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Response of Maize-Green Gram Intercropping to Manure and Mineral Fertilizers in Post Mined Soils

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Authors' contributions

This work was carried out in collaboration among all authors. Author OK designed the study, wrote the protocol and first draft of the manuscript. Authors EMM, JBN and JMM guided on study design, data collection, analysis and interpretations while authors AWW and NO was involved in study design, data collection and review. All authors read and approved the final manuscript.

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ABSTRACT

Mining is an important economic activity globally that is associated with provision of raw materials, industrial growth, employment creation as well as degradation of natural ecosystems and agricultural land. A study was conducted at Base Titanium limited mining company to evaluate the response of maize-green intercrop to farmyard manure and mineral fertilizer in post mined soils. Treatments were sole manure, sole inorganic fertilizer, manure + inorganic fertilizer and unfertilized (control) laid down in randomised complete block design (RCBD) and replicated three times. Data

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collected included soil nutrients before and after cropping, maize and green grams growth and yield parameters. Obtained data was subjected to analysis of variance using genstat software and means separated using Fisher's LSD. The post mined soils were slightly acidic with optimal levels of Ca, Mg, Mn and Zn, Low levels of P,K, S, B,Cu, CEC, TN and organic matter. After two cropping seasons, S and TN was observed to increase in all treatments, while Ca, Mg, Mn, B and Zn decreased in all treatments. Combined manure and fertilizer application increased average maize plant height, stem circumference and LAI by 38%, 34%, 60% respectively and ears per plant, cob length, grains per cob, grain yield and dry matter weight by 57%, 13%, 47%, 31% and 35% respectively compared to unfertilized plants. Green grams growth and yield in the intercropping system was however not significant after either manure and/or fertilizer application. Although the findings showed that manures and fertilizers application improved nutrient availability in this post mined soils, further research is required to ascertain maize–green gram intercrop, optimal establishment time, spacing, fertilizer and manure rates that can provide optimal intercrop yield as well as soil regeneration.

Keywords: Post mined soils; mineral fertilizer; farmyard manure; intercropping; green grams.

1. INTRODUCTION

Green gram (*Vigna radiata* L.) is a short duration (65-90 days) grain legume grown on more than 6 million hectares globally and primarily produced for its protein-rich dry edible seeds and fresh sprouts [1]. The crop is drought tolerant and a central income generating agro-enterprise in many semiarid areas across sub Saharan Africa [2]. In Kenya, Green grams is an important pulse crop cultivated primarily for food, income generation and soil fertility management [3,4]. It is commonly cultivated in Taita Taveta, Kilifi, Tana River, Migori, Busia, Homa Bay, Kerio valley, Elgeyo Marakwet Baringo, West Pokot, Kitui, Makueni, Tharaka Nithi, Machakos, Meru, Embu and Kwale [3,5]. Most cultivation is carried out in small holdings as either mixed crops, intercrops or relay with longer duration associate crops such as cotton, sorghum and maize [6]. According to [7], Kenya has the potential to produce 3MT/ha but only produces 0.46MT/ha. The low production is attributed to myriad of factors such as unreliable rains, quality of inputs and land degradation due to change of land use or soil health decline [8].

Maize is the main staple food in Kenya; contributing up to 3% of the agricultural domestic product, 21% of the total value of primary commodities and per capita consumption is 98kg per year [9]. As Maize is a major source of livelihood for resource poor farmers in developing countries. It is established either as a sole crop or intercropped with other crops such as legumes, vegetables or fodder and utilized as staple food, feed for livestock and cash crop by small scale farmers [10,11]. Total land area under maize production in Kenya is about 1.5 million hectares, with an annual average production estimated at 3.0 million metric tons giving a national mean yield of 2 metric tons per hectare against a demand of over 4.8 million metric tons posing over reliance on imports [12,13]. The low maize production has been largely attributed to myriad of factors such as low quality seeds, soil fertility decline, continuous land degradation, poor agronomic practices and climate change effects [14,15,16].

