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Onion (*Allium cepa* L.) Performance as Influenced by Manure and Fertilizer in Titanium Mined Soils

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Abstract

Mining is an important economic activity that promotes income generation, job creation, and industrialization globally. In spite its economic importance, it is classified as land degradation form that disrupts natural ecosystem through loss of biota and soil health. Paucity of information regarding the performance of reclaimed mined soils in supporting crop production abound in Kenya. To contribute to this knowledge gap, a study was conducted at Base titanium limited -Kwale to investigate the response of performance of bulb onions (red creole onion variety) to farmyard manure and inorganic fertilizer application on post mined soils. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replicates Treatments included: inorganic fertilizer, farmyard manure, inorganic fertilizer +farmyard manure and control. Obtained data that included: soil characterization, onion growth and yield parameters was subjected to analysis of variance (ANOVA) using R packages and means separated using the Fisher's protected least significant difference (LSD) at ($P \leq 0.05$). Results showed that the soils had low TN, exchangeable P, K, S, Bo and Cu levels. Manure+ fertilizer significantly ($P \leq 0.05$) increased plant height by 38%, bulb diameter by 44%, neck thickness by 19.5% total bulb yield by 89% and marketable yield by 88% compared to control. A significant positive relationship between manure, fertilizer, fertilizer+ manure with plant height, number of leaves, bulb diameter, neck thickness and total yield was observed indicating that manure + fertilizer can support optimal onion production in these post mined soils. Further research is however, required to ascertain production approaches that promote sustainable soil development and onion yield.

Keywords: fertilizer, Onion, land degradation, manure, mining, reclamation

1. Introduction

Onion (*Allium cepa* L.) is a biennial plant belonging to the family Amaryllidaceae (Alliaceae) and native to South East Asia (Grubben and Denton, 2004). It is one of the oldest vegetables known to man, cultivated for at least 5000 years (Shultz, 2010). Presently, onions are cultivated all over the world for both commercial and local consumption, with China being the leading producer globally followed by India (Tetteh et al., 2015). Although the plants nutritional value is low, the crop is also widely consumed globally (as a seasoning or vegetable in various dishes) with average annual per capita consumption of approximately 11 kg (FAOSTAT, 2019). It is also known to have high levels of vitamin C, Vitamin B6, Calcium, Magnesium, Phosphorus and Potassium, and medicinal properties such as anticancer, antidiabetic, antimicrobial, anti-cholesterol, antiasthmatic, antithrombotic, anti-inflammatory and anti-oxidative (Griffith et al., 2002; Lanzotti, 2006; Pareek et al., 2017; FAOSTAT, 2019).

Onion crop is a shallow rooted crop that thrives in well-drained, sandy-loam textured soils. The crop doesn't require a lot of water compared to other arable crops but has high nutrient demand particularly nitrogen, phosphorus and potassium. According to research carried in several parts of the world by Gateri et al. (2018);

Gererufael et al. (2020); Kazimierczak et al. (2021); Yoldas et al. (2011) adequate levels of nitrogen (N), phosphorous (P), potassium (K) significantly increases seed survival, plant height, number of leaves, leaf length, average bulb weight, bulb diameter, total and marketable yield as well as quality. The crop Ranks as the third most important vegetable in Kenya after brassicas and tomatoes (MOA, 2004). , The annual average production within the country in 2019 was estimated at 10.01 MT/ha far below prevailing per capita consumption demands of 2.65 kg (FAOSTAT, 2019). The overall low production is attributed to poor agronomic practices, use of low-yielding local varieties, limited production knowledge, prevailing land degradation and pest and disease outbreaks in the face of industrialization and climate change.

World over, mining is an important activity that promotes income generation, job creation, source of industrial raw materials and industrialization. Despite the important role played by the industry, the mining process is classified as a form of land degradation that leads to disruption of natural ecosystem balance leading to lose of vegetation, above ground biota as well as soil physical, chemical and biological properties (Kanianska, 2016). Mines can be closed when the resource is depleted or, when it is no longer economically profitable due to a high cost of mining or low market prices (Laurence, 2011; Haque et al., 2014). Once mining is completed, post-mining reclamation activities are initiated which entails physical, chemical and biological approaches (Festin et al., 2019; Tetteh et al., 2015). The three approaches aim at returning soil into excavated areas and rebuild soil attributes by allowing colonization by indigenous plant species while maintaining sustainable stability and fertility management (Sheoran & Poonia, 2010; Mensah, 2014; Festin et al., 2019). This is achieved by establishing tree covers, grasslands, pasture land and in some cases crop farming (Sweigard, 1990; Cooke and Johnson, 2002; Sheoran et al., 2010; Siachoono, 2010; Festin et al., 2019). However, reclamation through crop farming requires proper planning for effective management of commonly occurring problems such as excess soil compaction, differential settlement and surface runoff (Sweigard, 1990). It also requires experimentation with different types of fertilization. The present experiment was undertaken to investigate the performance of bulb onion in mined out soils that have been relayed and treated with farmyard manure and inorganic fertilizers. The efforts were geared towards determine the suitability and therefore 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. Methodology

