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EFFECT OF BIOSLURRY UTILIZATION AND APPLICATION METHODS ON THE AFRICAN STALK BORER (*Buseola fusca*) AND YIELD OF MAIZE

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ABSTRACT
Declining soil fertility and upsurge of insect pests are among the major factors limiting maize production in Kenya. Adequate mineral nutrition has been reported to exert considerable influence on pest and disease development and crop yield. The impact of bioslurry from a biogas digester in reducing the maize stalk borer damage and improving maize yields was evaluated in the field. Three bioslurry application methods: soil incorporation, base application and inter-row application were tested alongside DAP fertilizer and untreated control. The results showed significant differences between treatments where bioslurry was applied compared to the controls. The basal bioslurry treatment increased the germination percentage of maize from 75 % in the untreated control to 88. 8% in season 1 and 80% to 90% in season 2. The maize grain yield was significantly higher in incorporation (4.4 tons) and basal (4.1 tons) treatments compared with DAP fertilizer. There was however no significant differences in the plant growth and yield parameters between inter-row treatment and the untreated control. The results indicated that incorporation and basal bioslurry treatments had a significantly lower stalk borer damage scores of <2 compared to the DAP (3.2) and the untreated control (5.8). Biogas slurry can significantly improve soil fertility, crop yield and resistances to biotic and a biotic stresses.

KEY WORDS: fertilizers, soil fertility, bio pesticides, biogas.

INTRODUCTION

Maize (*Zea mays*) is a staple food crop that provides a large portion of the caloric intake for most households in Kenya and other parts of the world. The annual production of maize in Kenya is about 3.71 million tonnes translating to an average yield of 2 tonnes per hectare (Government of Kenya, 2018). This is way below the estimated potential yield of 6 tonnes per hectare. The low yields are attributed to declining soil fertility and upsurge of insect pests and diseases among other factors. The decline in soil fertility in many maize growing area of Kenya is primarily as a result of intensive and continuous land use without adequate and appropriate replenishment of nutrients. Furthermore, maize growers in Kenya often rely on inorganic fertilizer sources that contain only nitrogen (N) and phosphorus (P), resulting in a steady decline in other nutrients in the soil. Continuous applications of inorganic fertilizers have a negative impact on physical, chemical, and biological properties of soil (Getachew *et al*., 2014). The situation is further confounded by the high costs of inorganic fertilizers that lead to sub-optimal nutrient application particularly by the resource poor small holder farmers (Mbuthia *et al.,* 2015). The African maize stalk borer (*Buseola fusca*) on the other hand constitutes one of the major insect pest problems limiting maize production worldwide (Meihls *et al*., 2013). The younger larval stages of the stalk borer feed on leaf tissues while older stages tunnel and feed on the pith within the maize stems (Samayoa *et al*., 2015). Stalk borers also attack cobs, resulting in secondary fungal infection and contamination of grain with mycotoxins such as aflatoxin (Visconti *et al*., 1999). Stalk borers cause an estimated yield loss of 0.315 – 0.386 t/ha which is about 13% of the total maize yield (De Groote, 2002). Several approaches have been used to manage stalk borers on maize but chemical control still remains the preferred and most effective. Chemical control is however expensive to most small-scale farmers and risky to humans, livestock, and the environment.

Adequate mineral nutrition is key in crop production and has also been reported to exert considerable influence on pest and disease development (Westerveld *et al*., 2003). Soil nutrients are important for growth and development of plants and hence important factors in pest control (Agrios, 2005). Host plant resistance to insect pests and diseases is related to optimal physical, chemical and biological characteristics of soils. Mineral nutrition influences growth and yield by affecting plant resistance or susceptibility to pathogens and pests. Ghada *et al.* (2017) reported that nitrogen, phosphorus, potassium, calcium and silicon have a strong influence on plant susceptibility to pest attack. Chemical fertilizers may however not be an appropriate solution to correct nutrient deficiencies and poor soil structure in low input maize production systems (Mungai, *et al.,* 2009). There is an urgent need to evaluate affordable and locally available organic nutrient resources that can enhance maize production in Kenya.

