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Evaluating Plantmate organic manure and prime EC foliar on plant performance and yields in five agro-ecological zones in Kenya

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Key words: Organic manures, EC foliar, Crop performance, Crop yields.

Abstract

Trials for the effectiveness of Plantmate organic manure and Prime EC Foliar Plant Food for increased yields for selected crops were done in five different Agro-ecological zones and soil types, in Kenya. The approach was executed through controlled greenhouse experiment and in the field. The trials data obtained indicated Plantmate organic manure and Prime EC Foliar Plant Food in combination with half the rate of recommended inorganic fertilizer performed significantly ($p<0.05$) better than all other treatments. Thus, plots treated with Plantmate organic manure and Prime EC Foliar Plant Food gave higher yields in common beans, French beans, maize, onions, cabbages, capsicum with percentages exceeding 100 compared to the control in most cases. In many soils fertilizers are fixed and rendered insoluble under certain soil conditions such as soil pH. The Plantmate organic manure and Prime EC Foliar Plant Food ameliorated the soil conditions as it interacted with inorganic fertilizer thus increasing its use efficiency by crops. Plantmate organic manure and Prime EC Foliar Plant Food not only increased soil chemical fertility but also improves water use efficiency at low matric potential and generally improves plant vigor and soil health.

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Introduction

Agriculture continues to dominate Kenya's economy, although only 15-17 percent of her total land area has sufficient fertility and rainfall to be farmed with 7-8 percent being classified as first-class land (Kenya Country Profile, 2007; Mwanda, 2000). In 2006, almost 75 percent of working Kenyans made their living by farming, compared with 80 percent in 1980 (Kenya Country Profile, 2007). Agriculture is also the largest contributor to Kenya's gross domestic product (GDP) (Kenya Country Profile, 2007). In 2005, agriculture, including forestry and fishing, accounted for about 24 percent of the GDP, as well as for 18 percent of wage employment and 50 percent of revenue from exports (Kenya Country Profile, 2007). About one-half of Kenya's total agricultural output is non-marketed subsistence production (Kenya Country Profile, 2007). Farming is the most important economic sector in Kenya, although less than 8 percent of the land is used for crop and feed production, and less than 20 percent is suitable for cultivation. Kenya is a leading producer of tea and coffee, as well as the third-leading exporter of fresh horticultural produce such as cabbages, onions, corn, potatoes, bananas, beans, peas and currently flowers.

The horticultural sector remains an important foreign exchange earner to Kenya and contributes significantly in the local diets. Fresh horticultural crops often identified as commodity group for which there is high demand, are of value nutritionally and have potential for local and export markets. Development of this sector will stimulate economic growth as well as provide employment opportunities given the relatively high premium price attached to horticultural crops.

The gains made in the horticultural and agricultural sector in general have however been jeopardized by the rapid population growth that was estimated at 2.7% in 2011 (www.en.wikipedia.org/wiki/ Demographics of_Kenya.2013; World Bank, 2012). The rapid population growth has put enormous pressure on prime arable land. The result has been reduced land holdings, soil fertility decline from continuous cropping or reduced fallows, and untenable utilization of marginal lands. More mouths to feed and decline in land productivity have reduced nutritional level of the farm families. Secondly the amount of surplus agricultural production from small-scale farm system has declined. This in turn has depressed the level of farm income and exacerbated the situation at the farm household level (www.ilo.org/wcmsp5/ groups/public/@ed_norm/@relconf/documents/meetingdocument/wcms_091721.pdf). Due to growing competition for both domestic and export markets, growers require technologies, which will exert less pressure on the available land, inputs, environment and guarantee good health. As a consequence, there is need to strongly develop technological options for sustainable production and post-harvest handling. Most farmers in Africa appreciate the value of fertilizers, but seldom apply them at the recommended rates and at the appropriate times because of high costs, lack of credit, delivery delays and low and variable returns (Sanchez, *et al.*, 1997).

Rapid population growth estimated at 3.4% for the period 1975–1997 (UNDP, 1999) has resulted in land fragmentation hence small/uneconomical land holdings, nutrient mining from continuous cropping or reduced fallow periods followed by decline in soil fertility. Restricted use of external inputs and dependence on fallows for maintaining soil fertility and weed control is cited as one of the major constraints to raising productivity in Africa (Wesonga *et al.*, 2002). This in turn has depressed the level of farm income and exacerbated hunger and malnutrition in many households including those found in what is referred to as high potential zones.

To address these challenges, technologies that enhance productivity of farms are required. A traditional approach has been the development of higher yielding crop varieties as in cereals (HYCV .However in nutrient depleted soils, the full potential of improved germplasm such as HYCVs will only be realized with adequate application of external inputs such as inorganic fertilizers and chemicals. Most farmers in Africa appreciate the value of fertilizers, but seldom apply them at the recommended rates and at the appropriate times because of high costs, lack of credit, delivery delays and low and variable returns (Sanchez *et al.*, 1997).

Three requirements for increasing agricultural production have been identified as (i) An enabling environment for small-holder farming sector (infrastructure, education, credit, inputs, markets and extension services), (ii) Reversing soil fertility depletion and, (iii) Intensifying and diversifying land use with high value products (Sanchez and Leakey, 1997).