2.1 Description of the Study Site

The study was carried out at the south dune site of Base Titanium Limited (BTL) company. The company is an Australian based mining company located in Kwale, County (4.1816 ° S, 39.4606 ° E), within the Kenyan coast. The mining process involve: 1) Clearing the vegetation ahead of the area to be mined, 2) separation and stockpiling the topsoil for further use in the rehabilitation process, 3) mining the deposit using a hydraulic mining method, and 4) mixing water with the ore to create a slurry for pumping to the Wet Concentrator Plant (WCP). The project utilizes three 400tph Hydraulic Mining Units (HMU) to more effectively mine the thinner, lower grade perimeter blocks of the SML. HMU's have replaced the Dozer Mining Units (DMU) as the mining method. The mineral processing component consists of two main stages: 1) The WCP, which removes slime and recovers the HMC from the coarse sands, and 2) the Mineral Separation Plant (MSP), which separates the HMC into the three products and removes the remaining rejects. The MSP uses gravity, magnetic and electrostatic separation to separate the minerals; no chemicals are used in the mineral separation process. The tailings (slimes or rejects) that result from the wet processing of heavy mineral sands occur in two distinct streams, namely fine tailings and coarse sand tailings. The coarse sand tailings are directed to mine voids, where they are used to build walls and provide backfill. Once the mining process is completed, the soil profile is reconstructed by overlaying sand on bedrock followed by compacted layer of sand and clay mixture at varying proportions. Then a layer of original top soil is spread.

2.2 Experimental Design and Crop Husbandry

The experiment was set up in a Randomized Complete Block Design (RCBD) with three replicates. Treatments consisted of control (no input), sole farmyard manure, farmyard manure +inorganic fertilizer and sole inorganic fertilizer. Red Creole bulb onion variety was used in the trial. It is a red, flat-round, globular bulb, with a very distinctive pungent smell caused by sulphur-containing chemicals and excellent storage qualities. It matures within 150 days after transplanting and has an average yield potential of 16 tonnes/acre.

Experimental material was raised from certified seeds in a nursery and transplanted six (6) weeks later. Manure was applied at the rate of 8 tonnes/ha before transplanting and split fertilizer application was carried out during planting and repeated four (4) weeks later at the rate of 150kgN/ha, 100kgP/ha, 100kgK/ha, 30kgMg/ha and 60kgS/ha. The plants were transplanted in 5 rows comprising of 31 plants per row at spacing of 30 x 10 cm giving a population of 155 plants in a plot of 11mx 10 m. Each block occupied an area of 3 x 10.2 m including paths. A total of 12 plots were set up. The blocks were separated by 1 m path making a total experimental area of 11 x 10.2 m. Routine cultural practices on weeds, pests and disease control were carried out as recommended throughout the cropping season. Micronutrient deficiency was managed by applying easygro flower and fruit water soluble fertilizer at the rate of 10 liters /ha at 3rd week and 7^{th} week after transplanting. At harvest, sampling was done from the three (3) inner rows of each, excluding guard plants. The outer two (2) plants were regarded as guard plants from each row, giving a sample of 15 onions from which data was taken. Harvesting was done when 75% of the plants had fallen over.

2.3 Data Collection and Analysis

Data collected included, initial and final soil characterization, plant height, number of leaves, % fallen plants at maturity, total and marketable yield, bulb diameter, neck thickness. The data was collected from 5 tagged plants selected from each plot's three (3) innermost rows. Procedures taken for each parameter are as follows.