Bioslurry from anaerobic biogas digesters is an emerging organic fertilizer with great potential in boosting agricultural productivity and reducing the cost of artificial fertilizers and pesticides (Garg *et al.,* 2005). The process of bio-digestion increases the ratio of NH_4^+ to total N, therefore converting nitrogen into a form more readily available for uptake (Velthof, *et al.*, 1998). Studies by Nyang'au *et al*. (2016) also indicated a relatively higher concentration of nitrogen, phosphorous and potassium in bio-slurry compared to slurry compost and farmyard manure. Studies have further indicated that bioslurry contains pesticidal and antibiotics substances that can be used to control plant pests such as aphids, red spider mites and diseases such as watermelon wilt, wheat scab, potato blight, wheat root rot among others (de Groot and Bogdanski, 2013). Bioslurry has also been reported to enhance the production of plant hormones that improve plant tolerance to both biotic and abiotic stress factors. It is however unclear how consistent these effects are and what are the mechanisms behind it.

The efficacy of bioslurry from biogas units as an organic fertilizer and bio-pesticides has not been widely tested nor documented. Among key factors that influence nutrient availability from bioslurry are the methods and timing of application (Monlau *et al*., 2015). Understanding bioslurry application methods and how this impact maize yield is critical to the development of sustainable crop and livestock production systems that incorporate crop and clean energy production. A two year (2015 to 2016) study was therefore conducted to evaluate the positive impact of bioslurry utilization and its application methods in the management of *Buseola fusca* stalk borer incidences and severity for improved maize yields.

MATERIALS AND METHODS

Study Site

A Field experiment to evaluate the effect of bioslurry utilization and application methods in the management of stalk borers for improved maize growth and yield was conducted at Egerton University Tatton Agro-Park (TAP) farm situated in Nakuru county Kenya during 201 and 2016 growing seasons. The farm lies at a latitude of 0˚30'S, longitude 36˚30'E and an altitude of 2238m.The experimental site receives an mean annual rainfall of 1013 mm and the dominant soil type is mollic andosols with an average pH ($CaCl_2$) of 5.0.

Soil analysis

Soil sampling and analysis was done in three stages; at the beginning of the experiment, after the first season and after the second season. Soil samples were taken from the 0-30cm of each experimental plots at the beginning of the experiment to make a composite sample. The second and third soil sampling was done after the first and second season whereby soil samples were taken from 5 random points in each plot to make separate composite samples. The different soil samples were air dried, crushed and then sieved through a 2 mm sieve. Soil analysis was done to determine the total N using the Kjeldahl method (Hinga *et al.*, 1980). Organic carbon was determined by calorimetric method and Soil pH was determined in a 1:1 (w/v) soil-water suspension with a pH meter. Exchangeable K and extractable P were determined through extraction with 0.5 M $NaHCO_3$+0.01 M EDTA (pH 8.5, modified Olsen) using a 1:10 soil/solution ratio and analysed by flame photometer and calorimetrically (molybdenum blue) respectively.

Field experiment

The bioslurry collected from the Egerton University biogas digester was evaluated at three different application methods namely; spreading bioslurry in the whole plot and mixing with soil before planting (incorporation), placing the bioslurry in the holes before planting (basal) and spreading bioslurry in between the plant rows during planting (inter-row) was applied using buckets at a rate of 15t/ha. The treatments were arranged in a Randomised Complete Block Design (RCBD) replicated four times. Di ammonium phosphate (DAP) fertilizer was used as a positive control alongside the untreated control. Experimental plots measuring 4 m × 6 m with a spacing of 0.75 m between and 0.30 within the rows were planted with certified maize seeds (variety hybrid 614). Two most central plants in the four middle rows of each plot were tagged after crop emergency for subsequent for data collection.

Maize performance

Germination percentage

Data on germination percentage was collected by counting the number of maize plants that had fully emerged at 14 days after planting.

Plant height

Mean plant height (cm) was taken at 6 weeks after planting by measuring the height of the tagged plants.

Leaf area index

Mean leaf area index was calculated as the product of the total length and breadth at the broadest point of the longest leaf of the tagged plants at 6 weeks after planting as follows:

$LA = 0.75 (L X W)$

Where LA, L and W are leaf area, leaf length and leaf width respectively, and 0.75 is a constant.

Biomass

The above ground and below ground dry biomass was also taken at six weeks after planting by uprooting the whole two of the tagged plants and separating the shoot from the roots. The roots and shoots were dried in an oven at 70°C until constant weight was obtained.