At the farm level, for farmers to address the issue of the nutrient mining/loss the value of increased production brought about by fertilizer should be sufficiently high to cover cost of the fertilizers, compensate for the risk, and provide a reasonable return to the farmer. Fertilizer application by small-holder farmers to food crops is often not profitable due to combination of high fertilizer prices, low food crop prices and high risk. Even when fertilizer application is profitable, many farmers cannot afford to purchase fertilizer at the beginning of the season when other basic needs are pressing. Currently research efforts are in the search for alternate organic matter technologies for nutrient management. These include use of plant residues, green manures, and deep-root nutrient recycling systems. The latter two is where agro-forestry is making its contribution in soil fertility management (Buresh and Tian, 1998). However, use of organic materials to increase the carbon reserves of soil under tropical conditions requires large amounts of annual additions. Another way of increasing farm resource productivity is to make a more efficient use of the abundant agro by-products and to reduce farm waste. Many farmers use crop residues such as maize Stover, cassava stalks as construction materials or cooking fuel while some is burnt during land preparation. A tenth of the residues and weeds left on the fields after harvest are eaten by livestock (ILRI, 1999). The success of the second green revolution will depend on complete use of all the biomass and integrating them within the conventional soil improvement practices. One such technology to utilize organic waste is edible mushroom or production of composts for use in crop production and/or using residue as fodder for production of good quality manures. The objective of the study was to evaluate the effectiveness of Wanda Plantmate organic/Prime Ec plant foliar food as an organic-fertilizer when used singly or in combination with inorganic fertilizers on yields, N and P-uptake by selected crops in Kenya. The approach was executed through controlled greenhouse experiment at the University of Nairobi and field trials on selected farms under five different agro-ecological zones.

Materials and methods

Description of study sites

The trials sites were situated in Kirinyaga Agro-ecological zones UM4; LH- Kabete University field station and in Thika; UM6-Naivasha and Machakos County (2 farms).

Kirinyaga County: (Agroeco-Zone UM4 sub-zones s/m+s and s+s)

This is a mainly sunflower and maize zone. This farm is situated in Agro-ecological zone UM4 and sited between the Kutus-Sagana main road and river Thiba which provides a kind of a micro-climate to this farm (Jaetzoldt *et al.,* 2010). Crops grown include maize and sunflower. The rain season is very short and supplemental irrigation is necessary especially when rainfall is very little. Maize crop is mostly recommended where there are heavy soils that hold moisture for longer periods. The soils are well drained, extremely deep, dusky red to dark reddish brown, friable clay, with inclusions of petroferric materials; Eutric Nitisols (WRB, 2014), with nito-chromic cambisols and chromo Acrisols and Luvisols partly Lithic, pisoferric and petroferric phase. The physiograpy of the three Agro-eco zones is mainly volcanic footridges. In the upper part (UM2) the soils are fertile but highly erodible while down slope the natural fertility declines substantially.

Nakuru county: Naivasha- Agroeco-Zone UM6 sub-zone uri br)-Vegepro-Gorge farm (field)

The farm is commercially operated with heavy investment in human resources, machinery and inputs. The farm is in the upper midland Ranching zone with no reliable agro-humid period of at least 40 days. The altitude ranges from 1620 to 1820m asl in this zone with annual mean temperature ranging from 19.8 to 18.5°C and annual rainfall ranging from 600-700mm and 550-700mm in the upper midland and ranching zone, respectively.

This amount is surpassed normally in 10 out of 15 years during the agro-humid period that allows growing of most cultivated plants. The UM6 has unimodal rainfall (uri) and intermediate rains. In some rare cases there is bi-model rainfall (br). Irrigation is necessary to attain any meaningful agriculture. The study area is mainly the lacustrine plains around Lake Naivasha with low fertility and mostly derived from the volcanic activity around Longonot and Suswa. Two groups of soils are identified in this place: i.e. Excessively drained shallow to moderately deep, brown to dark brown, firm, slightly smearly, strongly calcareous, stony to gravelly clay loam, in many places saline and /or ando-calcaric regosols (WRB, 2014), partly lithic.

Excessively drained to well drained, very deep, dark grayish brown to olive grey, stratified, calcareous, loose fine sand to very friable sandy loam or silt ando-calcaric regosols (WRB, 2006). These two soils above requires different technologies to sustain productivity among them, heavy organic manuring and mulching, protection against wind and water erosion and control of floods and proper drainage using deep rooting plants. These measures are necessary due to seasonal inundations and waterlogging as well as occurrence of complex soils (Ministry of Agriculture and German Technical Training Program; Jaetzoldt, 2010, GIS Cartogr. M. Teucher, 2010).

Kiambu: Greenhouse experiment and Kabete field: Agroeco-Zone LH sub-zone uri s/m +(s/vs) and s/m+ (vs/s) and a field experiment in Thika.

This is a wheat/maize/Barley zone. The Field Station farm lies $1^{\circ}15^{l}$ S and $36^{o}44^{l}$ E and is at an altitude of 1940m asl. The site is representative, in terms of soils and climate, of large areas of the Central Kenya highlands. The groundwater is more than 30m deep and runoff is negligible in the research plots. Slope gradient is relatively flat. According to the Kenya Soil Survey agro climatic zonation methodology (Sombroek *et al.*, 1982), the climate of the study area can be characterized as semi-humid. The site experiences a bimodal rainfall distribution with long rains in mid March-May and the short rains in mid October-December.