Mining is a significant activity that promotes income generation, job creation, source of industrial raw materials and industrialization across the globe [17]. In spite of the imperative role in global development, mining is associated with displacement of population and land degradation that disrupts natural ecosystem balance leading to lose of vegetation, biota and soil health [18,19]. Closure of mining activities marks the beginning of post-mining reclamation activities which are depended on type of mining employed [20,21]. The overall goal of reclamation process is to return soil into excavated area and rebuild soil attributes by allowing colonization by indigenous plant species while maintaining sustainable stability and fertility management [22,20]. This is achieved by encouraging natural colonization or establishing tree covers, grasslands, pasture lands and in some cases crop farming [20,23,24,25]. Reclamation through crop farming however requires proper management of commonly occurring challenges such as compaction, surface runoff and erosion [23,26]. Striking balance between plant nutrition maintenance while promoting optimal soil regeneration poses a big challenge in post mined soils because of the delicate nature of the soils. Application of organic materials such as farmyard manure in landscapes have for many years been attributed with long term improvement of soil health through improved physical, chemical and biological activities [4,27]. Inorganic fertilizer on the other hand has the potential of providing short term solution to soil nutrient deficiency by providing readily available nutrients at the right proportions. Long term sole application of inorganic fertilizers in compromised ecosystems is however associated with amplification of land degradation due to decreased soil carbon and soil biota levels [28]. Maintenance of healthy soil ecosystem therefore requires a system that incorporates different soil fertility maintenance approaches [29]. This research was executed to explore the performance of maize- green gram intercropping in mined out soils that have been relayed and treated with farmyard manure and /or inorganic fertilizers. The efforts were geared towards evaluating the suitability and profitable use of post mined land to contribute towards food security and improved livelihoods within the region through crop production as a post mining land use option.

2. MATERIALS AND METHODS

2.1 Description of Study Site

The study was conducted at the south dune mining site of Base Titanium limited-company, Kwale County. The company is located in Msambweni Sub County, 10 kilometers from the Coastal line and 50 kilometers South of Mombasa City. It lies within lowland agro-ecological zone three (CL2-3), at an altitude of less than 45 meters above sea level and between latitude 4°29′29.8″ South and longitude 39°28′33.7″East [30]. Bimodal rainfall pattern with two distinct seasons, namely: March/April to June/July long rains and September/October to December short rains is commonly experienced within the region. The rainfall amount normally ranges between 1,200 mm to 1,400 mm per year with an annual average temperature of between 24°C and 26.6°C. According to Jaetzold et al. [31], original soils within the research area are well drained, red to dusky red, very friable, sandy clay loam to clay, with a topsoil of loamy sand to sandy: Rhodic Ferralsols.

2.2 Experimental Layout, Design and Crop Husbandry

The experiment was laid down in randomized complete block design (RCBD) and replicated thrice. Treatments included control (C), manure (M), mineral fertilizer (F), and integrated fertilizer (M+F), all applied on a maize-green gram intercrop established on plots measuring 4m by 3.3m. Plots earmarked for mineral fertilizer application received NPK and potassium sulfate at the rate of 200 kg ha^{-1} and 125 kg ha^{-1} respectively while the plots earmarked for FYM received well-decomposed cow dung manure at the rate of 10 t ha^{-1}. Manure was broadcasted on plots and incorporated into soil using a hoe before planting while NPK was applied in hills during planting. When maize reached knee height, the plots that were earmarked for inorganic fertilizers were top dressed with CAN applied on the rings of the crop. The maize variety planted was Dekalb (DK777) which was sown in hills spaced 30 cm between hills and 90 cm between rows. Three seeds were sown in each hill and later thinned to one plant per hill. For green grams, N26 variety was Sown at a spacing of 20 cm by 25 cm, two rows of green grams were planted between two maize rows and the distance between maize row and green gram row was 20 cm. Three green gram seeds were planted in each hill and later thinned to leave a single greengram seed per hill. Planting of both maize and greengrams was done simultaneously. Thinning was done 10 days after germination while hand weeding was done 3 times at an interval of 21 days from the date of planting. Pests and disease control formed part of the agronomic practices and was done using pesticides as need arose.

2.3 Data Collection

Data collected included initial and final soil properties where soil sampling and analysis was carried out by randomly sampling soils from twelve (12) points of the experimental area at a depth of 25-30 cm using soil auger. The soil was then mixed to form a composite sample from which a 1kg sample was packed and sent to the laboratory for physiochemical analysis. Soil texture was analysed using hydrometer method while exchangeable phosphorus (P), calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), manganese (Mn), iron (Fe), copper (Cu), molybdenum (Mo), boron (B), zinc (Zn), and sulphur (S) were determined using Optical Emission Spectrometry method. Potentiometric method was used to establish soil pH and EC. Available soil carbon and nitrogen was on the other hand established using colorimetric method [32].

