Preparation and Evaluation of Goat Manure-Based Vermicompost for Organic Garlic Production in Manyatta sub-county, Kenya

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***Abstract*— *Application of vermicompost in crop production results in improved soil chemical properties. Studies relating to use of vermicompost as alternative to synthetic fertilizers have gotten considerable attention as the demand for organically produced agricultural products increases. Goat manure has been reported to be rich in nitrogen, phosphorous and potassium. However, preparation and utilization of goat manure-based vermicompost in organic garlic production in the study area is scanty. Thus, farmers have solely relied on chemical fertilizers in garlic production which is a health and environmental hazards and causes ground and surface water pollution due to nitrate leaching. In Manyatta sub-county of Eastern Kenya, farmers use synthetic fertilizers in garlic production which is not sustainable despite having readily available goat manure which can be composted for use. The aim of this study was to prepare and evaluate effectiveness of goat manure-based vermicompost for organic garlic production in Manyatta sub-county, Kenya. Goat manure-based vermicompost was prepared at KALRO Embu station, Embu County between July–November 2018. The vermicompost obtained was dried, screened and filled into bags and was used for growing garlic. A sample of goat manure-based vermicompost was analysed for chemical properties and the results showed that it had very high total N (1.79%), very high available P (52 ppm), very high exchangeable K (1.75 Cmol Kg^{-1}) and it was moderately alkaline (pH 7.73). Hence, goat manure-based vermicompost is recommended in the organic production of garlic in Manyatta sub-county of Eastern Kenya.*

Keywords— ***Goat manure, organic production of garlic, vermicompost.***

I. INTRODUCTION

Vermicompost is a complex mixture of earthworm faeces, humified organic matter and microorganisms, which when added to the soil or plant growing media, increases germination, growth, flowering, fruit production and accelerates the development of a wide range of plant species (Lazcano and Dominguez, 2011). Vermicompost greatly increases microbial activity and nutrient availability. In addition, it contains most nutrients in plant available forms such as nitrates, phosphates, and exchangeable calcium and soluble potassium which are responsible for increased plant growth and crop yield (Arancon *et al.*, 2004). Vermicompost makes soil structure spongy, improves bulk and real density, porosity, increases aggregate's stability and soil structure, and increases the rate of water penetration in the soil and aeration (Ahmadabadi *et al.*, 2011).

Although there have been many studies relating to the benefits of using vermicompost as a fertilizer source (Alsina *et al.*, 2013), there is no available research which has focused on use of goat manure in preparation of vermicompost and on the optimum application rates of vermicompost on garlic in the study area. Mikile (2001) conducted a study which showed that goat manure is one of the richest sources of nutrients that can be used for soil enrichment. The study showed that, in terms of nutrients

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composition of different manures, cattle manure had the lowest nitrogen, phosphorus and potassium contents followed by sheep manure and goat manure had the highest content of nitrogen, phosphorous and potassium.

A wide range of organic residues, including sewage sludge, animal wastes, crop residues and industrial refuse are increasingly being converted by earthworms to form vermicompost (Pascal *et al.,* 2010). Earthworms breakdown the organic residues, which stimulate greater microbial activity, increase nutrient mineralization rates, and rapidly convert the wastes into a humus-like substance that has a finer structure than ordinary composts while possessing greater and more diverse microbial population (Atiyeh *et al*., 2000). Earthworms have an important influence on soil structure, forming aggregate and improving the physical conditions for plant growth and nutrient uptake. During vermicomposting, earthworms eat, grind, and digest organic wastes with the help of aerobic and some anaerobic micro flora, converting them into a much finer, humified, and microbial active material (Degwale, 2016). The organic carbon in vermicompost releases the nutrients slowly and steadily into the soil and enables the plant to absorb the available nutrients (Lalitha *et al.*, 2000).

Vermicompost has been reported to contain plant growth regulators and other growth influencing materials produced by micro-organisms which can contribute positively towards better crop yields (Atiyeh *et. al*., 2002). Studies have indicated effect of vermicompost on an improvement in soil physical properties, soil fertility and uptake of mineral nutrient (Azarmi *et al*., 2008). However, the effective preparation of goat manure-based vermicompost on garlic production is not yet fully understood in Kenyan condition. Therefore, the present research focused on studying the effective way of making goat manure-based vermicompost so as to enhance the soil chemical properties, growth and yield of garlic in the study area.

II. MATERIALS AND METHODS

2.1 Study site

The study was conducted at Kenya Agricultural and Livestock Research Organization station in Embu. The site lies at a latitude of 0.4762ºS and longitude 37.4702ºE. Manyatta sub-county is located on the eastern slope of Mount Kenya in Embu County. According to Jaetzold and Schmidt (1983), Embu County lies in the lower midland 3, 4 and 5 (LM3, LM4 and LM5), upper midlands 1, 2, 3 and 4 (UM1, UM2, UM3 and UM4) and inner lowland 5 (IL 5) at an altitude of approximately 500 m to 1800 m above sea level (a.s.l.). It has an annual mean temperature ranging from 17.4 to 24.5ºC and an average annual rainfall of 450 mm to 1400 mm. The rainfall is bimodal with long rains falling from around March to June and short rains from around October to December. It has *humic nitisols* soils. The prime cropping activity is maize intercropped with beans though livestock keeping is also equally dominant. Various agricultural activities have been carried out in the region hence the rationale behind its selection (Kisaka *et al.*, 2015).

