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Enhancement of Colonisation of Soybean Roots by Arbuscular Mycorrhizal Fungi Using Vermicompost and Biochar

Njunge Leah Wathira*, Wachira Peter, Okoth Sheila

School of Biological Sciences, University of Nairobi, Nairobi, Kenya

Email address:
leahwathira@gmail.com (N. L. Wathira), pwachira@uonbi.ac.ke (W. Peter), dorisokoth@yahoo.com (O. Sheila)

*Corresponding author

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Abstract: Pollution and contamination of soil is one of the major concerns in the world today. Excessive use of synthetic fertilisers has caused tremendous harm to the environment and the human population indirectly. Chemical residues accumulated in crops that find their way to into the human food chain have been found to have adverse health effects. Enrichment of lakes with runoff from heavily-fertilised farms has resulted in eutrophication and pollution of water bodies. Application of organic matter and use of mycorrhiza have been recommended as ways of mitigating these problems. The aim of the study was to investigate the effect of organic amendments on colonisation of soybean roots by arbuscular mycorrhizal fungi. The study consisted of a field experiment of seven treatments with 3 replications in a complete randomized block design. The treatments were biochar (B), vermicompost (V), mycorrhiza (M), biochar and vermicompost (BV), biochar and mycorrhiza (BM), biochar, vermicompost and mycorrhiza (BVM), and the control block which had no amendments (NT). Before planting of soybeans and application of amendments, soil samples were collected for characterization of soil chemical properties and mycorrhizal spores. Soybean seeds were planted in each plot. At flowering time, roots were screened for percentage mycorrhizal colonisation and dry mass of plants from each plot was taken. At harvest time, soil samples, plants and harvested soybeans from each plot were collected and dry weight taken. There was mean increase of 53.38% in levels of phosphorous and 15.33% of carbon in the soil after application of treatments. Levels of nitrogen decreased in all treatment blocks. There was a significant (P<0.0000) increase in arbuscular mycorrhizal fungi spores after application of treatments. The colonization percentage of arbuscules in roots was highest (14.7%) in the biochar and vermicomposting blocks (BV) while the blocks without any treatment, NT, had the lowest colonization percentage of 1.2%. The highest dry weight of both shoots and roots were recorded in blocks treated with biochar which also had the highest weight of harvested soy bean seeds with a mean of 171.28g. Blocks treated with mycorrhiza had the lowest harvest weight of soybean seeds with a mean of 58.17g. From this study it was concluded that the organic amendments enhanced the activity of the already-present mycorrhizal fungi in the soil, without requiring the introduction of commercial mycorrhizal amendments and biochar enhances microbial activity which stimulates crop productivity.

Keywords: Arbuscular Mycorrhizal Fungi, Organic Amendments, Soybean, Vermicompost, Biochar

1. Introduction

Particularly high levels of elements found in synthetic fertilisers like sodium and potassium have been reported to lead to soil and water pollution and loss of biodiversity in soils [1]. One of the most essential macronutrients for plant growth is phosphorous. Phosphorous availability in the soil leads to improvement in leaf area, root growth, stalk and stem vigour, crop maturity and yield; and resistance to pests and diseases. Phosphorous also plays a major role in important processes like photosynthesis, energy transfer and storage, cell enlargement and cell division [2]. Despite its
The area affects the water and nutrient holding capacity of the soils [11].

2.2. Study Design

The field treatment consisted of seven treatments used as soil amendments, in plots on which soybean was cultivated. The combinations were as follows: Biochar (B), Vermicompost (V), Mycorrhiza (M), Biochar+Mycorrhiza (BM), Vermicompost+Mycorrhiza (MV), Biochar+Vermicompost+Mycorrhiza (BVM), and no treatment (NT). All the treatments were arranged in a complete randomised block design with three replicates.

Land measuring 40m by 12m was cleared and sub-divided into 24 sub-plots each measuring 3m by 2m. The sub-plots were separated by paths measuring 1m wide. Soil samples...
weighing 500g were collected using a soil auger, from a
depth of 0-20cm. Samples were collected from different
random spots in each experimental block. It was assumed
that the soil properties before planting were homogenous, so
the samples from the different places were pooled together
to make a representative sample. Biochar was applied to the
individual holes intended for the seeds and mixed with the
soil. It was applied at the rate of 6.75kg per plot or 11.25t/ha,
in plots which require biochar alone (B), Biochar+mycorrhiza (BM), biochar, mycorrhiza and
vermicompost (BVM) and biochar and vermicompost (BV).

