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Effect of integrated use of biogas slurry and inorganic nitrogen on yield attributes, yield and economics of rainfed maize (*Zea mays* L.)

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ABSTRACT

An experiment was conducted with use of biogas slurry and inorganic nitrogen combinations on rainfed maize at farm of Dry Land Farming Research Station, Arjia, Bhilwara Rajasthan, India during khairf season of 2018 and 2019. The six treatments of biogas slurry (BGS) and inorganic sources of nitrogen viz., T_0-Control, T_1-100 % N by urea, T_2- 25 % N by BGS + 75 % N by urea, T_3 - 25 % N by BGS + 75 % N through urea, T_4-50 % N through BGS + 50 % N through urea, T_5-75 % N through BGS + 25 % N through urea and T_6-100 % N through BGS. Result indicated that plant height of maize was significantly increased under application of 75% N through BGS+25% N through urea over control and other treatments. Highest yield attributing characters viz., cob height, number of cobs per plant, cob length, seeds per cob, cob weight and 1000-grain weight were recorded in application of 100% N through BGS treatment over control and other treatments. Similarly, grain, straw and biological yields were significantly higher under the treatment were 100% N by BGS was applied as compared to control and other treatments and the increase in grain, straw and biological-yield to the extent of 29.18, 61.40, 93.97 and 124.42 per cent over T_4 , respectively. Gross and net returns were enhanced with application of various combinations of organic and inorganic nitrogen sources up to 75 % N by BGS + 25 % N by urea (T_5) as compared to T_1, T_2, T_3, T_4 over control, respectively. Application of 75 % N by BGS + 25 % by urea noted increase in net returns to the extent of 47.81, 90.45, 129.70 and 165.32 per cent over T_1, T_2, T_3, T_4 and over control, respectively. A successive increase in B:C was observed by 75 % N by BGS + 25 % N by urea as compared to other treatments.

Key words: Maize, biogas slurry, nitrogen, yield, economics

INTRODUCTION

Maize is one of the most versatile crops, has the highest genetic yield potential and known as queen of cereals in the World. It is considered as the third most important food crop among the cereals in India. Maize is emerging as an important world cereal crop after wheat and rice due to the high productiveness, easy to process and low cost than other cereals (Jaliya *et al.,* 2008) [13] provides nutrients for humans and animals, serves as basic raw materials for production of starch, oil, protein, alcoholic beverages, food sweetness and more recently fuel. Maize is a heavy feeder crop and it well responded to fertilization, especially where soils are generally low in soil fertility status. Nitrogen is universally deficient in majority of Indian soil and experiment conducted at various places in different agro-climatic zones of India indicated that nitrogen has beneficial effect on growth, yield attributing characters and yield of maize. Enhancing grain yield of maize, nitrogen fertilization has emerged as a serious matter of concern for maize growers. Agricultural intensification and continuous cultivation without replenishing nutrients decline in soil fertility is a major problem for the agricultural (Jones *et al.,* 2013). Inadequate nutrient supply and poor soil quality are major constraints in low input agriculture (Khan *et al.,* 2012). Application of chemical fertilizers in adequate amount by small farmers is limited by their high costs, while on highly resourced farms intensive application has led to pollution of water with nitrate and loss of soil carbon (Nkoa, 2014). Organic wastes need to be utilized to avoid waste or loss of nutrients to the environment (Smith *et al.,* 2014). Instead of direct soil application, manure can also be used to produce biogas for energy, with the potential benefit of biogas slurry as a by-product from the same waste. Biogas slurry from anaerobic digestion of various organic wastes through the biogas technology has received great attention worldwide (Abubaker *et al.,* 2012; Smith *et al.,* 2014;

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Nyangau *et al.,* 2016). The high nutrient composition of BGS has the potential to be used as an organic source of nutrients which is a cheaper and safer alternative source of nutrients compared to chemical fertilizers (Khan *et al.,* 2012). Biogas slurry has the potential to improve crop nitrogen uptake, growth and yields, and adds the necessary organic carbon and improve soil quality (Bachmann *et al.,* 2011; Galvez *et al.,* 2012). Use of BGS as a nutrient source could reduce the need for the use of chemical fertilizers, reducing fertilizer costs, especially for small and marginal farmers in the vicinity of biogas plants (Kumar *et al.,* 2015). Anaerobically digested cattle and pig slurry, which are sometimes referred to as BGS could improve structure, water-holding capacity and overall fertility of the soil, increase crop yields (Malav *et al.,* 2015a,b) compared to chemical fertilizers and other organic composts. A variety of BGS produced from different production systems contained 0.5–2.5% N, 0.5–1.9% phosphorus and 0.6–2.2% potassium (Surendra *et al.,* 2014; Kumar *et al.,* 2015. Application of BGS could help smallholder farmers, who generally apply chemical fertilizers at less than the recommended rates because of the high cost. It was hypothesized that, when applied at the same rate based on N, BGS produced from cattle manure will result in the same maize dry matter, grain yield and nutrient uptake as the feedstock and compound chemical fertiliser, with additional benefits of increasing available P under field conditions. The objective of this study was to assess the effect of integrated use of BGS and chemical fertilizer (alone and combinations) on maize growth, yield attributes and yield and under rainfed conditions.

