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The Effects of Combining Farm Yard Manure, Starter Nitrogen, Phosphorus and Zinc on Growth and Yield of Green Grams

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Authors' contributions

This work was carried out in collaboration among all authors. Authors EMM and CMM designed the study. Author CMM carried out the field studies, performed the statistical analysis, wrote the protocol. Authors CMM and EMM wrote the first draft of the manuscript and literature searches. All authors managed the analyses of the study, read and approved the final manuscript.

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ABSTRACT

Green gram *(Vigna radiate l.)* is an important legume grown within Kenyan Coast. Despite the crops importance as a locally available nutrient supplement, its production is constrained by declining soil fertility caused by poor agronomic practices. A field experiment was established during the March-June, 2019 long rains in multi locational sites at Matuga and Mivumoni in Kwale County. The experiment was aimed at investigating the effect of integrating farm yard manure, zinc and starter nitrogen and phosphorus on soil fertility, growth and yield of green grams. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Treatments included: Zinc, NP, Manure, Manure+ zinc, NP+ zinc and control. Green gram variety tested was KS20. Data collected included: Initial soil chemical properties, plant height, number of leaves per plant, number of pods per plant, grains per pod, weight of 100 grains, biomass and grain yield. Results showed that Zinc+ manure significantly promoted the highest plant height, number of leaves, grain yield. Plots treated with zinc+ manure recorded 32% higher plant height and 46% higher grain yield compared to NP applied plots. In conclusion, integration of manure and zinc was most effective in promoting green grams growth and yield. Since, this research was carried out on station in ferralic, chromic Luvisols; there is need for long term trials in farmers' fields with diverse soil properties and environmental conditions.

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1. INTRODUCTION

The main goal of integrated nutrient management is to supply required plant nutrients for sustainable crop productivity with minimum deleterious effect on soil health [1].The approach aims at ensuring adequate replenishment of soil nutrients, maintenance of soil physical, chemical and biological properties while safe guarding the environment. Organic amendments such as manure are known to add nutrients in the soil [2]. The nutrients includes: macro nutrients such as N,P, K, Ca, Mg and S and trace elements such as Fe, Zn, Cu, Mo, Bo, Cu, Ni, Mn among others. Addition of these nutrients leads to improved cation exchange capacity (CEC), anion exchange capacity (AEC), and buffering capacity hence improved availability of nutrients for crops uptake [3]. Manure is also important in the improvement of soil physical properties such as texture, structure, porosity that regulates soil temperatures, moisture content, nutrient holding capacity and porosity [4,5,6]. These properties are very important in the solubility of nutrients for uptake, root penetration and root growth. They also play great role in creating favourable environment for soil microbes that aid in nutrient cycling processes as well as mineralization processes [7].

Owing to the fact that plants require 17 elements to grow optimally and complete their life cycle with optimal yields, no single source of plant nutrients can meet the entire nutrient need of crops in modern agriculture [8] The nutrient sources need to be used in an integrated manner following a management technology that is appropriate, economically viable, socially acceptable and ecologically sound [8,9]. This is because, while inorganic fertilizer application provides nutrients in distinct known forms and quantities, organic fertilizers are very important in improving the soil physical and biological properties which promotes soil health in the long run leading to effective utilization of the applied nutrients by plants. Application of Farm Yard Manure alone as a substitute to inorganic fertilizer and vice versa is, therefore, not enough to maintain high yields from health soils [9,10]. Most of the recommended inorganic fertilizers such as Diammonium Phosphate (DAP), Calcium Ammonium Nitrate (CAN), NPK are highly refined and lack trace elements such as Zinc (Zn), Copper (Cu), Boron (Bo) which plays various vital roles within plants and are limiting in some soils. Integrated nutrient management which encompasses application of both organic manures and various inorganic fertilizers sources is, therefore, one of the best approaches of maintaining healthy and sustainably productive soils [1,7,11].