The mean annual rainfall is 1006 mm. The ratio of annual average rainfall to annual potential evaporation, r/Eo is 58%. The geology of the area is composed of the Nairobi Trachyte of the Tertiary age. The soils are well-drained, very deep (> 180cm), dark red to dark reddish brown, friable clay (Gachene, 1989). The soil is classified as humic Nitisol (FAO, 1990, WRB, 2014). There is no surface sealing or crusting and the profile has clay cutans throughout the B-horizon (Gachene, 1999). The land is cultivated for horticultural crops such as kales (*Brassica oleracea*), tomatoes (*Lycopersicon esculentum*), cabbage (*Brassica oleracea*), carrots, (*Daucus carota*), onions (*Allium fistulosum*), fruit trees such as avocadoes (*Persea americana*) and coffee (*Coffea arabica).*

Machakos: Agro-ecological zone UM4 s+s, s/vs+s/vs. Sunflower-Maize Zone (s+s; s/vs+s/vs)

The altitude ranges from 1340-1830 m asl and annual rainfall ranges from 700-800 and 800-950 mm in lower to higher altitude, respectively. The area has 2 short cropping seasons. First rainy season is short and ends in march with 66% being reliable and crops such as Katumani maize, sorghum, beans, tomatoes and onions being grown (UM4 s+s). In the drier (UM4 s/vs+s/vs) zone, there is 2 very short cropping seasons with good yield potential of barley, sorghum, Mtama, sunflower, chickpeas and sisal can be grown throughout the year. The temperature ranges from 20.9 to 17.9°C in the higher altitude. Most of Machakos County lies to the west of Yatta plateau, and the Tana River forms the boundary in the northeast. Relief differences are great in some parts, but generally lessen towards the southeast. Apart from the Chyulu Hills and an area near Tala, the underlying geology is Basement system of rocks. These rocks are mainly gneisses outcropping in a number of hills such as the Mua Hills, Machakos Hills etc; relicts of a very old mountain belt. The soils of the mountains (unit MU1) have a variable fertility according to depth. The soils of the hills (HP1, HU2) have a variable fertility, too. On the associated foot slopes soils are found which increase in clay with depth and they have a moderately low fertility (FUC). These soils are also found together with those of the uniform profile development and with humic topsoil (unit UU8) (Jaetzoldt *et al.,* 2010).

The soil (MU1) are somewhat excessively drained, shallow to moderately deep, reddish brown, rocky and stony, sandy clay loam: Eutric cambisols, partly lithic phase; with lithosols, orthic luvisols, eutric regosols and Rock Outcrops. Other soils described as HP1 are well drained, moderately deep to deep, black, very friable and smeary, very gravelly loam, with a humic top soil: Mollic andosols. The HU2 soils are somewhat excessively drained, shallow, reddish brown, friable, rocky or stony, sandy clay loam: Eutric regosols, lithic phase; with Rock Outcrops and calcic cambisols; well drained, very deep, dark red, very friable clay: Nito-rhodic ferrallisols. The LB8 soils are clay in places with calcareous, slightly saline deeper subsoil; in places with humic topsoil: Pellic vertisols, stony phase and partly saline phase; with verto-orthic greyzems and orthic rendzinas. The LB16 soils are calcareous, cracking clay; in many places with humic topsoil and gravelly, calcareous deeper subsoil: Pellic vertisols and orthic rendzinas in Matheka's Farm.

Site selection

Trials evaluated the response of selected crops to conventional fertilizers in combination with Plantmate/Prime Ec foliar products at different levels and conducted in six sites i.e. Kirinyaga (1 sites 2 experiments), Thika (1 site 1 experiment), Machakos (2 sites 3 experiments), Naivasha (1 site 2 experiments), and at the University of Nairobi farm at Kabete (1 site 2 experiments plus a greenhouse experiments). Farmers were selected on the basis of farm size and infrastructural developments necessary such as irrigation water, knowledge on use of bio-fertilizers and willingness to participate. The experiments were replicated in the farmers' field for uniformity in management and care of the test crop. Soil samples were collected at various random sites from the selected farms and mixed to make composite samples from 20 cm depth using a soil auger of 600cm^3. The samples were packed in sampling bags, stored in cool boxes and transported to the laboratories where they were processed for analysis. This was done at the onset and at the end of the experiment.

Experimental layout and design for field trial

The experimental designs was a factorial arranged in Completely Randomized Blocks (CRBD) due to topography/terrain of the area that gave rise to fertility gradients, different vegetation and soil types especially in Naivasha. Controlled pot experiments were conducted at Kabete field station in the greenhouse. The crops used in the field trials were Maize (*Zea mays)*, Cabbages (*Brassica oleracea* var. *capitata*), and French beans (*Phaseolus vulgaris* L.), Brocolli, Baby Corn, Pakchoi and onions. The experiment consisted of 5 treatments replicated four times. The plot sizes depended on size of land availed by the farmer and type of crop, varieties and the agro-climatic zonation.

Quality of Plantmate as an Organic Fertilizer in combination with EC foliar

The wanda Plantmate organic fertilizer was used in conjunction with EC foliar spay. The Plant mate EC foliar contains 10% TN, 6% P2O5 and 4% K2O plus other adequate chelated micro-nutrients and growth promoters. The application rates are given according to crop types and ranges from 3-4 liters per hectare per month for maize and onions. It is manufactured by ELR Trading Company, Inc, Science City of Munoz, Nueva.

Table 1. The manufacturers' chemical characterization of plant mate organic fertilizers when moist and under oven dry conditions.

Chemical	Moist condition	Oven dry conditions
% Total N	2.44	4.14
% NH_4^+-N	1.84	3.11
% NO_3^--N	0.60	1.03
% Total P (P_2O_5)	3.74	6.34
%Total K (K_2O)	3.61	6.13
% Total Ca (CaO)	4.46	7.57
% Total Mg (MgO)	0.19	0.32
pH	7.50	-
% Moisture content	2.55	-

Chemical	Moist condition	Oven dry conditions
S (ppm)	1.59	2.70
Zn (ppm)	1966.00	282.00
Cu (ppm)	32.5	55.11
Fe (ppm)	3,375.00	5,723.00
Mn (ppm)	151.00	256.00
% OC (Walkley Black Method)	11.85	20.09

Source: Richfund international Company Ltd (2006). www.plantmateorganic.com

Biological characterization of selected microorganism contained in "Plantmate" organic fertilizer in the laboratories during the study

Plantmate is a Basal Fertilizer that is packed in a 50-kg polypropylene bag and a liner which have excellent biodegradability properties. It is dark brown to slightly black in color and friable in texture. The product is said to be produced from a mixture of plant and animal wastes through an advanced bio-fermentation process. The fertilizer is said to contain 22 beneficial microbes categorized as:

7 Bacteria for decomposition, enzyme production and nutrient transformation

2 Actinomycetes for decomposition of polysaccharides and enzyme production

3 *Bacillus* sp. for enhanced decomposition, compost 'sweetening' and probiotics production

5 Nitrifiers for nitrogen fixation and nutrient transformation

5 Thermophilic Fungi for decomposition, probiotics production and nutrient transformation.

This report therefore presents laboratory investigation of selected microorganisms contained in the fertilizer.