2.3.1 Soil Characterization

Soil chemical properties were evaluated before crop establishment and after second season harvesting. Initial soil sampling was carried out by taking soil from 10 random points at 20 cm depth within the entire project field using stratified random sampling method (Carter and Gregorich, 2007). The samples were mixed to make one composite sample that was taken to the laboratory for chemical analysis. Final sampling was carried out by collecting soil samples at a depth of 20 cm from 5 points along a zigzag line after harvesting in each treatment. The sampled were mixed to make 12 composite samples that were taken to the laboratory for chemical analysis. Parameters analysed in the laboratory were: Soil pH, Organic carbon (%), Total Nitrogen (%), exchangeable Boron, Copper, Zinc (ppm, Potassium (ppm), Calcium (ppm), magnesium (ppm), Manganese (ppm), Sulphur (ppm), Electrical conductivity (Us/cm)) and cation exchange capacity (meq/100gsoil). All the analysis was carried out as described by (Okalebo et al., 2002).

2.3.2 Plant Height

Plant height was evaluated by taking measurement from the ground level up to the highest leaf using a standard ruler. The measurements were carried out (in cm) weekly from the third week after establishment up to the ninth week.

2.3.3 Number of Leaves

Leaf development data collection commenced three (3) weeks after transplanting and leaves were counted until physiological maturity. Fully developed leaves capable of photosynthesis (>5 cm) were visually counted from the five (5) tagged plants per plot.

2.3.4 Percentage (%) Fallen Over at Maturity

Percent fallen over at maturity was evaluated by visually counting plants with fallen tops in the three middle rows of each plot when 50% of the tops were fallen. The obtained number and total number of plants per plot was then used to calculate percent fallen per plot.

2.3.5 Total Yield

Leaves and roots were cut from bulbs at harvesting time and the fresh weight determined using electronic weighing balance and recorded in kilograms. The weight was then converted to tonnes /ha.

2.3.6 Marketable Yield

To determine the marketable yield, consideration was made of the diameter of the bulbs excluding any bulbs within <20cm diameter. The determination also excluded split, bolted, sprouted and rotten bulbs. The weight was taken using an electronic weighing scale and expressed in tonnes/ha.

2.3.7 Bulb Diameter

Bulb diameter was evaluated using a Vernier calliper by measuring the widest bulb circumference at right angles to the longitudinal axis. The following groups were then used for grading: Size A; < 40 mm diameter - small (grade 3), Size B: Between 60-80 mm diameter - medium (grade 2), Size C: >80 mm diameter - large (grade 1).

2.3.8 Neck Diameter

The narrowest part 5mm above the top of each bulb was measured using Vernier calliper for all sampled bulbs.

2.4 Data Analysis

All obtained data was subjected to Analysis of Variance (ANOVA) using the R statistical packages (R Core Team, 2021). In the event that ANOVA showed significant differences, mean separation was carried out using Fisher's protected Least Significant Difference (LSD) test at 5% probability significance level. Correlation and regression analysis was done to determine the relationship between plant attributes and amendments.

3. Results

3.1 Soil Chemical Properties as Influenced by Bulb Onion Subjected to Manure and Inorganic Fertilizers

3.1.1 Initial Soil Chemical Properties

Initial soil analysis showed that the soils had a sandy loam texture with a slightly acidic (pH 6.1-6.4) reaction (Figure 1). Exchangeable Phosphorus (P), Potassium (K), Sulphur (S), Boron (B) and copper (Cu) levels were low while Exchangeable Calcium (Ca), Magnesium (Mg), Sodium (Na), Iron (Fe), manganese (Mn) and Zinc (Zn) levels were optimal. The cation exchange capacity (CEC), total nitrogen (TN) and organic carbon (OC) levels were low. Although the levels of exchangeable Na, Ca: Mg ratio, ESP, OC, and TN were observed to increase in all treatments after two cropping seasons, exchangeable K, S, Mg, Mn, Bo and EC decreased in all treatments. Soil pH was observed to increase in all treatments except manure and manure + fertilizer treated plots. Similarly, control and fertilizer reduced exchangeable P levels while manure and manure+ fertilizer promoted increased P levels. A combination of manure + fertilizer increased exchangeable Ca, Zn and CEC levels while manure, fertilizer alone and control significantly reduced the levels. Additionally, exchangeable iron levels were observed to increase in manure + fertilizer and fertilizer treated soils and reduce in manure and control soils.