Growth of maize and green gram was monitored by collecting data on number of leaves, leaf length and width, plant height, stem circumference and Leaf Area Index (LAI) while yield was evaluated by collecting data on number of maize ears plant^{-1}, length of cobs, number of grains cob^{-1}, total grain yield, pods plant^{-1}, grains pod^{-1}, 500 grain weight and dry plant biomass. For green grams, the number of leaves were physically counted and recorded after every seven days from the day of emergence. Height of selected maize and green gram crops was measured using tape measure at 7 days' interval after crop emergency. The number of pods were counted on the selected green gram plants and recorded on a weekly basis from the day of first pod formation. Harvesting was done by hand picking at physiological maturity and pods from the 5 selected green gram plants were opened and seeds counted to obtain the number of seeds pod^{-1}. After handpicking the pods, they were sun dried for 10 days, threshed and the grain dry weight as well as 500 grain weight obtained. The whole green gram plant was dug out after harvesting while ensuring that there was minimal root damage, roots were washed and then the plant dried in an oven for 72 hours at a temperature of 65°C after which the dry weight was measured using electronic balance.

2.4 Data Analysis

Data collected were subjected to an Analysis of Variance (ANOVA) using GenStat (14th edition) and means ranked using Fisher's Least Significant Difference (LSD) [33].

3. RESULTS

3.1 Effect of Manure and Inorganic Fertilizer on Soil Physiochemical Properties

Initial soil analysis indicated that the soils had sandy loam texture with slightly acidic reaction (pH 6-6.5) (Table 1). Exchangeable Ca, Mg, Mn and Zn levels were optimal while exchangeable P, K, S, B and Cu levels were low. The CEC, total nitrogen (TN) and organic matter (OM) levels were also observed to be low at 4.29 meq/100g, 0.078% and 1.65% respectively.

After two cropping seasons, exchangeable Sulphur (S) and Total Nitrogen (TN) were observed to increase in all the treatments while exchangeable Potassium (K) increased in all treatments except control plots. Exchangeable Calcium (Ca), Magnesium, Manganese (Mn), Boron (B) and Zinc (Zn) on the other hand decreased in all the treatments while exchangeable phosphorus (P) increased only in soils amended with sole fertilizer and manure + fertilizer. Sole fertilizer and control led to declined percentage organic matter levels while soil pH values were observed to decline in all treatments except sole manure treated soils.

3.2 Growth and Yield of Maize and Green Grams as Influenced by Farmyard Manure and Mineral Fertilizer

3.2.1 Plant Height

Manure and /or fertilizer significantly ($P \leq 0.05$) increased the intercropped plants height compare to unfertilized plants (Table 2). Maize height was observed to increase by 39%, 43%, 30% and 39% in season one week 5 and 7 and, season two week 3 and 5 respectively compared to unfertilized plants. Green grams height on the other hand increased by 28% in week 5 of season two compared to unfertilized plants. No significant differences were observed for plant height difference among manure, sole fertilizer and manure + fertilizer treated plants. Green grams height was only different in week of second season.

3.2.2 Stem circumference

Manure and /or fertilizer was observed to significantly ($P \leq 0.05$) improved maize stem circumference in the maize- green gram intercropping system (Table 3). Manure + fertilizer was observed to increase maize stem circumference by 33%, 33% and 36% in season one and 25% in week 3 of season 2 compared to unfertilized plants. Stem circumference of plants treated with manure and/ or fertilizer was however not significantly different throughout the cropping seasons.

3.2.3 Leaf area index of maize

Manure and /or fertilizer was observed to significantly ($P \leq 0.05$) improved maize leaf area index (LAI) in the maize- green gram intercropping system (Table 4). Manure + fertilizer was observed to increase maize LAI by 57%, 62% and 62% in season one and 40% in week 3 of season 2 compared to unfertilized plants. Leaf area index of plants treated with manure and/ or fertilizer was however not significantly different throughout the cropping seasons.