MATERIALS AND METHODS

An experiment on maize was conducted using biogas slurry at experimental farm of Dry Land Farming Research Station, Arjia, Bhilwara Rajasthan, under Bhilwara agro-climatic conditions (Zone-IVa, Sub-humid Southern plain and Aravalli hills of Rajasthan) during *khairf* season of 2018 and 2019 under rainfed conditions. The six treatments of BGS and inorganic nitrogen consistent *viz*., T_0-Control, T_1-100 % N through urea, T_2- 25 % N through biogas slurry + 75 % N through urea, T_3 - 25 % N through biogas slurry + 75 % N through urea, T_4-50% N through biogas slurry + 50 % N through urea, T_5-75% N through biogas slurry + 25% N by through and T_6-100 % N through biogas slurry and replicated four times. The recommended dose of 50 kg N ha^{-1}, 30 kg P_2O_5 ha^{-1} and the soil of Mewar region of Rajasthan is already reach in potash that's why we are not applied potassic fertilizer for rainfed maize was applied and sown in lines adopting standard package of practice Bhilwara, Rajasthan. The soils of the experimental field was loamy sand having slightly alkaline pH 8.11, EC 0.27 dSm^{-1}, low in organic carbon (0.43%), available N (226 kg ha^{-1}), medium in P_2O_5 (28.0 kg ha^{-1}) and high in available K (370 kg ha^{-1}), The analysis of biogas slurry nitrogen content was done by adopting the procedure suggested by Subiah and Asija, 1956. The nitrogen 1.41%, phosphorus 1.1% and potassium1.0% content were observed in biogas slurry. The nitrogen was applied as per treatment through organic and inorganic fertilizers. The maize variety PM-3 was sown on Ist July during both the years on the same site at 45 cm row to row and 15 cm plant to plant spacing with a seed rate of 20 kg ha^{-1}. All other standard cultural practices were followed during the cropping season. The nitrogen phosphorus were applied through urea & biogas slurry and single super phosphate(SSP) respectively in which full dose of biogas slurry and phosphorus was applied at the time of sowing and half dose of nitrogen as per treatments through urea was applied as basal and the rest 50% was applied at 45 DAS (days after sowing). Observation on growth parameters, yield attributes, yield of maize was recorded at maturity. The economics of produce was calculated as per the prevailing market prices of the inputs and produced during *kharif* season. Statistical analysis was done as per process suggested by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Growth and yield attributes

Plant height

Application of nitrogen through BGS as well urea enhanced plant height of maize at maturity stages. Plant height of maize at harvest was significantly increased with progressive increase of nitrogen by 75 % N through BGS +

25 % recommended dose of nitrogen through urea application over control Plant height at harvest stage was increased by 15.7, 27.9, 37.2 and 44.3 per cent with-75 % N through BGS + 25 % through urea application over 100 % N through urea, 25 % N through BGS + 75 % N through urea, 50 % N through BGS + 50 % N through urea and over control, respectively (Table 2). The increase in plant height might be due to application of BGS is reported to be rich in macro- and micronutrients present in-readily available forms, which are essential for plant growth and development as reported by Smith *et al.,* 2014; Kumar *et al.,* 2015; Cao *et al.,* 2016).

The response in cob height from ground was noted upto 50 % N through BGS + 50 % N through urea and other treatments were statistically at par with each other. The per cent increase in cob height from ground was 17.5, 32.5 and 44.0 with 50% N through BGS + 50% N through urea over 100 % N through urea, 25 % N through BGS + 75 % N through urea and control, respectively (Table 2). These finding are in consonance with Tiwari *et al.,*2022. The number of cobs per plant were significantly enhanced under 25 % N through BGS + 75 % N through recommended dose of N applied through urea over control and 100 % N applied trough urea. The number of cobs per plant under organic and integrated treatments were found to be statistically similar to each other. The per cent increase in cobs/plant under 25 % N through BGS + 75 % N through urea treatment-was 15.0 over 100 % N through urea treatment (Table 1). Faisal *et al.,* 2017 also reported positive effect of integrated use of organic manures and inorganic fertilizer on yield attributing characters on maize.