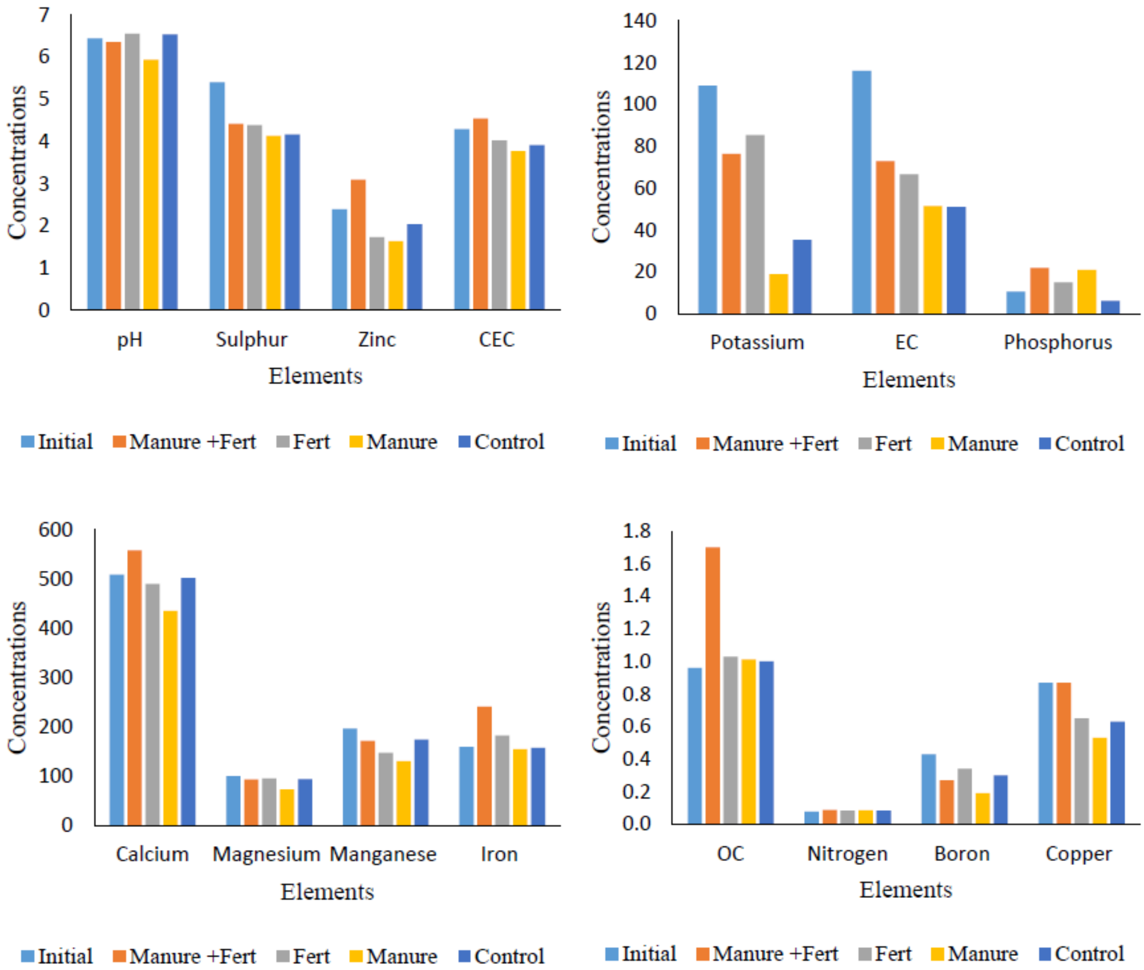

Figure 1. Residual Impact of organic and inorganic fertilizer on Soil pH, Organic carbon (%), Total Nitrogen (%), exchangeable Boron, Copper, Zinc (ppm, Potassium (ppm), Calcium (ppm), magnesium (ppm), Manganese (ppm), Sulphur (ppm), Electrical conductivity (Us/cm)) and cation exchange capacity (meq/100gsoil) after two onion cropping seasons

3.2 Growth Parameters

3.2.1 Plant Height

There was significant difference ($P < 0.05$) between manure and fertilizer for plant height in both seasons (Figure 2). Application of 150 kg N/ha and 100 kg P/ha Inform of DAP (Diammonium Phosphate) Fertilizer combined with 8 tons/ha of manure recorded maximum plant height throughout the growth period. Manure + fertilizer increased plant height by 37% in season one and 39% in season two compared to control.