Mycorrhizal treatment applied was Rhizatech(R) supplied
by Dudutech Ltd., at the rate of 2.25l per plot or 46.875l/ha.

2.3. Data Collection

At flowering time, ten soybean plants in each plot were
randomly selected and carefully uprooted so as to obtain the
roots. Roots were cut off from the shoot with some of the
surrounding soil, wrapped in damp paper and sealed in
labelled polythene bags. These were analysed for root
colonisation. At harvest time, soybean pods were harvested
and weighed and spread out to dry. After one week, the
soybean seeds were extracted from the dry pods and
weighed.

2.4. Samples Preparation

2.4.1. Spore Extraction

The soils were pre-soaked before processing, then mixed
with water, stirred and decanted through 710 and 45 micron
sieves. This process was repeated several times, and any
lumps present were broken between washes. The sediment
from the 45 micron sieve was sieved into two or four 50ml
centrifuge tubes, which were balanced by weight and
centrifuged for 5 minutes at 1750 rpm. Water from the tubes
was decanted out and floating debris discarded as well. 48% sucrrose was added to the pellet in the tube, and the substance
mixed thoroughly and balanced by weight, before centrifuging for 15 seconds at 1750 rpm. The sucrose
solution was carefully decanted through a small 45 micron
sieve. Spores retained on the sieve were rinsed thoroughly
with water to wash out the sucrose. The spores were
transferred into a small Petri dish for examination using a
dissecting microscope.

2.4.2. Soil Analysis

Soil samples collected were analysed for total carbon,
nitrogen, pH and available phosphorous at soil laboratories at
Kenya Agricultural Research Institute (KARI). Organic
carbon was determined calorimetrically after H_2SO_4
dichromate oxidation at 1500C for 30 minutes. Total
Nitrogen was determined by Kieldahl digestion with
sulphuric acid and selenium as a catalyst and was estimated
calorimetrically. Soil pH was measured in aqueous
suspension (1:2.5 w:v), while phosphorus was extracted
with 0.5M NaHCO_3+0.01M ethylenediaminetetraacetic acid
(EDTA) pH 8.5 modified Olsen using a 1:10 soil/solution
ratio [12].

2.4.3. Root Staining

Root samples were transferred to modified syringes. The
root samples were cleared by autoclaving in 2.5% potassium
hydroxide (KOH) for 15 minutes, and then rinsed in water.
Bleaching in alkaline hydrogen peroxide was then carried
out, after which the roots were again rinsed in water. The root
samples were then acidified in 1% hydrochloric acid (HCL)
for one hour, and subsequently stained in 0.05% trypan blue
in acidic glycerol by autoclaving for 3 minutes and finally
washed out into a Petri dish for assessment. The roots were
cut into pieces approximately 5mm in length. Drops of
glycerol were placed on a slide, and fifteen root fragments
were laid out, one on each drop. Another slide was placed on
top of the previous one to protect the root fragments. The
fragments were then scored under a compound microscope
for extent of root colonisation.

The method described by [13] was used to score
occurrence of mycorrhiza in the soybean roots. Three
parameters are observed in this method: Frequency of
mycorrhiza in root system (F %), Intensity of Mycorrhizal
colonization in root system (M %), and arbuscule abundance
in root system (A %).

2.5. Data Analysis

After fulfilling the assumption of normality and
homogeneity of variances, the data was subjected to analysis
of variance (ANOVA) to test the differences in AM
colonisation and spore populations. Mean separation was
done by Fisher’s least significant difference (LSD) at the
0.05 level of probability. The analysis was carried out using
Genstat software [12].

3. Results

3.1. Characterisation of the Study Area

At the beginning of the experiment, soil phosphorous
content was 159 ppm. The soil pH level was at 7.38, while
nitrogen content was 0.51%. Organic carbon content of the
soil before application of treatments was recorded at 0.84%
(Table 1).
A total of 2390 isolates were characterized as arbuscular mycorrhizal fungi (AMF) in this study. They were grouped into four genera and ten species. *Scutellospora* was the most diverse genus with a total of four species, followed by *Glomus* with a total of three species, with *Acaulospora* and *Gigaspora* having one species each. The most frequent species was *Glomus etunicatum* with a mean occurrence of 17.74 and 17.03 respectively in that decreasing order (Table 2).