Fungi

Plant mate fertilizer was said to contain five Thermophilic Fungi for decomposition, pro biotics production and nutrient transformation. Laboratory investigation on the diversity of the fungi in the fertilizer sample was conducted following protocol described herein below.

Isolation and characterization of the fungi: Decomposition fungi

Serial Dilution, Agar Plating and Direct inoculation methods were used for the detection and isolation of the fungi species in the sample. On the serial dilution method, the suspension was diluted up to 10^5 and each dilution was plated into four petri dishes.

Direct inoculation and agar plating methods involved the direct inoculation of the fertilizer samples on the petri dish. All the inoculations were replicated four times and were all cultured on commercially prepared Potato Dextrose Agar. The plates were incubated for 7 days at 25°C and observations done daily. Each morphologically unique fungal colony from the petri dish was isolated and sub cultured into pure culture using standard techniques.

The fungal species were identified on their morphological characteristics, microscopic examinations, taxonomic guidelines and standard procedures.

The following morphological characteristics were evaluated; Colony growth (length and width), presence or absence of aerial mycelium, colony color, -presence of wrinkles and furrows and pigment production. For microscopic analysis, identification was successfully done by staining in lacto phenol blue then observed under x10 and magnified under x 40 respectfully.

Bacteria

A selective media that decompose the long complex polymer (polysaccharide) from plants and animals was prepared and dispensed in bottles. Strips of filter papers were placed inside the bottles and the preparation was autoclaved for 15 minutes at 121°C at 1 Pascal. After cooling, it the fertilizer samples were inoculated and preparations were treated appropriately. *Bacilli* species: Characterization of the bacteria was done according to their gram reaction and Zich-Neelson methods. 1 gm of the basal fertilizer was heated in an oven at a temperature of 70°-80°C for 15 minutes and later.

Actinomycetes for decomposition

Specific media for growth of actinomycetes was prepared and autoclaved. The basal fertilizer was heated first (1gm) at a temperature of 50ºC to kill off all the mesophilic sporulating microbes. After serial dilution of up to 10^{-6}, 0.1mm of every serial dilute was plated on the specific media plate, spread and then incubated. Serial diluted up to 10^{-6} plated and incubated.

Abuscular mycorrhiza

The presence of mycorrhiza fungi in the fertilizer sample was also evaluated using the method described by Daniels and Skipper (1982).

A greenhouse experiment: Response to Plantmate and Foliar C and interactions with fertilizers

The treatments were five different rates of Plantmate as follows:-

0 grams plantmate

50 grams plantmate

100 grams plantmate

150 grams plantmate

200 grams plantmate

Field observations and analysis

The parameters to be measured will be the above- and belowground biomass of the crop at various phenological stages (2, 6, 12 and 16 weeks after planting) and the economic yield and dry matter yields (DMY) of the crop (Harvest) as well as N and P-uptake by selected crops in Kenya compared to conventional fertilizers for increased yields on Maize, beans, French beans, Pakchoi, onions and baby corn as test crops. Data were statistically analyzed and observations made $P \leq 0.05$ confidence level. For soils C, available N and P after harvest will be determined.

Results and discussions

Quality of Plantmate as an Organic Fertilizer

Biological characterization of selected microorganism contained in "Plantmate" organic fertilizer Fungi

The following composting fungi were isolated and identified from the fertilizer; *Penicillium notatum, Aspergillus oryzae, Humicola insolens and Aspergillus niger*. However, none of the methods was able to detect the presence of *Rhizopus oligosporous and Saccharomyces cerevisiae* with reference to *Arbuscular mycorrhiza*, only two (2) spores of *Acaulospora* species were recovered from 50 g of the fertilizer sample. No other mycorrhiza spores were detected. Therefore; Plantmate fertilizer is rich of composting/saprophytic fungi but has a low population of mycorrhiza fungi.

Bacteria

Bacteria for decomposition: Disintegration of the paper was observed daily until dissolution was complete and gram stains preparation from the cultures were observed under oil immersion. *Clostridium, Vibrio, Pseudomonas, Bacillus* spps and *Cellulomonas* bacterial activity was involved in the breakdown of the paper. Biochemical tests confirmed the presence of *Pseudomonas, Bacillus* and *Cellulomonas* spp. Gram positive long rods were observed after 24-48 hrs, characteristic of *Bacillus subtilis* plenty in manure and soil and confirmed through staining after 72 hrs.

The fertilizer sample was positive of the *Bacillus spp and B. licheniformis* which is a similar also in characteristics with *subtilis* was also identified. The Nitrifiers where a yellow color to orange observed on one of the sample: positive result for ammonia. The red (raspberry) color after several minutes observed on the other samples: a positive result for nitrite and a blue color at interface of 2 drops observed in the last set of the samples: positive result for nitrate. The fertilizer sample was positive to presence of nitrifies. N.B. Amount of ammonia was too little in the sample.

Actinomycetes for decomposition

After three days, compact colonies that -penetrating deep into the agar were observed with a leathery surface. Microscopic observation showed short aseptate aerial mycelia and a chain of conidia. This confirmed that the fertilizer samples were positive of Streptomyces.