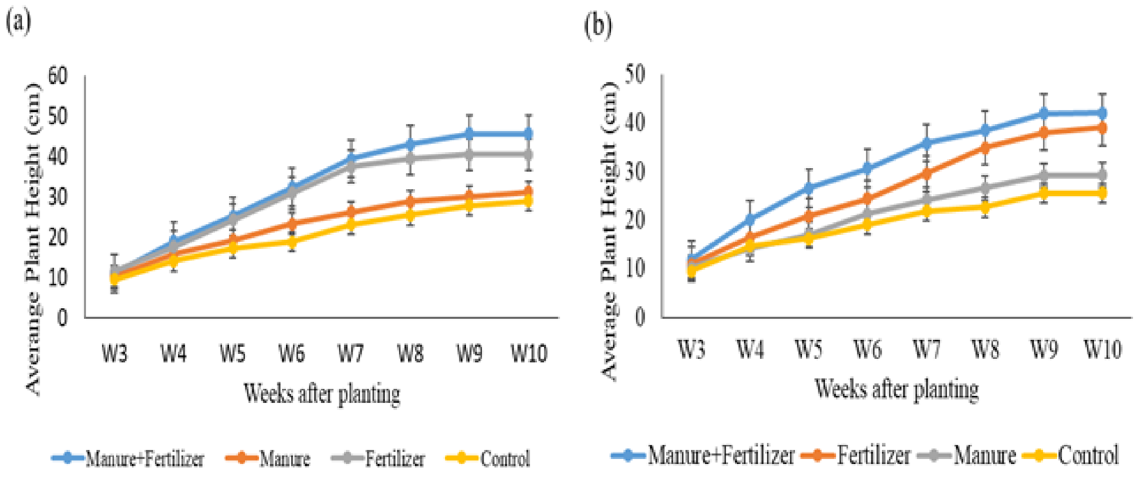

Figure 2. Average plant height (cm) of onion plants amended with manure and inorganic fertilizer in post mined soils in season one (a) and season two (b)

3.2.2 Leaf Numbers

Although leaf numbers were not significantly different ($P > 0.05$) during the 3rd week, the average number of leaves on crops treated with manure + fertilizer was significantly different ($P < 0.05$) in the 6th and 9th weeks after transplanting in both seasons (Table 1). Manure + fertilizer treated crops had the highest overall mean number of leaves, followed by sole fertilizer, sole manure while control recorded the lowest.

Table 1. Mean number of leaves of onions amended with manure and inorganic fertilizer in post mined soils

	Average Number of Leaves					
	3 Weeks		**6 Weeks**		**9 Weeks**	
Amendments	**Season 1**	**Season 2**	**Season 1**	**Season 2**	**Season 1**	**Season 2**
Control	3.63a	3.63a	4.82a	5.167a	6.93a	7.03a
Manure	3.92a	3.60a	5.09a	5.59a	7.06a	7.23a
Fertilizer	4.07a	4.20a	5.15a	5.67a	7.32b	8.02b
Manure+ Fertilizer	4.17a	4.13a	5.7b	6.33b	7.55b	8.70c
LSD	0.51	0.97	0.42	0.64	0.25	0.67
P-Value	ns	ns	0.012	0.026	0.004	0.003
%CV	0.7	2.4	3.1	7.9	2.2	1.2

3.2.3 Bulb Diameter

Manure and fertilizer application significantly ($P < 0.05$) affected bulb diameter and neck thickness development (Table 2). Plants treated with manure + fertilizer were observed to have the highest neck thickness (means ±sd cm), while the control (means ±sd cm) had the lowest. The neck thickness of onions from manure + fertilizer was 19.5% bigger than onions from unfertilized plots. A similar trend was observed in bulbs from manure + fertilizer treated plots. Bulbs from manure + fertilizer treated plots had 44% higher diameter compared to unfertilized plots in both seasons. Onions falling at harvest differed with treatment during the second season with manure alone, fertilizer alone and fertilizer + manure plots having the highest percent fallen onions while the control had the lowest.

Table 2. Mean Bulb diameter (mm), % fallen after Harvest and Neck thickness (mm) of onions amended with manure and inorganic fertilizer in post mined soils

	Bulb Diameter (mm)		**%fallen at harvest**		**Neck Thickness**	
amendments	**Season 1**	**Season2**	**Season 1**	**Season2**	**Season 1**	**Season2**
Control	30.40a	30.23a	38.6a	14.63a	11.68a	11.84a
Manure	47.58b	37.36a	45.0a	32.75b	12.96ab	13.37b
Fertilizer	50.79b	49.96b	50.50a	38.74b	14.29b	14.37bc
Manure + Fertilizer	53.66b	54.89b	52.00a	48.57b	14.43b	14.80c
LSD	12.08	11.02	18.25	17.59	1.665	1.3
P value	0.012	0.005	0.349	0.017	0.021	0.006
%CV	7.1	1.1	5.3	9.3	2.9	1.7

3.2.4 Yield

Analysis of variance showed that manure and fertilizer significantly ($P < 0.05$) affected total and marketable yield of the onion crop in both seasons (Table 3). Manure + fertilizer promoted total bulb yield by 89.9% and 87.6% during seasons 1 and 2, respectively compared to control. The treatment also increased marketable yield by 89% and 86% in seasons 1 and 2, respectively compared to control. It was however, observed that the total marketable yield from control and sole manure were not significantly different ($P < 0.05$) in both seasons except season 1. Yield from fertilizer and fertilizer + manure treated plots were also not significantly different.