Cob length of maize was significantly increased with integrate use of organic and inorganic fertilizer as well as organic alone treatment of nitrogen over 100% RDN through chemical fertilizer treatment (Table 1). Application of 75 % N through BGS + 25 % through urea treatment increased the cob length to the extent of 10.6 per cent over 100 % N of through urea treatment. Nitrogen application 75 % N through BGS + 25 % recommended dose of nitrogen through significantly increased number of grains per cob over control and other treatments except organic alone treatment. Treatments, 75% N through BGS +25 recommended dose of nitrogen through urea and 100% N through biogas slurry were statistically similar with each other in respect of number of grain per cob. Application of 75 % N through BGS + 25 % N through urea increased number of grains per cob to the extent of 10.2 per cent over, 50 % N through BGS + 50 % N through urea (Table 1). Galvez *et al.,* 2012 in their study, reported that biogas slurry might increase soil carbon, N dynamics and nutrient availability that have resulted in increased number of grains per cob. Applied 75 % N by biogas slurry + 25 % recommended dose of nitrogen through urea enhanced cob weight over to the tune of 16.82, 25.36, 31.69 and 37.00 per cent over 100 % N of through urea, 25 % N through biogas slurry + 75 % N through urea, 50 % N through biogas slurry + 50 % N and over control, respectively (Table 1). Cob weight is the integration of number of increased grains per cob may be the result of increased cob weight as that biogas slurry increases soil carbon and N dynamics and nutrient availability as reported by Galvez *et al.,* 2012.

Table1: Effect of organic and inorganic nitrogen combination on growth and yield attributing characters of maize (mean over two years)

Treatments	Plant height at harvest stages (cm)	Cob height from ground (cm)	No. of cobs/ plant	Cob length (cm)	No. of grains/ cob	Weight of cob (g)	Test weight (g)
Control	101.71	44.45	1.33	13.49	248.88	86.19	219.63
100 % N through urea	117.72	52.23	1.54	14.92	260.02	100.69	236.78
25 % N through biogas slurry + 75 % N through urea	130.10	58.88	1.67	16.04	267.58	108.05	243.88
50 % N through biogas slurry + 50 % N through urea	139.52	64.00	1.72	16.78	274.23	113.50	250.50
75 % N through biogas slurry + 25 % N through urea	146.75	66.13	1.73	17.42	279.58	118.08	256.25
100 % N through biogas slurry	148.50	66.40	1.74	17.54	280.00	118.69	256.75
SEm±	2.00	1.57	0.03	0.18	1.55	1.32	1.78
CD (P=0.05)	6.03	4.72	0.10	0.55	4.67	3.97	5.38

Application of 100% N through BGS significantly increased 1000-grain weight as compared to 100 % N trough chemical fertilizer treatment. It was significantly at par with 75% N through BGS + 25% N through urea. Application of 75 % N through BGS + 25 % through urea treatment increase 1000-grain weight to the extent of 7.8 per cent over 100 % N of through urea, (Table 1). Enhanced maize production have been reported by Mdlambuzi *et al* 2021[22] as a culmination of increased yield attributing traits in maize by use of nitrogen fertilizer and BGS. Kumar *et al.,* 2015[19] and Kumar *et al.,* 2022[18] advocated that biogas slurry and nitrogen fertility levels has profoundly increased yield attributes in rainfed maize.

Yield

The fertilization with 75 % N through biogas slurry + 25 % N through urea enhanced grain yield of maize over control and other treatment combinations viz., 100 % N of through urea, 25 % N through biogas slurry + 75 % N through urea, 50 % N through biogas slurry + 50 % N and over control under rainfed conditions. Application of 75 % N through biogas slurry + 25 % through urea noted perceptible increase in grain yield to the extent of 29.18, 61.40, 93.97 and 124.42 per cent over 100 % N of through urea, 25 % N through biogas slurry + 75 % N through urea, 50 % N through biogas slurry + 50 % N and over control, respectively. These findings are in consonance with the results of Khan *et al.,* 2015, Faisal *et al.,* 2017 and Tiwari *et al.,* 2022. The increased yield of maize may the result of anaerobically digested cattle and pig slurry, which are sometimes referred to as BGS could improve structure, water-holding capacity and overall fertility of the soil, increase crop yields (Malav *et al.,* 2015a,b)[20,21]. Islam *et al.,* 2010[12] Huiying Du,*et al.,* 2019[11] have reported beneficial effects of biogas slurry on maize production in their study.