Green grams are leguminous plants that have capacity to fix their own Nitrogen through biological nitrogen fixation (BNF) [12]. Effectiveness of BNF process is however influenced by several factors such as initial soil nutrition and soil physical properties such as moisture content. Inadequate initial nitrogen and phosphorus levels in the soil have been documented to reduced BNF activity and growth in most legumes [12,13]. Starter Nitrogen is important in the initial plant metabolic activities while initial phosphorus is important in the initial plant metabolic activities and root formation [12,13,14]. According to research carried out by [15] starter Nitrogen leads to increased grain yield, fodder yield, nitrogen use efficiency and legumes net returns. Similary, [16] working on mung beans reported an increase in plant height, number of nodules and availability of Nitrogen, phosphorus and potassium in succeeding crop on application of starter Phosphorus. Micronutrients such as zinc on the other hand plays an important role in enzymatic reactions, protein synthesis, growth hormones production, internode elongation, defense against pathogens, decreased susceptibility to injury by light intensity, temperature, pests and diseases [17,18,19,20,21]. Phosphorus and zinc, though antagonistic to each other in certain circumstances, such as when P is supplied in high levels and Zn uptake becomes slower or inadequate [22], they work in harmony to promote crop growth and production. Combination of Phosphorus and Zinc is also associated with increased leghaemoglobin, K, and Fe concentration in nodules leading to improved Nitrogen fixation ability in legumes [23].

Declining crop production within the Kenyan coast has been attributed to factors such as unreliable rains, quality of inputs and land degradation. Declining soil fertility if one of the major land degradation forms [24]. The fertility decline is attributed to inadequate use of both organic and inorganic fertilizers [25,26]. The available inorganic fertilizers in the market are also highly refined providing at least three nutrients; that is nitrogen, phosphorus and potassium [26,27,28]. Continuous application of these fertilizers, coupled with introduction of modern varieties, crop intensification, and increased micronutrient removal has led to mining of these other minerals required by plants from the soil reserves without replenishment [26,27,29,30]. Research carried out by FAO [31] and [32] shows that most soils within the region are deficient of minerals such as Boron, manganese, zinc, sulphur. Owing to the fact that these deficient minerals play specific roles in plant growth and production, replenishment of the nutrients is paramount. This study therefore aimed at evaluation of the effects of integrating farmyard manure, zinc and starter nitrogen and P on green grams growth and yield.

2. MATERIALS AND METHODS

2.1 Experiment Location and Description of Materials

Field experiments were carried out during the March-June, 2019 long rains in multi locational sites at Matuga and Mivumoni in Kwale County. Matuga lies between latitudes 3°S-4°S and longitudes 39°E - 40°E while Mivumoni lies between latitudes 4.33°S and longitudes 39.52^{0}E in the Coastal lowlands. Kwale County is generally warm throughout the year with temperatures ranging between 24.2°C during the coldest months (June and July) and 32°C during the hottest months (January and February) [33].

2.2 Experimental Design and Crop Husbandry

The experiment was laid down in a randomized complete block design (RCBD) and replicated three times. The treatments included: Control (No zinc application), Zinc, starter NP, FYM, NPK + zinc, FYM + zinc. The source of starter NP was NPK fertilizer, the fertilizer was applied at the recommended rate of 100 kg ha^{-1} while farm yard manure (FYM) was applied at 5 tonnes per hectare. Zinc sulphate was applied as Zn source at a rate of 4kg ha^{-1} while 23:23:0 was applied as NPK source at a rate of 50 kg ha^{-1}. Zinc, NPK and FYM was applied at planting time using placement method. The experimental land had been left fallow for one calendar year. Green gram variety tested was KS20. The crop was established at a spacing of 45 cm by 15 cm making an experimental plot of 2 m by 1.5 m and a plant population of 450. Individual plots were separated by 0.5 m wide gap while blocks were separated by 1m gap leading to a total experimental plot 24 m by 8.5 m. Fertilizer was applied during planting while Zinc Sulphate was applied 14days after crop emergence. All other agronomic practices such as thinning, weeding, pest and disease control were carried out as need occurred.

2.3 Data Collection

Data collected included: initial soil chemical properties, crop growth measurements and yield components. Soil chemical properties were evaluated by carrying out by randomly collecting 15 soil samples at 0-20 cm depth in the experimental plots using systematic sampling procedure. The samples were composited to make one sample per site and taken to the laboratory for chemical analysis. The parameters analysed were pH (water), total nitrogen (N), exchangeable phosphorus (P), potassium (K), Calcium (Ca), magnesium (Mg), Zinc (Zn), iron (Fe), manganese (Mn), copper (Cu) and sodium (Na). The analysis ws carried out following the procedures described by Jaetzold and Schmidt [34]. Ten plants were tagged randomly from the middle rows of each plot 14 days after emergence and the tagged plants were used for data collection throughout the experimental period. Data collected included: plant height, number of leaves, pods per plant, days to 50% flowering, days to 50% ponding, 100grains weight and grain yield. Plant height were determined by measuring the height of the ten tagged plants from the base of plant to the longest leaf by use of a ruler on weekly basis from two weeks after emergence till physiological maturity.