Table 3. Average total and marketable yield (tons/ha) of onions amended with manure and inorganic fertilizer in post mined soils

	Total Yield (Tons/ha)		**Marketable Yield (Tons/ha)**	
Amendments	**Season 1**	**Season2**	**Season 1**	**Season2**
Control	2.90a	3.90a	2.66a	3.62a
Manure	6.30a	7.10a	5.62b	6.38a
Fertilizer	21.27b	22.80b	19.99b	20.54b
Manure + Fertilizer	28.8b	31.40b	25.22b	26.17b
LSD	8.95	10.79	8.53	9.04
P value	0.001	0.002	0.002	0.002
%CV	20.6	22	18.4	21.6

3.5 Relationship between Amendments, Plant Growth and Yield

A significant correlation was observed between soil amendments, % fallen at harvest, bulb diameter, plant height, number of leaves, neck thickness and total yield (Table 4). Manure had a significant ($P < 0.001$) positive correlation with bulb diameter, plant height, number of leaves, neck thickness and total yield. A similar trend was observed in fertilizer and manure + fertilizer treatments with both having a significant ($P < 0.001$) positive correlation with bulb diameter, plant height, number of leaves, neck thickness and total yield. All the amendments also had a significant (($P < 0.05$) positive correlation with % fallen at harvest.

Table 4. Relationship between selected soil amendments and, crop growth and yield

Parameter	**Manure**	**Fertilizer**	**Fertilizer + manure**
%_fallen at harvest	0.685*	0.689*	0.638*
Bulb Diameter	0.956***	0.999***	0.954***
Plant Height	0.860***	0.998***	0.986***
No. of Leaves	0.808***	0.852***	0.813***
Neck Thickness	0.886***	0.937***	0.898***
Total Yield	0.927***	0.907***	0.883***

**correlation is significant at 0.001 level (2tailed); *correlation is significant at 0.05 level (2 tailed);

3.6 Relationship between Applied Nitrogen and Phosphorus and Onion Yield

A significant ($P < 0.05$) positive relationship was observed between quantities of applied nitrogen, phosphorus and bulb onion yield (Figure 3). Both marketable and total tuber yield were observed to increase with increasing levels of nitrogen and phosphorus in applied manure and fertilizer.