Table 1. Status of soil nutrients before and after two maize-green gram intercrop cropping seasons

	Initial	After two cropping seasons			
Variable	**Value**	**Control**	**Manure**	**Fertilizer**	**Manure + fertilizer**
pH (H_2O)	6.44	6.09	6.47	5.98	6.32
Exch. Phosphorus (ppm)	10.6	3.49	8.56	98.5	115
Exch. Potassium (ppm)	109	68.6	119	132	316
Exch. Calcium (ppm)	509	300	379	320	281
Exch. Magnesium (ppm)	100	50.2	98.2	48.1	55.2
Exch. Sulphur (ppm)	15.4	54.5	32.1	23.7	20.7
Exch. Manganese (ppm)	196	237	172	168	150
Exch. Boron (ppm)	0.43	0.22	0.31	0.24	0.25
Exch. Copper (ppm)	0.87	1.02	0.79	0.72	0.96
Exch. Zinc (ppm)	2.39	1.77	1.1	1.79	1.09
CEC (meq/100g)	4.29	2.66	3.53	3.03	3.26
Total Nitrogen (%)	0.078	0.084	0.095	0.08	0.085
Organic matter (%)	1.65	1.21	1.95	1.49	1.73
Textural class	Sand loam	Sand loam	Sand loam	Sand loam	Sand loam

Table 2. Response of maize and green gram height (cm) to farmyard manure and mineral fertilizer in post mined soils

	Season one			Season two		
Maize Plants						
Amendments	**Week 3**	**Week 5**	**Week 7**	**Week 3**	**Week 5**	**Week 7**
Control	26.4a	45.9a	88.4a	20.3a	58.9a	129.0a
Manure	27.3a	68.8b	125.0ab	27.3b	73.1ab	160.0a
Fertilizer	26.4a	64.9ab	140.6b	32.8c	99.0b	165.0a
Manure +Fertilizer	31.7a	75.7b	154.2b	29.0bc	96.7b	185.0a
P value(< 0.05)	Ns	0.039	0.025	0.006	0.026	Ns
% CV	5.2	9.4	11.2	7.3	3.5	36.6
Green gram plants						
Control	9.3a	26.3a	57.9a	8.1a	17.4a	49.1a
Manure	9.8a	30.7a	79.6a	10.1a	27.5b	69.0a
Fertilizer	10.7a	31.9a	77.2a	11.1a	28.7b	46.1a
Manure+Fertilizer	10.3a	30.0a	76.6a	8.0a	24.2b	57.2a
Pvalue(< 0.05)	Ns	ns	Ns	Ns	0.008	Ns
% CV	5.0	16.2	6.2	10.1	6.9	8.4

Values followed by the same letter(s) on the same column are not significantly different at P ≤ 0.05

Table 3. Response of maize stem circumference (cm) to farmyard manure and mineral fertilizer in post mined soils

Amendments	Season one			Season two		
	Wk3	**Wk 5**	**Wk 7**	**Wk3**	**Wk 5**	**Wk 7**
Control	6.1a	6.2a	5.6a	7.9a	8.4a	8.5a
Manure	7.9a	8.2b	7.5b	9.3ab	9.4a	9.17a
Fertilizer	7.7ab	9.1b	8.7b	10.3b	10.2a	9.5a
Manure + Fertilizer	9.1b	9.3b	8.6b	10.6b	10.8a	10.2a
P value(< 0.05)	0.023	0.022	0.004	0.03	ns	Ns
% CV	9.5	6.8	5.0	8.7	2.1	2.63.9

Values followed by the same letter(s) on the same column are not significantly different at P ≤ 0.05; Wk=Weeks after crop emergence; CV= Covariance of Variation

Table 4. Response of maize Leaf Area Index (LAI) (m^2 m^{-2}) to farmyard manure and mineral fertilizer in post mined soils

Amendments	Season one			Season two		
	Wk 3	**Wk 5**	**Wk 7**	**Wk 3**	**Wk 5**	**Wk 7**
Control	0.9a	1.1a	1.1a	1.8a	2.5a	2.6a
Manure	1.7b	2.1b	2.4b	2.2a	2.9a	2.9a
Fertilizer	1.7b	2.4bc	2.9b	3.2b	3.5a	3.3a
Manure + Fertilizer	2.1b	2.9c	2.9b	3.0b	3.7a	3.4a
P value(< 0.05)	0.027	0.002	0.005	0.008	ns	Ns
% CV	21.7	18.9	18	12.9	11.3	8.4