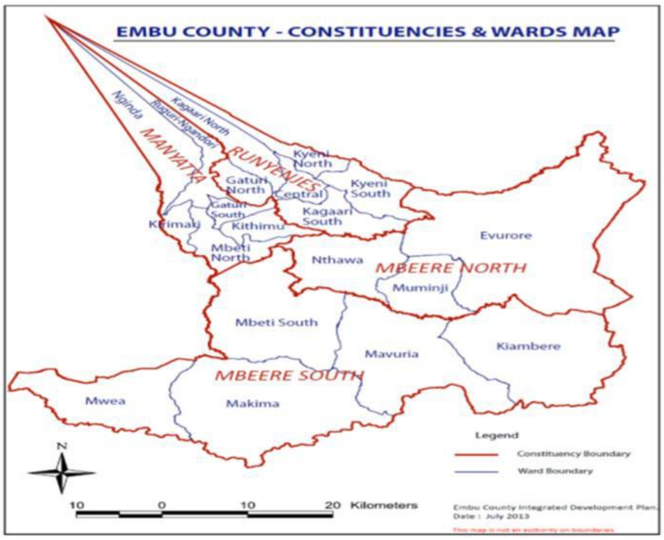

Fig.1: Map of Embu County (Sourced from Kenya mpya County maps, 2012)

2.2 Preparation of Goat Manure-Based Vermicompost

Goat manure was used as the main raw material to prepare vermicompost. A vermicompost bed was constructed using bricks and mortar on the walls. The bed measured three metres long by one-metre-wide by one-metre-high according to Ansari and Sukhraj (2010). A shed was erected above the vermicomposting bed to prevent direct sunlight and rain and also fenced around using wire chain link to prevent predators of earthworms like chicken and other birds.

A basal layer composed of broken bricks followed by a layer of coarse sand to the thickness of seven centimetres was placed inside this bed to ensure proper drainage according to Ramnarain *et al.* (2019) and restrict earthworm movement towards the soil layer. A layer of 15 cm of loamy soil was placed at the top and moistened. Small lumps of fresh goat manure were scattered over the soil. This acted as an active growing medium for earthworms according to Rekha *et al.* (2018).

Two thousand and eight hundred red wiggler earthworm (*Eisenia fetida)* species were introduced to facilitate decomposition of the materials according to Mbithi *et al.* (2015). The earthworms were sourced from AAA growers in Naromoru, Laikipia County. This was followed by ten centimetres thick layer of dry grass, dry banana leaves and dry bean husks which were placed above it to act as bedding material of the worms. Dry goat manure weighing 100 kg was placed and spread on these materials in the bed up to ten centimetres thick. The same set of layers was continued till a height of one metre according to Rekha *et al.* (2018).

This was followed by sprinkling uniformly five litres of water to the vermicompost bed in order to keep it moist and facilitate easy earthworm movement in these materials. Water also prevents desiccation of earthworms. Gunny bags were placed on the top to cover the materials.

The vermicompost bed was kept moist by sprinkling two litres of water once a week and this continued up to the seventh week. Turning of these materials was done once after 15 days and it was done gently to avoid injuring earthworms since they have soft bodies. Goat manure-based vermicompost was harvested after 120 days according to Ramnarain *et al.* (2019). This was after the earthworms were found sticking to the under surface of gunny bags indicating that composting process was complete.

The goat manure-based vermicompost from the bed was harvested and spread on a polythene sheet. From this harvested goat manure-based vermicompost, adult worms and young ones were handpicked and isolated. The goat manure-based vermicompost obtained was dried under a shed for one day, screened and was filled into bags ready for organic growing of garlic.

A sample of goat manure-based vermicompost was analyzed for pH using a digital pH meter (Jones, 2001), total N using kjeldahl method (Bremner and Mulvaney, 1982), available P using extraction with 0.5 M $NaHCO_3$ according to methods of Olsen *et al.* (1954) and exchangeable K using Flame photometer (Jackson, 1967). The analysis was done at the University of Nairobi, upper Kabete campus soil laboratories.

2.3 Goat manure based-vermicompost and goat manure sample analysis results

A sample of goat manure-based vermicompost (GMBV) and goat manure (GM) used in the experiment were analysed for chemical properties and the results are presented in Table 1.