### Table 2. Frequency of arbuscular mycorrhizal fungi isolated before the study.

<table>
<thead>
<tr>
<th>Isolate</th>
<th>Rank</th>
<th>No. of isolates</th>
<th>Mean</th>
<th>Percentage</th>
<th>Cumulative frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>G. etunicatum</em></td>
<td>1</td>
<td>531</td>
<td>23.09</td>
<td>22.2</td>
<td>2.7</td>
</tr>
<tr>
<td><em>G. mosseae</em></td>
<td>2</td>
<td>408</td>
<td>17.74</td>
<td>17.1</td>
<td>2.6</td>
</tr>
<tr>
<td><em>G. intraradices</em></td>
<td>3</td>
<td>398</td>
<td>17.03</td>
<td>16.7</td>
<td>2.6</td>
</tr>
<tr>
<td><em>S. nigra</em></td>
<td>4</td>
<td>292</td>
<td>12.70</td>
<td>12.2</td>
<td>2.5</td>
</tr>
<tr>
<td><em>S. verrucosa</em></td>
<td>5</td>
<td>274</td>
<td>11.91</td>
<td>11.5</td>
<td>2.4</td>
</tr>
<tr>
<td><em>A. denticulata</em></td>
<td>6</td>
<td>250</td>
<td>10.87</td>
<td>10.5</td>
<td>2.4</td>
</tr>
<tr>
<td><em>S. calospora</em></td>
<td>7</td>
<td>123</td>
<td>5.35</td>
<td>5.1</td>
<td>1.9</td>
</tr>
<tr>
<td><em>G. albida</em></td>
<td>8</td>
<td>73</td>
<td>3.17</td>
<td>3.1</td>
<td>1.9</td>
</tr>
<tr>
<td><em>S. pellusa</em></td>
<td>9</td>
<td>41</td>
<td>1.78</td>
<td>1.7</td>
<td>1.6</td>
</tr>
</tbody>
</table>

### 3.2. Effect of Soil Amendments on Soil Chemical Characteristics

The phosphorous content in the soil increased after addition of soil amendments. The block treated with vermicompost recorded the highest phosphorous content at 262 mg/kg (Table 3).

### Table 3. Soil chemical characteristics before and after application of amendments.

<table>
<thead>
<tr>
<th>Soil Chemical Characteristics</th>
<th>P (Mg/Kg)</th>
<th>pH</th>
<th>%N</th>
<th>%C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before treatments</td>
<td>159</td>
<td>7.38</td>
<td>0.51</td>
<td>0.84</td>
</tr>
<tr>
<td>After treatments</td>
<td>250</td>
<td>7.46</td>
<td>0.098</td>
<td>0.9</td>
</tr>
<tr>
<td>M</td>
<td>247</td>
<td>7.36</td>
<td>0.14</td>
<td>0.95</td>
</tr>
<tr>
<td>B</td>
<td>243</td>
<td>7.41</td>
<td>0.1</td>
<td>1.03</td>
</tr>
<tr>
<td>MV</td>
<td>250</td>
<td>7.4</td>
<td>0.112</td>
<td>1.08</td>
</tr>
<tr>
<td>BVM</td>
<td>245</td>
<td>7</td>
<td>0.098</td>
<td>0.99</td>
</tr>
<tr>
<td>NT</td>
<td>236</td>
<td>7.28</td>
<td>0.112</td>
<td>0.91</td>
</tr>
<tr>
<td>V</td>
<td>262</td>
<td>7.36</td>
<td>0.098</td>
<td>1.03</td>
</tr>
</tbody>
</table>

This was a 64.78% increase from the initial content, as shown in Table 4. This was followed by the BVM block and the B block, with an increase of 57.23% (Table 4). The M block recorded the lowest phosphorous content at 215 mg/kg (Table 3). This was still 37.11% higher than the initial soil phosphorous content (Table 4).

### 3.3. Effect of Soil Amendments on Mycorrhizal Spores

The soil pH at the end of the experiment increased in some treatment blocks and reduced in others. The biochar block recorded the highest pH of 7.46 (Table 3), an increase of 1.08% from the initial pH, followed by that of the BV block with an increase of 0.41% and BVM with an increase of 0.27% in that decreasing order (Table 4). The mycorrhiza block and the control block recorded the lowest pH of 7.17 and 7 respectively, as shown in table 3.

Percentage nitrogen content in the soil decreased after application of amendments, with the highest nitrogen content being recorded in the MV treatment block at 0.14% (Table 3). This was a 72.54% drop from the initial nitrogen in the soil, as shown in table 4. The lowest percentage nitrogen was recorded in the V, B and control blocks, at 0.098% which was an 80.78% drop from initial percentage nitrogen (Tables 3 and 4).