Chemical Characterization of the organic fertilizer

Table 2 shows the bio-assay of the Plantmate manure and prime EC bio-fertilizer. Heavy metals were not detected except little quantities of lead less than 0.25 ppm which are not toxic in soils. NIOSH at CDC has set a Recommended Exposure Limit (REL) of 50µg/m³ to be maintained so that worker blood lead remains < 60µg/dL of whole blood www.cdc. gov/niosh/npg/npgd0368.html. Uncontaminated soil contains lead concentrations less than 50 ppm but soil lead levels in many urban areas exceed 200 ppm (AAP 1993).

The allowable levels of lead in fertilizers are 5ppm according to Washington State Standards for Metals. (www.ecy.wa.gov/programs/hwtr/dangermat/fert_standards). Plant uptake factors are low ranging from 0.01-0.1 hence amount in these bio-fertilizers are negligible. The values agree to those in the packaging bag of the Plantmate organic fertilizer.

In soil, elemental selenium is essentially insoluble and may represent a major inert 'sink' for selenium compounds introduced into the environment under anaerobic conditions (ATSDR, 2003). The main forms of selenium in soil are selenate (Se^{6+}), selenite (Se^{4+}) and selenide (Se^{2-}). Their proportions in soil solution are governed by various physical-chemical properties including pH and oxidation potential and biological processes (Kabata-Pendias and Mukherjee, 2007). Selenites and selenates in soil tend to be adsorbed on clay particles, iron and manganese minerals, and organic matter (Environment Agency, 2007).

Characterization of soils from experimental the sites

Initial soil chemical characteristics at onset of experiment in all trial sites are shown in Table 3.

Table 2. Laboratory characteristics of Plantmate organic fertilizer and EC foliar plant food.

Sample description	pH	%N	%OC	K Cmol+/kg	ppm				
					P	Pb	Cr	Zn	Se
Plantmate Organic fertilizer	7.07	1.80	7.65	5.60	2300	9.56	38.98	38.60	2680.00
EC Foliar Plant Food	9.41	6.00	-	40.00	620	ND	ND	9.64	ND

Table 3. Initial soil chemical characteristics at onset of experiment.

Sample description	pH	%N	%C	K Cmol+/kg	P ppm
Kirinyaga bean plot	5.65	0.21	2.23	1.50	57.50
Kirinyaga maize plot	6.01	0.28	2.65	1.43	92.00
Wambua MachaKos	5.80	0.14	2.11	1.15	63.00
Jacob Matheks-Machakos	7.11	0.13	1.29	1.00	36.65
Thika AAA Growers	6.43	0.17	1.46	1.22	85.50
Naivasha Veg Pro	6.01	0.43	3.00	1.00	59.80
Kabete Field Station	5.85	0.35	3.00	1.50	18.00

Table 4. show the chemical characteristic of soils after crop harvest in all trial sites.

Table 4a. Soil analysis at harvest for Vegepro- Gorge farm-Naivasha.

	pH	Ppm												%	CEC
		P	K	Ca	Mg	Mn	S	Cu	B	Zn	Na	Fe	EC(s)	OM	Meq/100g soil
Current	7.18	105	430	964	159	25	7.46	1.56	0.32	10.5	147	218	79.0	0.98	8.23
Guide															
Low	6.00	30	120	988	98.8	50	20	2.00	0.80	2.00	-	50	-	3.00	15.00
High	7.00	100	-	1150	177	250	200	10.00	2.00	10.00	<94.6	350	< 800	8.00	30.00

Analysis by Crop Nutrition Laboratories Services Ltd: Cooper Center, Kaptagat Road. Their guidelines used for interpretation of this data only.

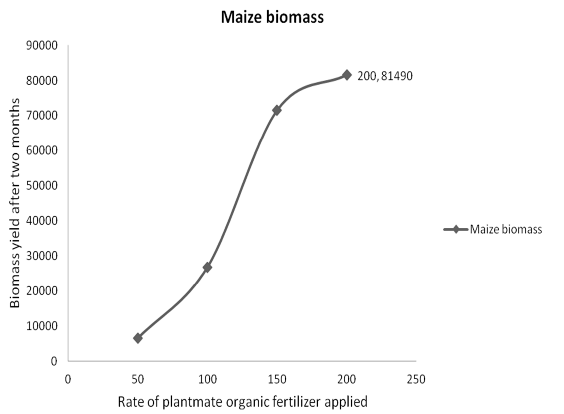
Table 4b. Soil chemical characteristics after crop harvest at Kabete field station

	Kabete maize soil analysis					
Treatment	$pH(H_2O)$	$pH(CaCl_2)$	%		p(ppm)	K(cmol/kg)
			nitrogen	carbon		
1	5.82	4.78	0.22	1.8	6.01	1.24
2	5.54	4.65	0.34	2.1	22.5	2.14
3	5.76	5.01	0.34	2.94	17.2	2.21
4	5.98	4.84	0.31	3	12.2	1.74
5	6.01	5.12	0.36	3.1	15.6	1.85

	Kabete maize soil analysis					
Treatment	pH(H_2O)	pH($CaCl_2$)	% nitrogen	% carbon	p(ppm)	K(cmol/kg)
Kabete beans soil analysis						
Treatment	pH(H_2O)	pH($CaCl_2$)	nitrogen	% carbon	P(ppm)	K(cmol/kg)
1	5.54	4.8	0.17	1.45	10.21	1.05
2	5.6	4.76	0.38	2.72	26.7	2.1
3	5.82	4.82	0.33	3.21	35	1.8
4	5.9	5.01	0.31	2.74	27	2.21
5	5.72	4.98	0.27	2.81	24	1.62
Machakos onions soil analysis						
Treatment	pH(H_2O)	pH($CaCl_2$)	nitrogen	% carbon	P(ppm)	K(cmol/kg)
1	6.82		0.11	2.1	28	0.66
2	6.54		0.24	2.52	42	0.78
3	6.88		0.14	2.82	32	0.62
4	7.01		0.18	2.7	38	0.88
5	7.28		0.21	3.21	33	0.72