Yield

Yield was estimated by harvesting the remaining six most central plants in the 2 middle rows (equivalent to I m^2) and sun-drying to 15% before threshing. The grains were further dried to 13% moisture before weighing.

Stalk borer incidence and damage

The stalk borer incidence was taken by visually examining and recording the number of plants showing windowing on leaves, tunnelling on stems or dead hearts in each plot at vegetative stage (4 weeks after emergence), 50% flowering stage and at physiological maturity. The stalk borer damage score was done by counting the number of windows on the leaves at vegetative stage (4 weeks after emergence), the number of holes on the stems at 50% flowering and on the cobs at physiological maturity. The damage was score was computed using a 1-6 scale as follows 1 = no holes, 2 = 1-3 holes, 3= 4-6 holes 4 = 7-9 holes, 5=10-12 holes, 6=13-15 holes.

Data analysis

The differences in soil, maize growth and yield parameters and stalk borer damage, in the different bioslurry application methods were assessed using the general linear model (GLM) of the Statistical Analysis System (SAS, 1999). The least significance difference method (LSMEANS) was used to assess differences in treatment means

RESULTS

Soil analysis

The soil analysis results indicated that bioslurry had a significant effect on the soil chemical properties (Table 1). The highest extractable P values of 11.6 mg kg^{-1} in season 1 and 11.9mg kg^{-1} in season 2 were recorded in the incorporation treatment. This was not however significantly different from the basal treatment which recorded 10.9 mg kg $^{-1}$ in season 1 and 11.0 mg kg $^{-1}$ in season 2. A similar trend was observed in the extractable K values whereby incorporation treatment recorded 600 mg kg $^{-1}$ and 630 mg kg^{-1} in season 1 and 2 but was not significantly different from basal treatment which recorded 582 mg kg -1 and 615 mg kg -1 in season 1 and 2 respectively. The bioslurry application methods also presented some variations in the soil total N and organic carbon but statistical differences (P <0.05) were only observed in the treatment with incorporation method (0.29 %) and (3.12%) for total N and for organic C respectively during the season 1. The total N and organic C content however increased to 0.31% and 3.31% respectively in the season 2. This was however not significantly different from basal treatment which recorded 0.28% for N and 2.99 % for total N and organic C respectively in the season 2. There were no significant differences in total N and organic C content among the inter row treatment, DAP fertilizer and the untreated control in season 2. The highest pH value of 5.60 was recorded in the incorporation treatment in season 1 and 5.74 in season 2. The pH values were however not significantly different in the basal treatment which recorded a pH of 5.60 in season 1 and 5.57 in season 2. The inorganic fertilizer DAP indicated an acidification process by reducing the pH from the initial value of 4.7 to 4.65 in season 1 and 4.4 in season 2.

TABLE 1: The effect of bioslurry application methods on soil extractable P and K, Total N and organic C and pH

	initial	Season 1					Season 2				
Treatment		**T0**	**T1**	**T2**	**T3**	**T4**	**T0**	**T1**	**T2**	**T3**	**T4**
P mg kg^{-1}	4.9	4.9b	4.5b	11.6a	10.9a	4.9b	3.9b	4.3b	11.9a	11.0a	4.9b
K mg kg^{-1}	578	578a	580a	600a	582a	579a	475b	585b	630a	615a	579b
Total N (%)	0.15	0.15c	0.16b	0.29a	0.23b	0.18b	0.09c	0.18b	0.31a	0.28a	0.21b
Organic C (%)	2.54	2.54c	2.67b	3.12a	2.94b	2.70b	2.56b	2.65b	3.31a	2.99a	2.75b
pH 1:1 (w/v)	4.70	4.70c	4.65c	5.60a	5.55a	4.71b	4.70	4.4c	5.74a	5.57a	4.73b

Germination

Bioslurry application methods influenced germination percentage particularly in season 1 (Table 2). Basal application and incorporation recorded the highest germination percentage of 88.8% and 83.8% in season 1 and 90.8% and 88.7% in season 2. There were no significant differences in germination percentage between DAP fertilizer, the untreated control and inter row bioslurry treatment.

Plant height

The bioslurry application methods significantly affected plant height taken at 6 weeks after planting (Table 2). The maximum plant height of 430.2 cm was recorded with the basal treatment in season 1 and 440.2 cm in season 2. This was followed by incorporation treatment which recorded a plant height of 390.7 cm in season 1 and 435.7 cm in season 2. This which however not significantly from DAP fertilizer which recorded a plant height of 370.9cm and 380.9 cm in season 1 and 2 respectively.