Carbon content in the soil increased as a result of application of amendments. The BVM block recorded the highest carbon content of 1.08 (Table 3). This was 28.22% higher than the initial carbon content in the soil, followed by both BV and V blocks, both of which recorded a 22.62% increase (Table 4). The lowest carbon content of 0.86 was recorded in the mycorrhiza block (Table 3). This was a 2.38% increase above the initial carbon content (Table 4).

### Figure 1. Total occurrence of Arbuscular Mycorrhizal fungi across different soil amendments applied.

Key: Vermicompost (V), Biochar (B), Mycorrhiza+Vermicompost (MV), Biochar+Mycorrhiza+Vermicompost (BVM), Biochar+Vermicompost (BV), Mycorrhiza (M), Biochar+Mycorrhiza (BM), No Treatment (NT).
A significant difference (P=0.0000) was observed on the population of arbuscular mycorrhizal fungi (AMF) spores as a result of different soil amendments. The highest number of AMF was isolated from the plot amended with vermicompost (V), with 1,348 isolates, followed by biochar (B) with 1,325 isolates, and the MV block with 1,242 in that decreasing order (Figure 1).

Glomus etunicatum, was the most frequently isolated species with a mean of 3.04. The most frequently occurring genus was Gigaspora, with 4 species, while the least frequently occurring genus was Scutellospora (Table 5).

<table>
<thead>
<tr>
<th>Isolate</th>
<th>Rank</th>
<th>No. of isolates</th>
<th>Mean</th>
<th>Proportion</th>
<th>Cum frequency</th>
<th>P value (P=0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G. etunicatum</td>
<td>1</td>
<td>2797</td>
<td>117</td>
<td>33.7</td>
<td>33.7</td>
<td>0.307</td>
</tr>
<tr>
<td>G. intraradices</td>
<td>2</td>
<td>1910</td>
<td>79.6</td>
<td>23</td>
<td>56.7</td>
<td>0.018</td>
</tr>
<tr>
<td>G. mosseae</td>
<td>3</td>
<td>1481</td>
<td>61.7</td>
<td>17.8</td>
<td>74.6</td>
<td>0.073</td>
</tr>
<tr>
<td>A. denticulata</td>
<td>4</td>
<td>766</td>
<td>31.9</td>
<td>9.2</td>
<td>83.8</td>
<td>0.021</td>
</tr>
<tr>
<td>S. nigra</td>
<td>5</td>
<td>605</td>
<td>25.2</td>
<td>7.3</td>
<td>91.1</td>
<td>0.032</td>
</tr>
<tr>
<td>S. verrucosa</td>
<td>6</td>
<td>409</td>
<td>17</td>
<td>4.9</td>
<td>96</td>
<td>0.197</td>
</tr>
<tr>
<td>S. calospora</td>
<td>7</td>
<td>166</td>
<td>6.92</td>
<td>2</td>
<td>98</td>
<td>0.563</td>
</tr>
<tr>
<td>S. pellusida</td>
<td>8</td>
<td>90</td>
<td>3.75</td>
<td>1.1</td>
<td>99.1</td>
<td>0.06</td>
</tr>
<tr>
<td>Gigaspora albida</td>
<td>9</td>
<td>73</td>
<td>3.04</td>
<td>0.9</td>
<td>100</td>
<td>0.026</td>
</tr>
</tbody>
</table>

Glomus etunicatum was ranked first in frequency of occurrence both before and after application of amendments. The population of Glomus intraradices surpassed that of Glomus mosseae, which ranked second as the most frequently occurring isolate before the experiment. Acaulospora denticulata also occurred more frequently than Scutellospora nigra at the end of the experiment. The population of Scutellospora pellusida was also higher than that of Gigaspora albida at the end of the experiment (Figure 2).

### 3.4. Effects of Soil Amendments on Root Colonisation

No significant difference (P=0.926) was observed on both the frequency (F %) and intensity (M %) of mycorrhiza in the root system as a result of applying different soil amendments on different plots. However, all treatments had significantly (P<0.05) higher levels of colonization than those of the control. A significant difference (P<0.05) was observed on the percentage of arbuscules in the root system as a result of applications of different soil amendments (Table 6).