Maize Response curve to different rates of Plantmate fertilizer

Fig. 1 shows different rate of Plantmate organic fertilizers applied to maize crop where the 150gm rate per hole is the most ideal. The pots with 150 and 200grams reached monthly spraying without showing any nutrient deficiencies. Also higher biomass at harvest was recorded at 200gms application but this has diminishing returns for any investments hence 150 kg gives better returns to the farmer.



Greenhouse experiment at the Kabete field station

The crops receiving Plantmate and other nutrient sources did not show any significant difference between treatments or any interaction. The neutral media (sand) did not provide some vitals available in natural soils that enhance proper crop growth and performance. The sand which is normally acid washed has little of known micro-organisms necessary for a healthy soil and healthy crop growth in terms of species diversity and populations. Observations from the study are presented in table 5.

Table 5. Biomass (dry weight kg/ha) from capsicum, cabbage and Maize at 12 weeks after planting.

Treatment	1	2	3	4	f-alue/significance
Capsicum	11,400	10,100	10,400	10,800	p= 0.99 NS
Cabbage	2,400	2,200	2,880	2,300	p = 0.89 NS
Maize biomass	19,700	18,700	19,750	18,250	p = 0.99 NS

Key: 1- Control; 2-Plantmate alone; 3- Plantmate + (½) 100kg/ha DAP; 4- (full) 200kg/ha DAP and 5- vermitec organic fertilizer.

Results

Kabete field station, University of Nairobi

Table 6a and b shows bean dry biomass at 1 and 2 month after emergence (1st & 2nd sampling) in kg/ha. In the first sampling, there was no interaction between treatments though significantly different. However, the combination of Plantmate and 1/2DAP (100kg/ha) gave the highest DMY at 1637kg/ha that was 311, 179 and 27% more than the control, Plantmate alone and full DAP (200kg/ha), respectively. In the 2nd sampling, the treatments were significantly different ($p<0.001$) where again the combination of Plantmate and ½ DAP (100kg/ha) outperformed all other treatments with the highest DMY at 4070kg/ha that was 315, 185, 33 and 127% more than the control, Plantmate alone full DAP (200kg/ha) and vermitech organic manure, respectively.

Table 6c show bean grains and straw weight at harvest (kg/ha) where treatments were highly significantly different ($p = 0.001$) with combination of Plantmate and ½ DAP (100kg/ha) having highest grain weight at 1730kg/ha compared to 435, 585, 1170 and 567kg/ha for the control, Plantmate alone, full

DAP (200kg/ha) and vermitech organic manure, respectively. On the other hand, Straw dry weight was not significantly different at harvest and where vermitech had the highest weight (1539kg) followed by Plantmate + 100kg/ha DAP (Table 5).

This implies that Plantmate + 100kg/ha DAP has potential for production of fodder crops for livestock production. A combination of grain and fodder yield is ideal to a farmer as he gets value for his investment. The residue/straw can also be incorporated into the soil to improve on structure and erosion control.

Table 6a. Bean dry biomass 1 month after planting (1st sampling).

Treatment	1	2	3	4	5	SF/ Grand mean
Bean dry weight	398	587	1637	1287	544	p = 0.01
	Lsd = 450.6					2266
	Sed = 206.8					

Table 6b. Bean dry biomass 2 months (2nd sampling) after planting

.Treatment	1	2	3	4	5	SF/ Grand mean
Bean dry biomass	980	1430	4070	3059	1791	p = 0.001
	Lsd = 5079					11347
	Sed = 2331					

Key: 1- Control; 2-Plantmate alone; 3- Plantmate + (½) 100kg/ha DAP; 4- (full) 200kg/ha DAP and 5- vermitec organic fertilizer.

Table 6c. Bean grains and Straw weight at harvest kg/ha.

Treatment	1	2	3	4	5	SF/ Grand mean
Bean grain weight	435	585	1730	1170	567	p = 0.001
	Lsd = 293					
	Sed = 134.7					897
Bean Stover biomass	577	958	1503	1337	1539	p = 0.01 NS
	Lsd =939.7					
	Sed = 431.3					1183

Key: 1- Control; 2-Plantmate alone; 3- Plantmate + (½) 100kg/ha DAP; 4- (full) 200kg/ha DAP and 5- vermitec organic fertilizer.

Table 7 shows Maize dry biomass 1 and 2 month after planting (1st & 2nd sampling). In both cases, there was a high and significant difference ($p<0.001$ and < 0.001, respectively between treatments.

However, vermitec organic fertilizer had highest DMY (1704) followed by a combination of Plantmate and ½ DAP (100kg/ha) (1503), 200kg/ha DAP (1300), Plantmate alone (904 kg/ha).

In the 2nd sampling, the combination of Plantmate and 1/2DAP (100kg/ha) had the highest DMY at 8196kg/ha followed by 200kg/ha DAP treated plots (6010kg/ha). Plantmate alone was only slightly higher than the control by 123kg. At harvest, maize grain yield was significantly different among treatments with Plantmate + 100 kg/ ha DAP highest at 8,528kg/ha followed by DAP at 200kg/ha at 7,797kg/ha.

The Plantmate + 100kg/ ha DAP was 73.4% higher than control and 12.3% above Plantmate alone hence a worthy combination to adopt.

