Innovations in Agriculture 2023, 6:01-08
www.innovationsagriculture.com

ISSN: 2617-1295
DOI: https://doi.org/ 10.25081/ia.2023-018

Research Article

Residual effects of lablab green manure on root rot pathogens and performance of common bean (*Phaseolus vulgaris* L.)

Oliver Otieno Okumu[1,2*], James Wanjohi Muthomi[1], John Ojiem[2], John Huria Nderitu[1]

[1]*Department of Plant Science and Crop Protection, University of Nairobi, Kenya*

[2]*Hamelmallo Agricultural College, Eritrea*

[3]*Kenya Agricultural and Livestock Organization (KALRO), Kibos, Kisumu, Kenya*

*Corresponding Author, Email: oliverotieno182@gmail.com

ARTICLE INFO

Received: August 21, 2023
Revised: October 01, 2023
Accepted: October 03, 2023
Published: October 04, 2023

Keywords:

Common beans; *Lablab purpureus*; organic manure *Phaseolus vulgaris;* root rot pathogens

ABSTRACT

Organic manures often have considerable residual effect on the subsequent crops in the soil. Residual effects of lablab green manure on root rot pathogens and bean crop establishment was evaluated by conducting field experiments at two sites with varying soil fertility in Nandi South. Common bean varieties KK8 and GLP2 seeds were planted on plots previously treated with different soil amendments. Soil samples were collected before planting and six weeks after emergence to determine the populations of root rot pathogens. Throughout the experiment, data was collected on crop emergence, plant stand, root rot incidence and severity, as well as crop yield. There was increase in crop emergence by 40% for GLP2 and 19% for KK8 with corresponding 7% reduction in root rot incidence in plots previously treated with lablab green manure. There were variations in the population of root rot pathogens between the two studies, with Kapkerer exhibiting a higher pathogen population compared to Koibem. The primary root rot pathogens isolated and identified were *F. solani, F. oxysporum* and *Pythium ultimum, F. solani* and F. *oxysporum* were the most dominant species isolated in over 90% plant and soil samples. Residual plots treated with lablab green manure recorded a substantial in yield with an impressive increase of 22% when compared to other treatments. Correlation analysis established that disease incidence, and severity was negatively correlated with yield while plant stand was positively correlated with yield. Our research highlights the long-term benefits of lablab green manure as an organic soil amendment, showcasing its ability to improve crop emergence, reduce root rot incidence, and boost overall crop yield. This knowledge can guide farmers in optimizing their agricultural practices for increased productivity and sustainable soil health.

INTRODUCTION

Beans (*Phaseolus vulgaris* L.) are only second to maize as the most important source of calories, dietary protein, micronutrients, and vitamins in Sub-Saharan Africa, with majority of the African population depending on it as a primary staple food [1,2]. Production is, however, constrained by many biotic and abiotic factors interacting during the growing cycle [3]. Significant losses, especially when plants are under stressful environmental conditions have been reported on susceptible bean cultivars [4]. Diseases and low soil fertility are the main factors limiting bean production in the tropics [5], root rot pathogens cause poor germination, reduces stand establishment, and results in poor plant vigor. While the fine roots may be completely destroyed by the pathogens and result in fewer nodules, the taproots may only become discolored but remain intact [6]. Uneven plant stands due to poor germination and seedling blight results in poor crop yields. Yield losses vary substantially among different bean varieties due to the interactions between the host and root rot pathogens activity under various environment and soil conditions [7]. The increase in root rots incidence, severity and prevalence in common beans is due to changes in farming systems and the resulting decline in soil fertility. Root rots are caused by many root rot pathogens such as *Fusarium solani, F. oxysporum Rhizoctonia solani, Macrophomina phaseolina* and *Sclerotium rolfsii* Sacc among others [3, 4]. The disease has been reported to cause total crop failures [8, 9] with yield loss estimates of up to 100% in susceptible bean varieties under favorable environmental [3].

