates for development of sink and balanced nutrition with integrated nutrient management. These findings are alike with those reported by Kumar and Singh (2001).

The experimental data pertaining to the stover yield presented in Table 1 revealed that the stover yield as per pooled data was 10.95 t ha^{-1} by the application of 75% RDFN+25% N by vermicompost which was statistically at par with the 100% RDF (10.92 t ha^{-1}). The lowest stover yield value of 5.47 t ha^{-1} was recorded with control where no organics nor chemical nitrogen had been applied. The improvement in stover yield might be due to significant increase in yield components like length of ear, girth of ear and grains per ear which ultimately resulted into higher productivity. The result was supported by Mahato et al., 2020.

The experimental pooled data of 2013 and 2014 on harvest index perused in Table 1 indicated that significantly highest harvest index was found with the application of 75% RDFN+25% N by vermicompost (0.39). The lowest harvest index was found in the treatment of 75% RDFN+25% N through Mustard oil cake (0.34). Highest harvest index may be due to the combined application of vermicompost with chemical nitrogen which could able to supply nutrients to meet its requirement for long time as well as quick requirement at various stages. This result was in conformity with the findings of Chhetri and Sinha, 2017.

3.4. Economics

Data on economics as influenced by integrated nutrient in hybrid maize (Table 1) revealed that a highest gross return of ₹ 88,318 ha^{-1}, net return of ₹ 52,099 ha^{-1} were recorded when 75% RDFN through chemical fertilizer and 25% N through vermicompost source was applied in hybrid maize. Similar economical result was also reported by Yadav et al., 2016. But, the highest return $rupee^{-1}$ invested (2.83) was obtained with (100% RDF). This might be due to lower cost of cultivation in 100% RDF treatment. Suroshe et al., 2009 also reported increase gross expenditure due to high cost of vermicompost.

4. Conclusion

75% RDFN through inorganic fertilizer and 25% N through vermicompost which produced the significantly higher yield (6.79 t ha^{-1}) and the highest net return of (₹ 52099 ha^{-1}).

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