Leaf area index (LAI)

The highest leaf area index was recorded in the plots with basal treatment (361.7, 368.7) cm followed by incorporation (287.0 ,290) in season 1 and 2 and DAP fertilizer with 243 in season 1 and 246 in season 2 (Table 2). There were no significant differences in Leaf area index between inter row treatment and the untreated control in season 1 and 2.

Biomass

After 6 weeks, basal bioslurry treatment had the highest mean above and root dry biomass Table 2). The highest root biomass of 29.5 g was recorded in the basal treatment in season 1 and 31.5 g in season 2. This was followed by incorporation treatment which recorded a below root biomass of 23.9 g and 25.9 g in season 1 and 2 respectively. A similar trend was observed in the shoot biomass where the highest weight of 84.0 g in season 1 and 91.0 g in season 2 respectively were recorded in the basal treatment. This was followed by incorporation treatment with 70.3g in season 1 and 85.3 g in season 2 and DAP fertilizer 47.3g in season and 50.5g in season 2. The lowest shoot biomass was recorded in the untreated control 14.6 g which was significantly different ($p < 0.05$) with inter row bioslurry application method in season 1 and in season 2.

Yield

The results showed that the total grain yields were significantly higher under plots that were applied with bioslurry compared to the control plots (Table 2). The highest grain yield was in the plots with basal bioslurry treatment (4.4ton ha^{-1}) which was not significantly different from soil incorporation treatment (4.1 ton ha $^{-1}$) followed by the DAP fertilizer (3.1 ton ha $^{-1}$). There was however no significant differences in the maize yields between the plots with inter-row bioslurry application (1.9 ton ha $^{-1}$) method and the untreated control (1.6 ton ha $^{-1}$).

TABLE 2: The effect of bioslurry application methods (T0-untreated, T1-DAP, T2-incoporation, T3-basal and T4-inter row) on soil maize germination percentage, plant height LAI shoot and root biomass and yield

Treatment	Germ. %	Plant ht (cm)	LAI	Root (g)	Shoot (g)	Yield ton ha $^{-1}$
T0	75.5b	280.4c	193.2c	5.9d	14.6e	1.6c
T1	75.3b	370.9b	243.0bc	18.9bc	47.3c	3.1b
T2	83.8a	390.7b	287.0b	23.9b	70.3b	4.1a
T3	88.8a	430.2a	361.7a	29.5a	84.0a	4.4a
T4	75.8b	285.4.c	207.3c	15.3c	24.9d	1.9c
Season 2						
T0	80.5b	300.4c	195.2d	6.9c	18.6e	1.8d
T1	80.3b	380.9b	246.0c	19.9b	50.5c	3.7b
T2	88.7a	435.7a	290.0b	25.9a	85.3b	5.1a
T3	90.8a	440.2a	368.7a	31.5a	91.0a	5.3a
T4	80.8b	320.3c	218.3d	9.9 c	34.9d	2.0d

Stem borer infestation and damage

Results indicated that applying bioslurry significantly influence on the stalk borer damage on maize during the two experimental seasons (Fig. 1a and 1b). The damage score on leaves was lowest in basal treatment (1.3 and 1.5) in season 1 and 2 which was not significantly different from incorporation treatment with a damage score of 1.5 in both season 1 and 2. The highest damage score on leaves was recorded on the untreated control (5.8 and 4.9) in season 1 and 2. There were no significant differences in the damage score on leaves between the untreated control and DAP fertilizer in season 1.The stalk borer damage score on stems was similarly lowest in the incorporation and basal treatments with each recoding a damage score of 1 in both seasons. This was followed by DAP (3.2) in season 1 and 2.2 in season 2. The highest score was in the untreated control (4.4) in season 1 and 4.2 in season 2 which was not significantly different from the inter row treatment. The most significant damage score on cobs was observed in the untreated control (4.0) while all other treatments had a damage score of equal or less than 1.5. The lowest stalk borer infestation percentage was recorded in the incorporation treatment (3.6 and 2.1) % in season 1 and 2 which was not significantly different from basal treatment (3. 4 and 2.0) (Fig. 2) This was followed by DAP fertilizer (11. 1 and 10.2) %) in season 1 and 2 which was however not significantly different with inter-row bioslurry application (10 9 and 9.0) % in season 1 and 2.