### 3.5. Effect of Soil Amendments on Soybean Plants and Harvest

At harvest time, the biochar block recorded the highest percentage change in shoot weight, at 235.29% up from the weight taken at flowering time, followed by the BM block and the M block, in that decreasing order. The highest percentage change in root weight was recorded in the vermicompost block, followed by the BM block and the M blocks in that decreasing order (Table 7).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Shoot weight</th>
<th>Root weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flowering (g)</td>
<td>Harvest (g)</td>
</tr>
<tr>
<td></td>
<td>Flowering (g)</td>
<td>Harvest (g)</td>
</tr>
<tr>
<td>MV</td>
<td>0.49</td>
<td>0.76</td>
</tr>
<tr>
<td>BM</td>
<td>0.38</td>
<td>1</td>
</tr>
<tr>
<td>V</td>
<td>0.4</td>
<td>0.95</td>
</tr>
<tr>
<td>B</td>
<td>0.34</td>
<td>1.14</td>
</tr>
<tr>
<td>NT</td>
<td>0.56</td>
<td>0.87</td>
</tr>
<tr>
<td>M</td>
<td>0.52</td>
<td>1.12</td>
</tr>
<tr>
<td>BVM</td>
<td>0.46</td>
<td>0.7</td>
</tr>
<tr>
<td>BV</td>
<td>0.52</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Key: F%: Frequency of mycorrhiza in root system. M%: Intensity of mycorrhizal colonisation in root system. m%: Intensity of mycorrhizal colonisation in root fragments. a%: Arbuscule abundance in mycorrhizal parts of root fragments. A%: Arbuscule abundance in root system. Treatments with different letters are significantly different.

**Table 5. Diversity of arbuscular mycorrhizal fungi isolated after the study.**

**Table 6. Mean occurrence of mycorrhiza in root system of soybean plants.**

**Table 7. Percentage change in shoot and root weight of soybean plants at the end of the study.**
At harvest, the B blocks recorded the heaviest weight of soybean seeds, at a mean of 171.28g, followed by the V blocks and the BVM blocks, as shown in figure 3. Compared to the other treatment blocks, the blocks treated with mycorrhiza had the lowest harvest weight of soybean seeds at 58.17g (Figure 3).

Carbon content in the soil increased as a result of application of amendments. This could be due to the fact that the amendments provided a suitable environment for development of micro-organisms, whose metabolic activities led to an increase in carbon. [15] reported an increase in soil carbon content after application of vermicompost. In another study, application of biochar to soils led to an increase in soil organic carbon, among other nutrients [17].

The addition of organic amendments to the soil enhanced sporulation. Moreover, the addition of commercial strains of mycorrhiza did not result in an increase in sporulation. The amendments may have enhanced development of both indigenous and introduced mycorrhizal fungi while the commercial strains introduced in some of the blocks may have taken time to adjust to the environment. These results agree with [16] who found that a block treated with biochar alone recorded the highest abundance of spores, compared to blocks treated with a combination of biochar and mycorrhiza, and attributed this to the slow adjustment of the introduced mycorrhizal species to the environment. The results of this study also agree with [21], who found that substrates treated with vermicompost produced the highest number of mycorrhizal spores compared with substrates treated with coir dust and Topstrato™. They attributed this to the high levels of phosphorous in the substrate provided by vermicompost, which played an important role in production of AM fungi propagules.

In terms of diversity, the genus Glomus recorded the highest spore count while Gigaspora recorded the lowest. It should be noted that the commercial mycorrhiza added to some of the plots contained Glomus spp. This, coupled with the presence of Glomus species in the soil before addition of the amendments, could explain the high spore count recorded. These results are consistent with a study carried out by [22] on the occurrence of AM fungi after organic fertilization, who found that Glomus species had the highest presence, presumably because species in this genus generally predominate in a pH of 6.0 to 8.0. The soil pH during this experiment ranged from 7.0 to 7.41. In addition, Glomus has the capacity to adapt to different organic matter contents in the soil. Furthermore, genera such as Glomus and Acaulospora produce small spores and are able to survive by adapting their sporulation patterns under unfavourable conditions like aridity [22]. The results of this study also agree with [21], who found that members of the Gigasporaceae family generally produce few spores and are incapable of colonising from hyphal fragments.

In this study, the population of Acaulospora spp exceeded that of the initial population of Scutellospora spp. It seems that some species respond better to organic fertilisation than other species. These results concur with [23], who reported a high frequency of occurrence of Acaulospora species and a low frequency of occurrence of Gigaspora and Scutellospora in areas with organic fertilisation.