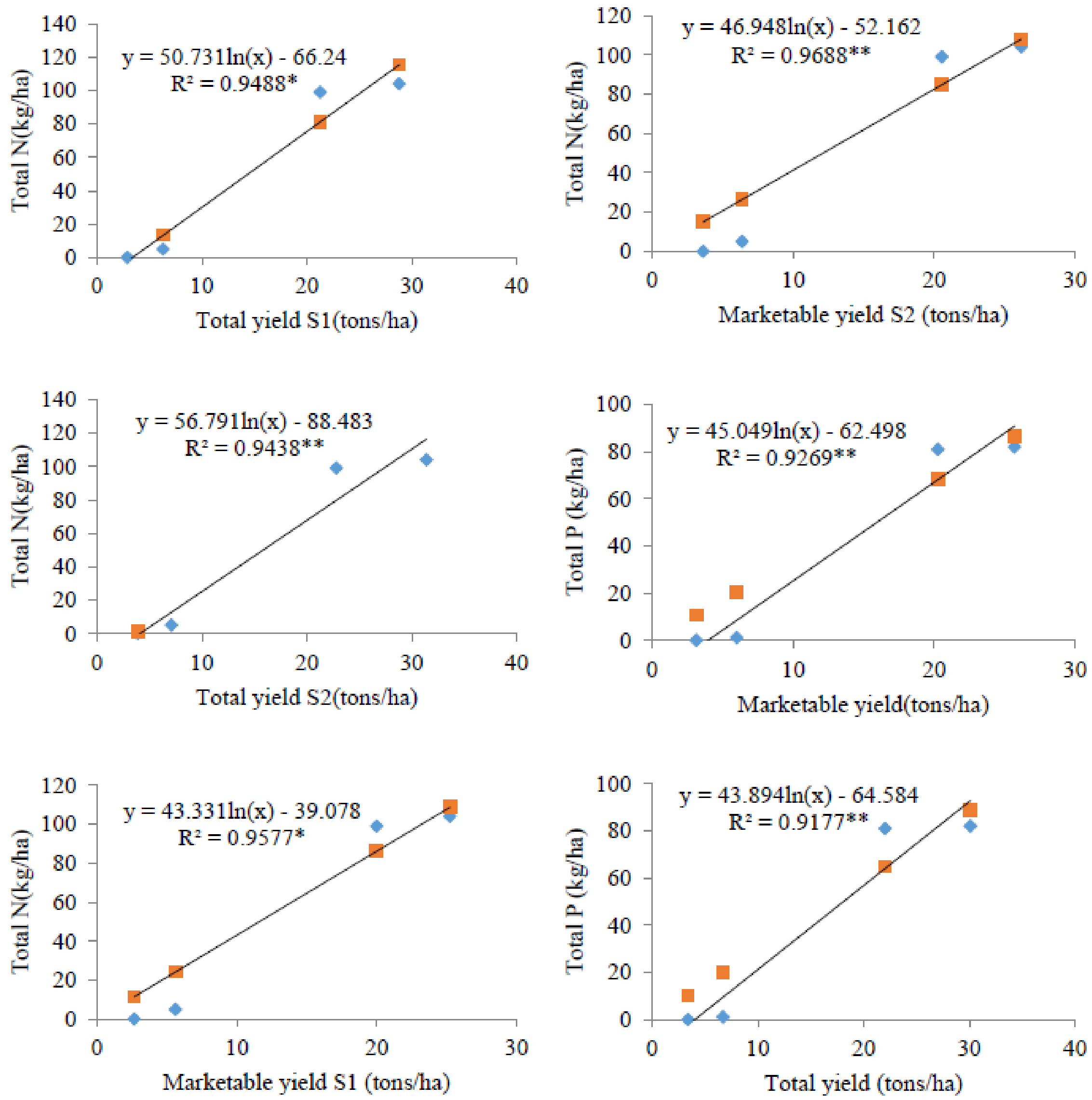

Figure 3. Relationship between onion marketable and total yield (tons /Ha) and soil nitrogen and phosphorus as affected by organic and inorganic nutrient sources

*significant at $p \leq 0.05$; **significant at $p \leq 0.01$, S1-season 1, S2-season 2.

4. Discussion

4.1 Soil Physical and Chemical Properties

Levels of exchangeable phosphorus (P<20ppm), potassium (K<120ppm), sulphur (S<20ppm), Boron (Bo<0.8ppm), copper (Cu<1.5ppm), Total nitrogen (<0.2%) and CEC< 15Cmolkg^{-1} soil as identified in this soils are classified by Landon (1991) to be low and unable to support optimal crop growth and yield. Such low nutrient levels are common phenomenon in post mined soils (Sheoran et al., 2010). According to Kundu and Ghose (1997), the low nutrient levels could be attributed to the mining process disrupting soil components such as horizons, structure, biota, and crucial nutrient cycles.

The observed increase of exchangeable sodium percentage (ESP) and sodium (Na) levels in the soils after two cropping seasons can be attributed to the fact that, sodium being a non-nutrient, tends to accumulate in soil from fertilizers, pesticides (Kumar et al., 2014), shallow salt-laden waters run off as well as breakdown of Na rich minerals. On the other hand, exchangeable sodium percentage (ESP) measures the proportion of cation exchange sites occupied by sodium within soils (Gupta and Goyal, 2017).

Lower levels of exchangeable K, S, Mg, Mn and Bo identified in the trials at the end of the cropping seasons compared to initial values can be attributed to nutrient loses through erosion, runoff, leaching or crop uptake (Baligar, Fageria, and He, 2001)among other factors. Since the soils had high levels (>80%) of sand, sand textured soils are associated with poor water and nutrient holding capacity due to leaching (Osman, 2012).

The low levels of EC in soils after the cropping season might have been caused by prevailing levels of exchangeable cations at the time of characterization. Since soil electrical conductivity (EC) measures the ability of soil water to carry electrical current and it is an electrolytic process that takes place principally through water-filled pores containing dissolved salts from cations such as Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, and NH4+, and anions such as $SO_4{}^{2-}$, Cl^{-}, $NO_3{}^{-}$, and $HCO_3{}^{-}$) (Corwin and Yemoto, 2017), the observed low levels of base cations might have contributed to the low soil EC.