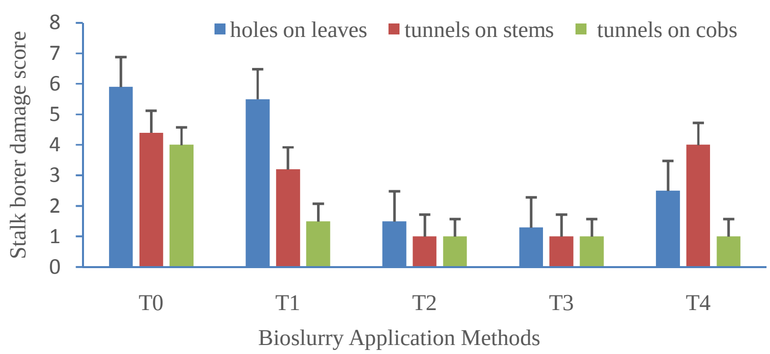

FIGURE 1 a: Effect of bioslurry application methods on stalk borer damage in season 1

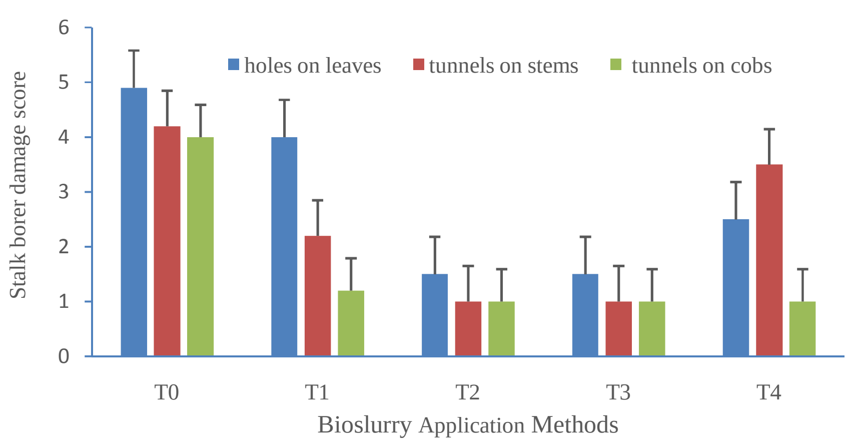

FIGURE 1b: Effect of bioslurry application methods on stalk borer damage in season 2

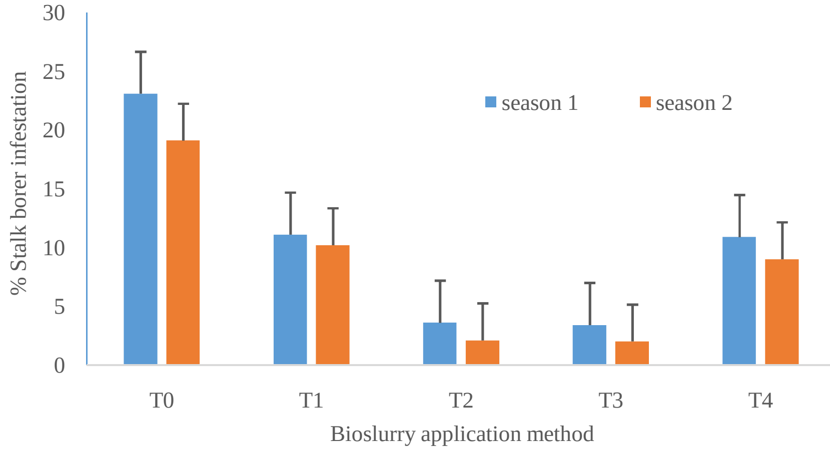

FIGURE 2: Effect of bioslurry application methods on % stalk borer infestation in season 1 and 2

DISCUSSION

Bioslurry application significantly increased the soil pH, total N content and organic C in the soil compared to the controls. (Malav, *et al.,* 2015; Nyangau *et al.,* 2916) reported that bioslurry from biogas digesters contains higher pH % organic matter and total Nitrogen compared to the initial manure. The application of organic materials such as bioslurry enhances the microbial biomass and microbial activity of soils (Krey *et al*., 2013; Requejo and Löbermann, 2014). This study indicated that bioslurry is an efficient material for increasing soil pH. This could due to the buffering properties resulting from high organic matter in the bioslurry. Studies done elsewhere have shown that pH exerts a strong influence on the composition of soil microbial communities (Risberg *et al*., 2017). The inorganic fertilizer (DAP) fertilizer on the other hand indicated an acidification process by reducing the pH from the initial 4.7 to 4.4 at the end of the experiment. Caires *et al*. (2008) also reported acidification of soils from inorganic fertilizer sources.