Contrary to the results of this study, [14] found that spore densities in the soil were not affected by addition of...
phosphorous. [22], reported negative responses of AM fungi due to the incorporation of organic residues to high nutrient content of these materials, presence of phytotoxic substances, specific composition of the residue and pressure of pathogens.

All the blocks treated with soil amendments resulted in significantly (P=0.0000) higher root colonisation than the control block. The B and BM blocks came fourth and fifth respectively, while the BVM block had the second lowest root colonisation rates. This indicates that the soil amendments enhanced the activities of the already-present mycorrhiza species in the soil without requiring the addition of commercial mycorrhiza. The results from this study show that the net effect of biochar on root colonisation was negative. These results agree with [20] who reported that application of biochar at different rates resulted in neutral to decreased AM fungi abundance, which was measured by percent root colonisation and/or extraradical hyphae production. The study suggested that biochar’s capacity to adsorb signaling compounds and act as a sink could decrease ability of mycorrhizal fungi to colonise plant roots. Permanent removal of signal molecules from soils could result in a net decrease in the number of signal molecules reaching mycorrhizal hyphae and spores, leading to a decrease in hyphal growth and spore germination and ultimately, fungal abundance. In addition, Biochar could also adsorb compounds toxic to mycorrhizal fungi [20]. However, contrary to the results in this study, positive effects on AM fungi root colonisation as a result of application of biochar to soil have been reported. [24] Found that AM fungi colonisation increased significantly in the biochar treatment for wheat grown in well-watered and periodic water stressed environments.

The results of this study show that the net effect of vermicompost on colonisation of soybean roots by mycorrhiza was positive. This result is consistent with previous findings by [22], who suggested that transport and absorption in mycelia of AM Fungi were favoured by humic substances like fulvic acids that result from the decomposition of organic fertilisers. The results of this study differ with [25] who found that mycorrhizal colonisation and arbuscule formation significantly decreased with the increase of green compost in soil. [21] Suggested that some substances present in organic composts could have a phytotoxic effect and/or inhibit the development of AM fungi.

The highest soybean harvest was recorded in the biochar and vermicompost treatment plots respectively. This indicated that in addition to enhancing colonisation of soybean roots by mycorrhiza, soil amendments also enhanced plant growth and yield. These results agree with a study where application of biochar increased yield of maize over the control plot by 2.2 tonnes per hectare [17],[26] also reported that biological yield was greater when vermicompost was applied along with azotobacter and arbuscular fungi, while according to [25], the best dry weight yield occurred at compost rates of 75% and AM fungi application. Contrary to the results in this study, [27] suggested that while vermicompost stimulated fungal development, as much as 20% of the total carbon assimilated by the sorghum plants may have been taken up by the mycorrhizal fungi. They concluded that the effect of vermicompost on mycorrhizal colonization was harmful, rather than beneficial, to plant growth. Contrary to the results in this study, [20] reported that plant biomass production was not significantly affected by addition of biochar. The mycorrhiza block recorded the lowest harvest of soybean seeds compared to the blocks treated with biochar and/or vermicompost. This could mean that these amendments enhanced the activities of the beneficial microorganisms in the soil, including indigenous mycorrhiza, by improving the soil properties, and creating a conducive environment for their development, thus leading to higher yields. In their study, [25] found that the best dry weight yield occurred at compost rates of 75% and AM fungi application.

5. Conclusion

The study has established the presence of indigenous populations of arbuscular mycorrhizal fungi in the Sulmac area of Naivasha. The study also showed that application of amendments to soil enhances colonisation of soybean roots by arbuscular mycorrhizal fungi. Plots that were treated with biochar and vermicompost showed greater colonisation than plots treated only with mycorrhiza. This showed that the amendments enhanced the activities of AM fungi that are indigenous to the soil without the need to apply additional commercial strains. The highest yield of soybean was in the plots treated with biochar and vermicompost respectively, again showing that these amendments both encouraged plant growth through improvement of soil characteristics and enhancement of the action of indigenous mycorrhiza.

It is evident that organic amendments and biochar have a positive impact on soil microbial organisms. They can improve the soil environment to aid the action of indigenous organisms, and also have a positive impact on general plant health through provision of additional nutrients and improving the soil structure, which in turn leads to increased plant growth and yield, without the negative effects on the environment brought about by inorganic fertilisers.

Recommendation

Further studies should be carried out to establish the effect of these soil amendments on individual species of arbuscular mycorrhizal fungi.

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