Number of leaves was determined by counting all the leaves from the ten tagged plants from one week after emergence on weekly basis until physiological maturity. Number of pods per plant and number of grains per pod were determined by counting the ten tagged plants per plot at harvesting time. Number of days to 50% flowering and pod formation were recorded. Physiological maturity was determined when the green grams color changed from green to brown.

Weight of 100-grains was determined by weighing 100 grains of the harvested grains per plot. Grain yield were determined by harvesting mature plants from an area of 1 M^2 in the middle part of the plot and weigh them.

2.4 Statistical Analysis

All obtained data were subjected to analysis of Variance (ANOVA) using general linear model

(GLM) SAS Computer package version 9.1. Means were separated using the Duncan's New Multiple Range Test at 5% level of significance [35].

3. RESULTS

3.1 Initial Soil Chemical Characteristics

The soils had a moderately acid pH, and low levels of total Nitrogen (N), organic carbon (%OC), exchangeable phosphorus, potassium, calcium, magnesium, iron and zinc (Table 1).

3.2 Effect of Combining Zinc, Farm Yard Manure and NPK on Green Gram Plant Height and Leaf Number

Combined application of zinc, farmyard manure, and starter NP significantly ($P \le 0.05$) improved mean plant height and number of leaves (Table 2). Manure + zinc recorded the highest plant height and number of leaves while control recorded the lowest. Combination of zinc+ manure led to 32% increase in plant height and 28% increase in leaf number compared to application of starter NP alone.

3.3 Effect of Zinc, Farm Yard Manure, Starter Nitrogen and Phosphorus on Green Grams Pods per Plant and Grains per Pod

Combining zinc, farm yard manure and NP had significantly ($P \le 0.05$) influenced green grams pods per plant and grains per pod (Table 3). Plots treated with farm yard manure + zinc recorded the highest pods per plant and grains per pod while control recorded the lowest.

3.4 Effect of Combining Zinc, Farm Yard Manure, Starter Nitrogen and Phosphorus on Dry Matter Accumulation and Grain Yield

Combining zinc, farm yard manure, NP significantly ($P \le 0.05$) improved green grams yield (Table 4). Mean comparison showed that the highest grain yield (0.6$kgha^{-1}$) was obtained from zinc enriched with manure while the lowest was obtained from control with a mean of 0.3$kgha^{-1}$. Zinc enriched with manure had no significant difference with NP + zinc with means 4.6$kgha^{-1}$. Mean comparison showed that the highest 100-seed weight was obtained from zinc enriched with manure with a mean of 4.7$kgha^{-1}$ while the lowest 100-seed weight was obtained from control with a mean of 3.4 $kgha^{-1.}$ .The highest dry matter was observed in manure + zinc with a mean of 0.97$kgha^{-1}$.

4. DISCUSSION

4.1 Effect of Combining Zinc, Farm Yard Manure and Starter NP on Green Grams Plant Height and Leaf Number

The significant increase in green gram plant height and number of leaves by zinc + manure treatment can be attributed to the combined effects of organic matter and zinc on the soil environment, nutrient availability and resulting uptake efficiency. Manure is important in modification of soil physical, chemical and biological properties leading to improved moisture holding capacity, nutrient holding capacity, soil temperature regulation, improved germination and root penetration [2,4,5,6,9,36]. Improvement of all this factors ensures adequate nutrient availability for plant uptake leading to improved crop growth [5,36]. Zinc on the other hand plays an important role in plant protein synthesis by nitrogen uptake; photosynthesis by carbon anhydrase activity and synthesis of chlorophyll; resistance against abiotic and biotic stresses such as oxidative damage resistance and pathogens among others [22,37]. Combination of these factors might have contributed to the improved plant height and number of leaves in zinc+ manure treated plots compared to other treatments. Similar findings have been reported by Ali et al. [38] in in Pakistan when he combined zinc with organic matter in wheat.