Combination of Plantmate and ½DAP (100kg/ha) 200kg/ha DAP had the best mature bean crop at Kabete field station. The ground cover by the bean crop that received Plantmate + ½ DAP was better than full DAP due to poor germination by the latter.

Kirinyaga site

Table 8 shows bean dry biomass 1 month after planting in kg/ha. The data indicate high significant differences ($p < 0.001$) between treatments whereby plantmate and ½ DAP (100kg/ha) (1730), 200kg/ha DAP (1170).

Plantmate alone, control, 200kg/ha DAP and vermitec organic fertilizer were 195.5, 297, 7, 47.9 and 205% less than Plantmate + 100kg/ha DAP. Bean seed grain yield and straw DMY are shown in Table 9 in kg/ha. The data has no significant differences between treatments in both cases though Plantmate and ½DAP (100kg/ha) (1273kg) residue biomass is highest while the seed grain weight is third highest to full DAP (545kg), then plant mate alone at 489kg/ha.

It should be noted that the beans were hit by frost after podding that led to the low yields observed in this site.

Table 7. Maize dry biomass 1 month after planting (1st sampling) in kg/ha aboveground biomass, cob and maize an Stover dry weight at harvest (kg/ha) at Kabete field station.

Treatment	1	2	3	4	5	F-value/Grand mean
1 st sampling maize dry biomass weight	785 Lsd = 1166 Sed = 535	904	1503	1300	1704	p = 0.001 1239
2nd sampling maize dry biomass wt	2870 Lsd = 3067	2993	8196	6010	3581	p = 0.01 4730
Maize Cob+grains (fresh)	13,579 Lsd = 1,462 Sed = 671	16,204	17,593	17,083	15,000	P=0.001
Maize Stover (fresh)	25,694 Lsd = 6,383 Sed = 2,929	29,722	46,213	41,528	31,806	P=0.001
Maize Grain (dry) kg/ha	4,917 Lsd = 1,019 Sed = 468	7,593	8,528	7,796	6,176	P=0.01 GM=7,002

Key: 1- Control; 2-Plantmate alone; 3- Plantmate + (½) 100 kg/ha DAP; 4- (full) 200kg/ha DAP and 5- vermitec organic fertilizer.

Table 8. Bean dry biomass in Kirinyaga (kg/ha) at 1 month.

Treatment	1	2	3	4	5	Significance
Biomass	435 Lsd = 293 Sed = 134	585	1730	1170	567	p<0.001

Table 9. Bean seed weight and straw biomass (kg/ha) at harvest-Kirinyaga.

Treatment	1	2	3	4	5	Significance
Been seed yield	409 Lsd= 401 Sed = 184	489	455	545	432	P=0.9 NS
Bean residue biomass	1023 Lsd = 488 Sed =224	977	1273	1250	841	p<0.3 NS

Key: 1- Control; 2-Plantmate alone; 3- Plantmate + (½) 100 kg/ha DAP; 4- (full) 200kg/ha DAP and 5- vermitec organic fertilizer.

Table 10 shows maize dry aboveground biomass at 1 and 2 months after planting. There were significant differences ($p < 0.001$) between treatments whereby plantmate + ½ DAP (100kg/ha) (678 & 3185kg) was highest followed by 200kg/ha DAP (546 & 2773kg) for 1st and 2nd month sampling, respectively. Control, Plantmate alone, 200kg/ha DAP and Vermitech organic fertilizer were 88.8 & 224.3, 75.6 & 71.0, 24.2 & 14.9 and 61.4 & 45.3% less than plantmate + 100kg/ha DAP for 1st and 2nd month sampling, respectively.

Maize seed grain yield and Stover DMY are shown in Table 11. There was no significant differences between treatments in both grain and Stover, though plantmate + ½ DAP (100kg/ha) had highest weights (5750 and 14208kg/ha) grain and residue biomass. This again continue to confirm the potential for plantmate + ½ DAP (100kg/ha) in fodder and food grain production.

Table 10. Maize aboveground biomass (kg/ha) 1 and 2 months after planting in Kirinyaga.

Treatment	1	2	3	4	5	Significance/ Grand mean
Ist sampling	359 Lsd= 108 Sed = 49	386	678	546	420	P = 0.001
2nd sampling	982 Lsd = 926	1863	3185	2773	2192	P =0.001 2199

Table 11. Maize aboveground biomass and grain yield at harvest (kg/ha) Kirinyaga.

Treatment	1	2	3	4	5	Grand mean
Maize grain weight at harvest	5208 Lsd = 1134.9 Sed =	5521	5750	4750	5250	P=0.426 NS 5296
Maize Stover dry wt at harvest	10854 Lsd = 3435	11542	14208	12833	12208	P=0.316 NS 12,329

Key: 1- Control; 2-Plantmate alone; 3- Plantmate + (½) 100 kg/ha DAP; 4- (full) 200kg/ha DAP and 5- vermitech organic fertilizer.

Machakos County

Table 12 shows bean dry biomass 1 after planting in kg/ha. The data indicate high significant differences ($p < 0.001$) between treatments whereby Plantmate + ½ DAP (100kg/ha) 941kg) was highest followed by 200kg/ha DAP (884 kg). However there was no significant difference between 200kg/ha DAP and Plantmate + 100kg/ha DAP. Control, Plantmate alone and 200kg/ha DAP were 180, 96 and 6.4% less than Plantmate + 100kg/ha DAP at 1st month sampling, respectively. Table 13 shows bean pod weight, dry bean biomass 2 months after planting and bean seed and straw weight at harvest in kg/ha.