The observed decrease of soil pH on manure applied soils after two cropping seasons can be attributed to the buffering capacity of the applied manure while the observed increase in soil pH levels in all treatments except manure treated plots can be attributed to the acidifying effect of the manure nitrification process. According to Namabuye and Hayned, 2006; Brady and Weil, 2008; Muindi et al., 2015), there exists both negative and positive correlation between organic matter in manure and pH within soils. The relationship, is however depended on manure quality (Rayne and Aula, 2020).

Although phosphorus is an immobile element, its availability in soils is limited by loss 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 (Lal and Stewart, 2017; Muindi, 2019a, 2019b). Continuous mineralization due to the action of organic matter on soil physical, chemical and biological properties might have led to the increased soil P levels (Laboski and Lamb, 2003; Muindi, 2019a). The presence of organic matter also reduces P chelation by lowering the activities of the polyvalent cations such as Ca, Al and Fe that form insoluble salts with P (Black, 1968; Muindi, 2019a).

The observed increased levels of exchangeable Ca, Zn and CEC in manure + fertilizer treated soils compared to all the other treatments can be attributed to organic matter and inorganic fertilizers synergy (Schulz and Glaser, 2012).While inorganic fertilizers provide required nutrients in available forms and quantities, organic matter on the other hand, plays an important role in improving soil properties leading to improved nutrient availability and retention within the exchange complex (Rayne and Aula 2020). Similar results have been reported by (Ejigu et al., 2021; Roba, 2018).

The significant improvement of onion growth parameters and resultant yield by manure + fertilizer can be attributed to improved synergism and synchronization between nutrient release and recovery leading to higher concentrations of available nutrients in exchange complex for crops uptake. While inorganic fertilizers are associated with the provision of required nutrients in readily available forms and quantities within the exchange complex, manure, on the other hand, promotes nutrient availability through improved aggregate stability, temperature regulation, water and nutrient holding capacity and biological activities(Brady and Weil, 2008; McGrath, Spargo, and Penn, 2014). Depending on the quality, manure also provides both organic and inorganic forms of nutrients. Interaction of the two therefore promotes favourable soil conditions such as temperature, water and nutrients for germination, root elongation, and nutrient uptake leading to improved plant growth. These findings are in agreement with previous research by Kokobe,et al. (2013) who reported 49% increase in the mean number of onion leaves in plots fertilized with manure + fertilizer compared to unfertilized plots. A 61% increase in bulb yield after using 103.5 kgN/ha + 20 tons FYM/ha compared to the unfertilized plot was also been reported (Gererufael et al., 2020). Similar results have been reported in agricultural soils in Argentina (Pellejero et al., 2017) and Turkey (Yoldas et al., 2011).

As observed in table 4, the significant correlation between manure, fertilizer and manure+ fertilizer with number of leaves, plant height, bulb diameter, neck thickness and total yield can be attributed to the availability of nutrients in the exchange complex for crops uptake. According to (Brady and Weil, 2008), manure improves aggregate stability, temperature regulation, nutrient and water holding capacity within the rhizosphere apart from providing organic and inorganic nutrients. This ensures optimal uptake and utilization of readily available nutrients from applied inorganic fertilizers promoting the production of photosynthates that are mobilized to the organ of economic value leading to increased bulb growth and yield per unit area. Similar findings have been documented by in Tigray (Gererufael et al., 2020).

The positive correlations between soil applied nitrogen and phosphorus status and bulb yield indicates that the soil nitrogen and phosphorus levels in both organic and inorganic amendments affect bulb yield and its components directly. These results are in confirmatory with work of Lima et al. (2009); Mahmood et al. (2017);

Iqbal et al. (2021) who stated that incorporation of organic manures improves soil physico-chemical properties that directly or indirectly effect on plant growth and yield attributes.

5. Conclusion and Recommendations

The study results depicted that the application of manure + fertilizer promoted increased levels of exchangeable P, Ca, Zn, Na, Ca: Mg ratio, ESP, OC, TN and CEC in the post mined soils. Additionally, manure + fertilizer was observed to support the highest plant height, leaf development, bulb diameter and total yield compared to fertilizer, manure and control. A significant positive correlation was also identified between manure, fertilizer and combination manure + fertilizer with plant height, number of leaves, bulb diameter and bulb yield per unit area. Despite the important role played by manure and fertilizer in the availability of nutrients and crop growth, manure and manure + fertilized plots were observed to have lower soil pH values compared to fertilizer and unfertilized plots. Because the soils have poor profile and aggregation attributes, long-term research is recommended to ascertain sustainable practices that support optimal soil development and onion production per unit area.

Competing Interests

Authors have declared that no competing interests exist.

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