Values followed by the same letter(s) on the same column are not significantly different at P ≤ 0.05; Wk=Weeks after crop emergence; CV= covariance of variation

3.2.4 Maize crop yield

Manure and /or fertilizer was observed to significantly (P ≤ 0.05) affect maize dry matter and grain yield in the intercropping system (Table 5). Manure + fertilizer was observed to increase maize ears per plant by 61%, cob length by 26%, grains per cob by 51% and grain yield by 61% in season one and ears per plant by 52%, grains per cob by 42% and dry matter by 69% in season two compared to unfertilized plants. Yield from sole manure and sole fertilizer were generally not significantly different in the cropping seasons. Maize grain yield was also not significantly different in all treatments in season two.

3.2.5 Green gram yield

Manure and /or fertilizer was observed to have no significant (P ≤ 0.05) effect on green gram dry matter and grain yield in the intercropping system (Table 6). Although manure + fertilizer treated crops had general higher average pods per plant, grains per pod, 500 grain weight, grain yield and dry matter, were not significantly different except for grain yield in season two.

4. DISCUSSION

4.1 Effects of Farmyard Manure and/or Mineral Fertilizer in Properties of Post Mined Soils after Two Maize-green Gram Intercrop Cropping Seasons

Initial levels of exchangeable phosphorus (10.6ppm), potassium (109ppm), Sulphur (15.4ppm), Boron (0.43ppm), Copper (0.87ppm), Total Nitrogen (0.078%) and CEC (4.29mol/100g) as observed in these soils are classified as low by Landon [34] and insufficient to support optimal plant growth and yield. Such low soil nutrient levels are common in mined ecosystems because mining is characterized by disruption of aboveground and belowground biota and nutrient cycles leading to low nutrient concentrations and biotic activities [17,35]

Total nitrogen (TN) was observed to increase in all the treatments while exchangeable Potassium (K) increased in all treatments except in control. The slight increase in Total Nitrogen (TN) in all the treatments compared to the initial level can be attributed to the manure and fertilizer application and bacterial nitrogen fixation as a result of green gram intercrop. This is because nitrogen is added to soil naturally from N fixation by soil bacteria and legumes and through atmospheric deposition in rainfall.

Exchangeable Calcium (Ca), Magnesium, Manganese (Mn), Boron (B) and Zinc (Zn) were observed to decrease in all the treatments while exchangeable phosphorus increased only in soils amended with sole fertilizer and manure + fertilizer. Considering that the soils were sandy textured with low organic matter levels, the decrease in exchangeable cations can be attributed to plant nutrient uptake as well as nutrient loses through erosion, leaching and run runoff. Sandy soils are susceptible to nutrient leaching due to poor water and nutrient holding capacity. This results are similar to findings by Tahir and Marschner [36] who recorded a higher nutrient leaching in sandy soils compared to clay soils.

The observed exchangeable P increase in soils treated with sole fertilizer and fertilizer + manure can be attributed to the immediate supply of P from applied mineral fertilizers. According to Lal and Stewart [37], Muindi et al. [38], Muindi et al. [39], Muindi [40], Weil and Brady [41] phosphorus is an immobile element that can persist in soils if not lost through crop uptake, runoff, adsorption by clay colloid, oxides and hydroxides of Fe and Aluminium in acidic soils and carbonates and bicarbonates of calcium and magnesium in saline soils. Continuous decomposition and mineralization of organic matter can also avail more mineral Phosphorus in soil solution or buffer soil pH promoting Phosphorus release from colloidal structures [40-42]. Additionally, the organic matter presence can avail more P in soil solution by reducing P chelation by lowering the activities of the polyvalent cations such as Ca, Al and Fe that form insoluble salts with P [43,44].

Plots amended with manure, which is a decomposed mixture of farm animal dung, urine, litter and leftover material from roughages or fodder fed to the cattle, and integrated fertilizer showed increased levels of organic matter. This is in agreement with a study done by Haynes and Naidu [45] who noted that additions of manure result in improved soil organic matter content, water holding capacity, porosity, hydraulic conductivity and bulk density.