Bioslurry application greatly improved the maize germination percentage particularly in the first season which was relatively dry compared to the second planting season. This is consistent with studies done by Gurung (1997). He reported higher germination rates with seeds that were treated with bioslurry. The possible bioslurry seed treatment effect observed in this study was more profound in the basal bioslurry application method which recorded the highest germination percentage in season 1. This is most likely due to the direct contact with the seed and also improved moisture when bioslurry is paced in the planting hole.

Maize plant height, leaf area and dry biomass also improved in plots that received bioslurry treatments. Similar observations were made by Garg *et al*. (2005) and Abera *et al*. (2017) who reported that bioslurry application increased the leaf area index, root length density and yield of wheat. The increase in the plant growth and yield parameters reported in this study can be attributed to the higher total N observed in the soils sampled from the bioslurry treated plots. Higher N increases cell division, cell elongation, nucleus formation as well as green foliage (Jothi *et al*. 2003). They further stated that Plants growing on fields amended with bioslurry were observed to have more vegetative growth than those under control treatment.

The response of below ground and above ground dry matter yield to bioslurry application was more pronounced in the plots hat received basal and incorporation treatments. Studies by Torbert *et al*. (2001) indicated that immediate incorporation of pig bioslurry through tillage increase the N value and hence had greater N/P fertiliser value. The higher root dry matter recorded in this study could be due to the increased P values in basal and incorporation treatments. Sufficient amounts of P in the soil supports root growth, stalk strength, crop quality and grain production (Schachtman, *et al*., 1998; Pintro *et al*. (2004).) K on the other hand plays an important role in improving nitrogen use efficiency (NUE) in addition to improved plant vigour and yield (Yost, *et al* 2012). The inter row bioslurry treatment on the other hand had very little or no impact on soil and plant parameters. Spreading bioslurry on the surface may have led to ammonia volatilization resulting into lower nutrient status. (Thomsen, 2004; Whelan, 2010). The results on improved soil chemical properties were more pronounced in the second season indicating that long term fertilization of agricultural crops with organic fertilizers such as bioslurry leads to changes in soil microbial biomass and community composition.

Bioslurry application significantly increased maize grain yield. This can attributed to the improved soil fertility that resulted from positive changes to the soil, including increased soil pH, extractable P and K, total N and organic C. Organic fertilizers have been reported to improve crop growth by supplying plant macro and micro nutrients at the same time improving the physical, chemical, and biological properties of the soil (Sadina *et al.*, 2019). The low plant growth and yield parameters observed in plots treated with DAP fertilizer could be as a result of the lower soil pH and poor chemical properties. A drop in soil pH below 5, has been reported to have negative effects not only on soil microorganisms but also on crop yields (Geisseler and Scow, 2014).

Bioslurry application significantly reduced the stem borer damage score and incidence compared to the DAP and the untreated control. This is consistent with studies done by (Ghada *et al.* 2017) have demonstrated how the shift from organic soil management to chemical fertilizers has increased the potential of certain insects and diseases to cause economic losses. Luong, *et al*. (2005) also reported that organic fertilizers on rice minimized the outbreak of insect pests and diseases. Soil pH, nitrogen forms and the availability of nutrients play a major role in pest and disease management. Further studies have indicated that low potassium (K) and sulfur (S) uptake can predispose the crop to serious disease and insect damage (Westered *et al*. 2003). Wani *et al*. (2017) concluded that organic crops are more tolerant and resistant to insect attacks.

CONCLUSION & RECOMMENDATION

Biogas slurry can significantly improve soil fertility, crop yield and resistances to biotic and a biotic stresses. It is however not clear whether the efficiency of the bio-slurry was due to the direct effect on the pests, or perhaps to an indirect effect through increased fertilization or both. The current study concluded that biogas technology as an emerging component of the dairy value chain should not only focus on energy but also in crop production particularly among the rural poor with limited or no access to agricultural inputs.

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