Table 1: Chemical analysis of goat manure-based vermicompost and goat manure samples used in the experiment

Type of manure	Parameters	Characterization	Very high	High	Medium	Low	Very low
GMBV	pH-H_2O (1:2.5)	7.73			>75.5-7.0	<5.5	
	TN (%)	1.79		>0.7	0.5-0.7	<0.5	
	P (ppm)	52	>46	26-45	16-25	10-15	<9
	K (Cmol Kg^{-1})	1.75		>0.60	0.31-0.60	0.21-0.30	
GM	pH-H_2O (1:2.5)	8.0			>75.5-7.0	<5.5	
	TN (%)	0.32		>0.7	0.5-0.7	<0.5	
	P (ppm)	24	>46	26-45	16-25	10-15	<9
	K (Cmol Kg^{-1})	0.59		>0.60	0.31-0.60	0.21-0.30	

Legend: GMBV – Goat manure-based vermicompost, GM – Goat manure, TN – Total Nitrogen, P – Phosphorous, K – Potassium

The results of chemical analysis of goat manure-based vermicompost used in the study showed that it had very high total nitrogen, very high available phosphorous and exchangeable potassium and it was moderately alkaline (Table 1) according to the ratings based on the ranges given by Hazelton and Murphy (2007). For goat manure which was also used in the study, the results showed that it had high total nitrogen, medium available phosphorous and exchangeable potassium and it was moderately alkaline (Table 1). The ratings were based on the ranges given by Hazelton and Murphy (2007). Hence, these results showed that goat manure-based vermicompost had higher nutrient availability (nitrogen, phosphorous and potassium) than goat manure that was used in this experiment.

2.4 Initial Soil Characteristics

The soil samples of the experimental site were analysed for soil chemical properties before planting and the results are presented in Table 2.

Table 2: Initial soil characterization of the study site

Soil parameter at Manyatta study site		Comparison soil nutrient rating scale				
Parameters	Soil characterization	Very high	High	Medium	Low	Very low
pH-H_2O (1:2.5)	6.33			>75.5-7.0	<5.5	
TN (%)	0.03		>0.7	0.5-0.7	<0.5	
P (ppm)	4.57	>46	26-45	16-25	10-15	<9
K (Cmol Kg^{-1})	0.26		>0.60	0.31-0.60	0.21-0.30	

Legend: TN – Total Nitrogen, P – Phosphorous, K – Potassium

The results showed that the pH of the soil at Embu was 6.33 which is moderately acidic based on the ranges given by Hazelton and Murphy (2007). This value lies within the ranges of 6.0 and 7.0 which is considered as optimum soil pH suitable for garlic (DAFF, 2017).

The initial total nitrogen content (0.03%) of the soils at Embu was very low when compared to Tadesse (2015) classification. According to Tadesse (2015), nitrogen content of soil of less than 0.05% is rated very low, between 0.15 – 0.25% is rated medium and greater than 0.25% is rated high. The deficiency of N results in reduced onion yields with respect to size and weight of the bulb (Mohammad and Moazzam, 2012). The initial low N level in the study area may be attributed to lower level of organic matter. Organic matter is a crucial source of soil N for crop growth through gradual decay and mineralization in the soil (Mbindah, 2017).

Soil available phosphorous in the site was very low when compared to the ranges given by Hazelton and Murphy (2007). Low available phosphorous in the soil implies that the garlic crops which belongs to the onion family could experience poor root development, stunted growth and delay in crop maturity unless P is supplemented as either foliar spray or soil fertilizer (Mbindah, 2017). Inadequate soil P may inhibit cell division in the meristematic tissues. This may encourage premature cell differentiation within the root tip that results in inhibition of primary root growth of young flowering plants (Chacon *et al.*, 2011). Most vegetables benefit from phosphorous fertilization if the soil test is less than 35 – 40 ppm phosphorous using the Bray – Kurtz P_1 extraction method (Tadesse, 2015).

Soil exchangeable potassium of the study site was found to be low when compared to ratings given by Hazelton and Murphy (2007). According to Tadesse (2015) soils that are less than 85 ppm potassium, are categorized under low potassium content. Garlic prefers a fairly neutral pH ranging 6.0 – 7.0 and hence if the soil is too acidic or too alkaline it causes slowed growth and late maturity in garlic. Moreover, nitrogen decreases as soil acidity increases while it becomes available as soil alkalinity increases (Tadesse, 2015). Potassium is important for maintenance of turgor pressure, accumulation and transport of metabolic products in the plant in water stressed conditions (Bationo *et al.*, 2012). Thus, potassium is an essential nutrient for optimal garlic production and yields. Mageed *et al.* (2017) reported that application of higher levels of K fertilizer in calcareous soils in an arid area, significantly improved plant water status of soya beans. Sufficient soil exchangeable K may therefore significantly contribute in enabling garlic crop to cope with prolonged drought.

III. CONCLUSION

The chemical analysis of goat manure-based vermicompost results showed that it contained higher levels of macronutrients nitrogen, phosphorous and potassium. Hence, if prepared well and applied using the appropriate rates it can sustain higher garlic plant growth by providing the macronutrients nitrogen, phosphorous and potassium. The soil analysis report of the experimental sites before planting revealed that the soils of the study area have low inherent soil fertility in terms of nitrogen, phosphorous and potassium. Hence, there is need to supply organic manures like goat manure-based vermicompost to enhance soil fertility for improved garlic productivity.

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