Application of manure moderately raised soil pH compared to control, fertilizer and integrated fertilizer which caused a reduction in soil pH. This increased in soil pH levels due to manure application can be attributed to buffering capacity of manure while the slight the increased buffering capacity, while the decreased soil pH levels on application of mineral fertilizer can be attributed to initial acidifying ability of nitrogen based fertilizers during oxidation of NH_4^+ to NO_3^-, which generates H^+ and lowers the soil pH. These results are in agreement with the findings of Caia et al. [46] who also found that application of manure increased the soil pH while the application of N–fertilizers reduced soil pH. The results also contradict findings by Masood et al. [47] who reported reduced soil pH after short term manure application.

4.2 Growth and Yield of Maize and Green Grams as Influenced by Farmyard Manure and Mineral Fertilizer

4.2.1 Plant height

The significant increase in maize and green gram height in week five of season one and from week 3 of season two of manure treated plots can be attributed to the slow -release characteristic of organic fertilizers thereby resulting to little effect on the growth of crops in the first few weeks but causes a notable effect after week three. These results resonate well with [48] who noted that application of manure increased green gram growth parameters such as height and branches due to the improved plant nutrient uptake. The increase in leaf number as a result of FYM could be due to improved soil conditions such as water and nutrient holding capacity created by manure and also the release of nutrients from manure to the soils after mineralization. The high levels of Sulphur in manure treated soils may have also created a synergy between S and N in soils leading to high availability of N for crop uptake. These results support the findings by Solomon et al. [49] who observed an increase in maize growth with application of farmyard manure.

Table 5. Response of maize yield to farmyard manure and mineral fertilizer in post mined soils

Amendments	Ears per plant	Season one			Grain yield (t/ha)	Dry matter (t/ha)
		Cob length (cm)	Grains per cob	500 grain weight (g)		
Control	0.8a	13.4a	242.8a	139.2a	1.5a	3.1a
Manure	1.2ab	14.4ab	335.9ab	141.8a	2.2a	4.1a
Fertilizer	1.7bc	16.3bc	387.7bc	142.1a	2.7ab	3.6a
Manure + Fertilizer	2.1c	18.2c	492.0c	148.2a	3.8b	5.9a
P Value (< 0.05)	0.013	0.009	0.01	Ns	0.024	Ns
% CV	29.0	5.2	6.7	3.1	5.2	5.8
Season two						
Control	1.1a	13.4a	272.0a	135.6a	2.1a	3.6a
Manure	1.5ab	14.8a	410.0b	163.1b	3.6a	5.3a
Fertilizer	1.9bc	15.2a	430.0b	156.2ab	4.5a	7.1a
Manure + Fertilizer	2.3c	16.4a	470.0b	178.6b	4.5a	11.6b
P Value (< 0.05)	0.004	ns	0.019	0.024	Ns	0.02
% CV	8.9	2.4	11.7	7.7	14.2	11.7

Values followed by the same letter(s) on the same column are not significantly different at $P \le 0.05$

Table 6. Response of green grams yield to farmyard manure and mineral fertilizer in post mined soils

	Season one				Dry matter (t/ha)
Amendments	**Pods per plant**	**Grains per pod**	**500 grain weight (g)**	**Grain yield (t/ha)**	
Control	6.93a	10.67a	26.07a	0.277a	1.45a
Manure	6.93a	9.83a	28.63a	0.23a	2.37a
Fertilizer	7.8a	11.0a	29.03a	0.36a	1.74a
Manure + Fertilizer	9.0a	11.13a	28.2a	0.23a	1.78a
P Value (< 0.05)	ns	Ns	Ns	Ns	Ns
% CV	10.8	4.6	10.37.2	67.5	2.5
Season two					
Control	14.0a	11.47a	25.27a	0.16ab	0.65a
Manure	15.5a	11.8a	26.33a	0.23b	0.84a
Fertilizer	19.5a	11.93a	26.03a	0.21a	0.54a
Manure + Fertilizer	24.1a	13.8a	29.13a	0.34c	1.09a
P Value (< 0.05)	ns	Ns	Ns	<0.01	Ns
% CV	23.1	4.6	3.6	9	17.2

Values followed by the same letter(s) on the same column are not significantly different at $P \leq 0.05$

The observed plant height increase in manure and fertilizer treated in both maize and green grams after inorganic fertilizer application might be plants compared to unfertilized plants can also be attributed to availability of soil solution nitrogen and phosphorus for uptake from applied fertilizers. While Nitrogen plays crucial role in vegetative growth, phosphorus is key in germination and root formation [40,41] promoting new cells development, plant vigour, leaves and height. This finding concur with Aslam et al. [50] who reported increased plant height and number of green gram branches on application of inorganic fertilizers and Rewe et al. [51] who reported increased maize height and number of leaves on combined application of slurry and inorganic fertilizer.