The application of 75 % N through biogas slurry + 25 % N through urea perceptibly enhanced stover yield of rainfed maize over control and other treatment combinations viz., 100 % N of through urea, 25 % N through biogas slurry + 75 % N through urea, 50 % N through biogas slurry + 50 % N and over control. 75 % N through biogas slurry + 25 % through urea noted perceptible increase in grain yield to the extent of 32.51, 69.58, 98.86 and 125.76 per cent over 100 % N of through urea, 25 % N through biogas slurry + 75 % N through urea, 50 % N through biogas slurry + 50 % N and over control, respectively. These findings are in consonance with the results of Malav *et al.* 2015 and Conney *et al.,* 2021.

Dosages of 75 % N through BGS + 25 % N through urea perceptibly enhanced biological yield of maize over control and other treatment combinations viz., 100 % N of through urea, 25 % N through BGS+ 75 % N through urea, 50 % N through BGS+ 50 % N and over control of rainfed maize. 75 % N through BGS+ 25 % through urea noted perceptible increase in grain yield to the extent of 30.24, 65.43, 96.36 and 124.37 per cent over 100 % N of through urea, 25 % N through BGS yield is the integration of both grain and straw yield resulted of rainfed maize due incorporation of BGS and urea nitrogen owing to increased increase soil carbon and N dynamics and nutrient availability resulted in increase in both grain and straw yields (Galvez *et al.,* 2012)

Table 2: Effect of organic and inorganic nitrogen combination on yield and economics of maize (mean over two years)

Treatments	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Biological yield (q ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs.ha^{-1})	B:C
Control	19.74	32.45	52.45	54,948	33,348	1.54
100 % N through urea	25.50	43.00	68.31	71,534	49,291	2.22
25 % N through biogas slurry + 75 % N through urea	31.86	55.03	86.77	90,027	63,510	2.39
50 % N through biogas slurry + 50 % N through urea	38.29	64.53	102.99	1,07,392	76,601	2.49
75 % N through biogas slurry + 25 % N through urea	44.30	73.26	117.68	1,23,545	88,479	2.52
100 % N through biogas slurry	46.00	78.44	124.69	1,29,474	90,134	2.29
SEm±	93.33	197.36	204.04	1,982.65	1,982.65	0.05
CD (P=0.05)	281.34	594.91	615.03			

Economics

Data Table 2, revealed that gross return is the integration of both grain and stover yield perceptibly enhanced through 75 % N through BGS+ 25 % N through urea perceptibly enhanced biological yield of maize over control and other treatment combinations viz., 100 % N of through urea, 25 % N through BGS + 75 % N through urea, 50 % N through BGS+ 50 % N and over control of rainfed maize. The application of 75 % N through BGS + 25 % through urea noted perceptible increase in grain yield to the extent of 30.18, 63.84, 95.44 and 124.84 per cent over 100 % N of through urea, 25 % N through BGS+ 75 % N through urea, 50 % N through biogas slurry + 50 % N and over control, respectively. Similar finding have been reported by Adhikari *et al.,* 2021 and Kumar *et al.,* 2022 in maize with the use of graded fertility levels in maize.

Data (Table 2) revealed that fertilization with 75 % N through BGS+ 25 % N through urea perceptibly fetch more remunerative net returns of rainfed maize over control and other treatment combinations of organic and inorganic sources of nitrogen *viz*., 100 % N of through urea, 25 % N through BGS+ 75 % N through urea, 50 % N through BGS+ 50 % N and over control under rainfed conditions. Application of 75 % N through BGS + 25 % through urea noted perceptible increase in net returns to the tune of 47.81, 90.45, 129.70 and 165.32 per cent over 100 % N of through urea, 25 % N through BGS+ 75 % N through urea, 50 % N through biogas slurry + 50 % N and over control, respectively. Similar to gross returns, Adhikari *et al.,* 2021 and Kumar *et al.,*2022 also advocated significantly increased net returns in maize with the use of graded fertility levels in maize.

B:C ratio

A positive and successive increase in benefit cost ratio (B:C) was observed up to 75 % N through biogas slurry + 25 % N through urea of rainfed maize over control and other treatment combinations but statistical increase was observed up to 25 % N through biogas slurry + 75 % N through urea. Other treatments viz., 75 % N through urea, 50 % N through biogas slurry + 50 % N were remained statistically apt par each other and a decline in B:C ratio was noticed with 100 % N applied through biogas slurry under rainfed conditions. Treatment of 25 % N through biogas slurry + 75 % N through urea observed an increase in B:C to the extend of 44.16 and 55.19 per cent over 100 % N of through urea and control, respectively. Verma *et al.,* 2020 and Kumar *et al.,* 2022 reported increased B:C in maize with the use of graded levels of fertility levels.

CONCLUSION

Based on result, it may be concluded that application of 100% N through biogas slurry significantly increased the yield attributes as well as yield of maize which was statistically similar to 75 % N through BGS+ 25%N through urea.

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