4.2 Effect of Combining Zinc, Farm Yard Manure and NP on Pods per Plant, Grains per Pod, Grain Yield, Grain Weight and Dry Matter of Green Grams

Zinc + manure application significantly increased green grams pods per plant, grains per pod, grams grain yield and grain weight and dry matter compared to other treatments. The increased yield components on plots treated with zinc + manure compared to other treatments can be attributed to a combination of factors. First, Owing to the fact that rainfall within that season was low and erratic, manure might have played a great role in modification of soil physical properties leading to modified moisture retention

Table 1. Initial soil chemical characteristics for the study sites

Parameters	Soil PH(water)	N%	OC %	PMgKg^{-1}	Potassium MgKg^{-1}	Calcium MgKg^{-1}	Magnesium MgKg^{-1}	Manganese MgKg^{-1}	Copper MgKg^{-1}	Iron MgKg^{-1}	Zinc MgKg^{-1}	Sodium MgKg^{-1}
Value	5.89	0.05	0.31	15	0.1	1.2	0.37	0.34	1.43	6.8	4.2	0.08
Class	Moderate acid	low	low	Low	Low	low	low	adequate	adequate	Low	low	adequate

Table 2. Effect of zinc, farm yard manure, starter NP on green grams height and leaf number

Treatments	Plant height	Leaf number
NP + Zinc	18.5cd	14.4c
Manure + Zinc	23.8a	20.1a
Zinc	16.3de	12.4d
NP	17.9de	14.5c
Manure	21.6b	18.5b
Control	15.1e	11.5d
Mean	18.8	15.1
CV (%)	7.7	5.6
LSD	0.8	0.5
P≤0.05	<.0001	<.0001

Values followed by the same letter(s) on the same column are on significantly different at P≤0.05. N-nitrogen, P-phosphorus

Table 3. Effect of combining zinc, farm yard manure, starter NP on green grams Pods per Plant and grains per pod

Treatments	Pods per plant	Grains per pod
NP + Zinc	21.7bc	13.0abc
Manure + Zinc	27.2a	14.7a
Zinc	13.4e	12.0d
NP	18.2d	12.0bcd
Manure	24.5b	13.0bc
Control	12.9e	11.0cd
Mean	19.6	12.2
CV(%)	8.2	9.9
LSD	0.9	0.7
P≤0.05	<.0001	<.0001

Values followed by the same letter(s) on the same column are on significantly different at P≤0.05

Table 4. Effect of combining zinc, farm yard manure and NP on green grams dry matter and grain yield and weight (kgha^{-1})

Treatments	100-seed weight (kgha^{-1})	Grain yield (kgha^{-1})	Dry matter (kgha^{-1})
NP +Zinc	4.1bc	0.5abc	0.8bc
Manure + Zinc	4.7a	0.6a	1.0a
Zinc	3.5d	0.3d	0.8c
NP	3.6cd	0.41bc	0.8bc
Manure	4.1b	0.4bc	0.9b
Control	3.4d	0.3d	0.7c
Mean	3.9	0.4	0.8
CV(%)	7.1	15.2	5.2
LSD	0.5	0.03	0.03
P≤0.05	<.0001	<.0001	<.0001

Values followed by the same letter(s) on the same column are on significantly different at P≤0.05

capacity hence improved availability of soluble nutrients within the rhyzosphere, hence improved nutrient and water uptake by the plants compared to plants without manure [39]. Apart from provision of nutrients, zinc also plays the role of regulating abiotic and biotic stresses within the plant by improving resistance to pest and diseases and other environmental stresses [19,40]. Additionally, the existing interactions between phosphorus, zinc and Iron might have played a role in the availability of other nutrients that support plant growth and yield. Since initial soil analysis showed that the soils were low in exchangeable inorganic phosphorus (Pi), Zinc and Iron, Pi deficiency have been documented to result in over accumulation of zinc in shoots and the inverse is true, zinc deficiency leads to over accumulation of Pi in shoots [41,42]. Similarly, deficiency of iron in soils has been associated with Pi and Zinc acquisition in both roots and shoots [43,44]. Interactive combination of this zinc and manure factors might have contributed to improved uptake of other nutrients throughout the growth period leading to high dry matter yield and grain yield. Similar findings have been reported by [38,39].

5. CONCLUSION AND RECOMMENDATION

Combined application of Zinc and manure significantly Increased green grams plant height, leaf number, dry matter, pods per plant, grains per pod, grain weight and overall yield compared to other treatments. Application of zinc + manure significantly increased green gram height by 32% and grain yield by 46% compared to application of starter NP alone. Although combination of starter N and P with Zinc seemed to increase plant height, number of leaves and overall yield, the performance didn't significantly differ with manure application. Due to the fact that the conclusions were made from a short-term research, the study, therefore, serves as an initial step in the analysis of the interactive effects of zinc, farm yard manure and NPK in green grams production. The research was also carried out on station in ferralic, chromic Luvisols; there is need for long term trials in farmers' fields with diverse soil properties and environmental conditions.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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