The increase in maize growth parameters due to combined manure and inorganic fertilizer corroborate the finding by Laekemariam et al. [52] who reported increased maize growth parameters such as leaf number and plant height due to integrated fertilizer application as compared to separate application of manure and fertilizer. Application of chemical fertilizers with organic manure increased the maize plant height owing to the stronger role of nutrients in cell division, cell expansion and enlargement which ultimately affect the vegetative growth of plant and ultimately higher dry-matter production.

4.2.2 Stem circumference and Leaf Area Index (LAI) of maize

Maize stem circumference and LAI was observed to significantly increase with application of manure and/or fertilizer. This response can be attributed to availability of nutrients within the exchange complex in soils treated with manure and / or fertilizers. Nutrients such as N, P, and K, are key in vegetative growth, cell multiplication and enlargement and development. The results are consistent with the findings of Efthimiadou et al. [53] who noted that organic manure increased stem girth and Leaf Area Index of maize. Similarly, Abd et al. [54] reported improved Plant height, LAI and number of leaves per plant on application of both organic and inorganic fertilizers. Ahmad et al. [55] on the other hand reported highest LAI in integrated fertilizers compared to separate application of fertilizer and manure.

4.2.3 Maize yield

Application of manure and/or fertilizer was observed to significantly improve maize ears, cob length, grain per cob, plant biomass, grain yield and 500 maize grain weight. This phenomenon can be attributed to role played by fertilizer in provision of readily available nutrients for crop uptake as well as overall soil properties improvement that is played by organic matter within soils. The combined effects of organic matter and mineral fertilizer might have synergised to provide suitable environment for maize growth and yield. This finding are in agreement with Munyabarenzi et al. [56] who reported significant ($P<0.05$) increase in maize grain yield, 1000 grain weight and stover biomass on application of manure and mineral fertilizer. Similarly, [57,58] on the other hand reported significant increase in maize stalk biomass, 100 grain weight and grain yield of maize on application of mineral fertilizers. Abd El-Gawad and Morsy [54] on the other hand reported increased ears per pod, grain per row, 100-grain weight, grain yield, biological yield and grain quality on combined application of manure plus fertilizer.

4.2.4 Green gram yield parameters

Neither manure nor fertilizer had significant effect on green gram yield parameters except grain yield in the second season. The findings contradict findings by Muindi et al. [4] who reported significant increase of green gram grain yield, stalk biomass as well as 100 grain weight on application of manure, starter nitrogen and phosphorus. The obtained low yields can be attributed the competition and shading effect that might have been caused by the intercropping system. According to Seran and Brintha [59], success is intercropping systems is negatively influenced by crops maturity, compatibility, planting density and planting time among other factors that influence light penetration reducing photosynthesis and translocation of photosynthates from source to sink. Similar low green gram yields in intercropping system compared to sole crops have been reported by Manasa et al. [60].

5. CONCLUSION AND RECOMMENDATION

The post mined soils were slightly acidic with optimal levels of Ca, Mg, Mn and Zn, and Low levels of P, K, S, B, Cu, CEC, TN and organic matter. After two cropping seasons, S and TN was observed to increase in all treatments, while Ca, Mg, Mn, B and Zn decreased in all treatments. Combined manure and fertilizer application in intercropping system increased average maize plant height, stem circumference and LAI by 38%, 34%, 60% respectively compared to unfertilized plants. Similarly, combined application of manure and mineral fertilizer in maize- green gram intercropping system increased average maize ears per plant, cob length, grains per cob, grain yield and dry matter weight by 57%, 13%, 47%, 31% and 35% respectively. Manure and/or fertilizer did not however have significant effect on green gram pods per plant, grains per pod, 500 grain weight, grain yield and dry matter weight. Although the findings show that manure and fertilizer application has potential to improve nutrient concentrations within the soil solution, green grams were observed to perform poorly in maize-green gram intercrop, there is therefore need for further research to ascertain optimal manure and fertilizer quantities as well as establishment time and spacing that can provide optimal maize and green gram growth and yield while promoting soil regeneration.

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COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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