The data indicate high significant differences ($p<0.001$) between treatments with Plantmate + ½ DAP (100kg/ha) (6888kg) highest followed by 200kg/ha DAP (6109kg) after 2 months. The same trend is observed with straw biomass. However there was no significant difference between 200 kg/ha DAP and Plantmate + 100kg/ha DAP for both seed and straw weight. Harvested seed and straw weight also show same trend as pods at 2 months. This indicates that Plantmate combined with inorganic fertilizer can boost bean yields in the dry areas of Machakos County.

Table 12. Bean biomass 1 month after planting in Machakos.

Treatment	1	2	3	4	Grand mean/Significance
1st Sampling	336 Lsd =113 Sed =50	480	941	884	P=0.001 660

Table 13. Aboveground biomass 2 months after planting and bean grain and straw at harvest in Machakos County.

Treatment	1	2	3	4		Significance
2nd sampling dry Straw biomass	4224	3938	15794	10678	Lsd = 3861 Sed = 1706	p =0.001
Grains at harvest	208	417	937	729	Lsd = 283 Sed = 125	p =0.001
Straw at harvest	125	240	573	469	Lsd = 201.9 Sed = 89.2	P= 0.003

Key: 1- Control; 2-Plantmate alone; 3- Plantmate + (½) 100 kg/ha DAP; 4- (full) 200kg/ha DAP and 5- vermitec organic fertilizer.

Table 14 shows Maize dry biomass 1 and 2 month after planting (1st & 2nd sampling) in Machakos. In both cases, there was a high and significant difference ($p<0.001$ & $p<0.002$) between treatments.

A combination of Plantmate and 1/2DAP (100 kg/ha) (161.8kg) had highest biomass followed by 200kg/ha DAP (145.4) though the two were not significantly different after separation of means in first sampling.

In the second month, the maize biomass was highest at 200kg/ha DAP treated plots followed by plantmate + 100kg/ha DAP though not significantly different. However Plantmate + 100kg/ha DAP was significantly higher compared to control and Plantmate alone.

Table 15 shows onion biomass 1 and 2 month after planting (1st & 2nd sampling) and bulb yield weight at harvest. There was a high and significant difference ($p < 0.01$) between treatments at 2nd harvest with Plantmate + 100kg/ha performing better.

In 1st sampling, no significant difference was observed. At harvest, 200kg/ha DAP had highest yield (15,848kg) compared to Plantmmate + 100kg/ha DAP though not significantly different. However Plantmate + 100kg/ha DAP was significantly higher compared to control and Plantmate alone.

Table 14. Maize biomass 1st sampling maize biomass.

Treatment	1	2	3	4	5	Significance
1st sampling	51.9 Lsd =34.4 Sed = 15.8	82.6	161.8	145.4	94.5	P=0.001
2nd sampling	1631 Lsd = 1240	911	2838	3818	1922	P=0.002

Key: 1- Control; 2-Plantmate alone; 3- Plantmate + (½) 100 kg/ha DAP; 4- (full) 200kg/ha DAP and 5- vermitec organic fertilizer.

Table 15. Onion biomass – 1st and 2nd sampling and bulb yield at yield harvest kg/ha.

Treatment	1	2	3	4	5	Grand mean
1st sampling	990 Lsd =454.4 Sed = 208.5	1215	1120	1040	980	P=0.077 1069
2nd sampling	9292 Lsd = 2082 Sed = 995	11688	12445	13102	11995	P=0.01 NS 11,704
Bulb yield at harvest	10125 11171 Lsd =1679 Sed = 770		15125	15848	11667	P=0.001 12787

Key: 1- Control; 2-Plantmate alone; 3- Plantmate + (½) 100kg/ha DAP; 4- (full) 200kg/ha DAP and 5- vermitec organic fertilizer.

Naivasha (VEGPRO FARM)

Pakchoi vegetable crop

Tables 16 and 17 show average weekly Packchoi harvest kg/per treatment and estimated final yield in kg/ha. The data indicate high significant differences ($p < 0.01$) between treatments whereby 200kg/ha DAP (88.25kg) was highest followed by Plantmate + 100kg/ha DAP (85.50kg) though not different statistically.

However there was no significant difference between Plantmate and 100kg/ha DAP with control and Plantmate alone. Harvested Packhoi estimated yield followed same trend as weekly harvest.

Babycorn-Vegepro-Naivasha

Table 18 shows baby corn yield weight at harvest. There was no significant difference observed between treatments. At harvest, Plantmate + 100kg/ha DAP and Vermitech organic treatments had highest yields of 16,458 & 16, 563kg, respectively.

However, Plantmate + 100kg/ha DAP was 20.6 and 12.9% higher compared to control and Plantmate alone.

Table 16. Average weekly Packchoi harvest in kg per treatment.

Treatment	1	2	3	4	5	f-value/Grand mean
Average weekly harvest	78.75	79.00	85.50	88.25	82.5	p =0.01
		Lsd = 6.05 Sed = 2.78				83.00

Key: 1- Control; 2-Plantmate alone; 3- Plantmate + (½) 100 kg/ha DAP; 4- 200kg/ha DAP and 5- vermitec organic fertilizer.

Table 17. Total plot yield and estimated yield in kg/ha per treatment.

G. Totals	315	316	346	353	330
Est. yield/ha	65,625	65,833	72,083	73,542	68,750

Table 18. Baby corn yield at harvest in Vegepro-Naivasha.

Treatment	1	2	3	4	5	F-value/Grand mean
Mean yields at harvest kg/ha	13,646	14,583	16,458	15,833	16,563	p= 0.24
	Lsd = 3,099 Sed =1,422					15,417

A total yield of 9983 tons of snap or French beans was realized from the plots treated with Wanda Plantmate.

Recommendations

Use of Wanda Plantmate organic manure in combination with inorganic fertilizer at half the recommended rate recommended especially for commercial farms that target high yields.

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