In modern agricultural production, practices such as green manuring offer effective technologies for achieving sustainable and efficient crop production. Continuous and conventional cultivation practices have been observed to cause a decline in soil organic matter (OM) content, significantly impacting the soil's nutrient retention capacity and ultimately leading to a loss of soil sustainability [10]. Organic manures improve soil fertility thereby increasing nutrient supply in the soil through biological nitrogen fixation and improved soil structure. Organic manure also reduces populations of soilborne pathogens and at the same time induces soil suppressive by stimulating activities of antagonists in soil thus reducing the quantity of viable root rot pathogen inoculum [10]. The addition of organic manures to the soil improves soil health and soil fertility by inducing biological changes in the soil microbial environment, promote nutrient cycling, bring crop nutrients up from lower soil profiles, and reduce the external nutrient inputs [11, 12]. Soil microbial changes following manure application improve soil biological properties while application of inorganic fertilizers in poor soils only improve crop production [13]. Therefore, applications of manures have superior effect on soil organic matter and related soil properties because they supply additional nutrients [14]. Fertilizers influences microbial organisms; thus, the amount of nitrogen may negatively correlate to soil microbial components [15]. The impacts of green manure on crop diseases are not clear due to the different impacts these materials have in the soil biological community [16]. Soil borne pathogens can be suppressed by some organic amendments or enhanced by others depending on the chemical components of the organic manure and soil health conditions [17]. Organic manure often supplies nutrients to the current crops, increasing organic matter thereby improving crop productivity, these materials often have residual effect on the

subsequent crops in the soil [18]. According to Thorup-Kristensen et al. [18] the residual impact of green manures can offer the most efficient means of enhancing nitrogen supply for subsequent crops. This effect refers to the carry-over benefit of the manure incorporation on the subsequent crop [19]. The nutrients applied in organic form are not fully available to the crops in the first season of application and therefore remains to be utilized by the succeeding crop in the following season. In the recent assessment of the direct effect of lablab green manure and other soil amendments on common bean yields, it was found that there was improvement in soil nutrient status [9]. The objective of this study was to investigate the residual effects of lablab green manure on the suppression of root rot pathogens and its impact on the performance and health of common bean (*Phaseolus vulgaris* L.) plants.

MATERIALS AND METHODS

Study site description

The study was conducted in Nandi County, Kenya located in the North of Rift valley at latitude 0o34'N to Longitude 34o45'E, at an altitude of 1850-2040m above sea level [20]. The area experiences the long rain season between March and August and the short rain season between September and December. The average annual precipitation ranges from 1200mm to 2000 mm with a mean yearly temperature ranging from 18-25oC and well drained clay loamy soils [21].

Experimental design and layout

A randomized complete block design, with three replicates in split-split-plot arrangement was used. All treatment applications were done in the short rainy season of 2016. In each plot measuring 4m by 6m 10 kg of chopped lablab was applied over the whole plots and in rows. Diamonium phosphate (DAP) fertilizer was applied at the rate of 75Kg per ha in band method by creating furrows and placing fertilizer in continuous band on the furrows while lime was broadcasted at the rate of 4t/ha by uniformly distributing it all over the plot [22]. No amendment was applied in the control plots. Bean varieties KK8 and GLP2 were planted in the plots at a spacing of 50cm×10cm by placing two seeds per hill immediately after treatment applications at a seed rate of 50kg/ha. Soil amendments treatments comprised the subplots while the bean varieties GLP2 and KK8 formed the main plots. Data was collected on crop emergence, incidence, and severity of root rot, plant stand, and yield. Soil samples were collected from 0- 20cm depth in each plot for isolation of soil microorganisms and for determining soil nutrient status. Weeding was done twice, at seedling stage and at early pod formation. Harvesting was done at physiological maturity.

Analysis of soil chemical characteristics

Soil samples were collected immediately before planting and at sixth week after emergence to evaluate the changes in soil's chemical characteristics [23]. Soil samples collected was air dried and then broken by pounding with pestle and mortar [22]. The samples were then subjected to chemical analyses to measure pH, available nitrogen, organic carbon, and available phosphorus and potassium. Soil pH, organic carbon was determined by volumetric method according to Walkley and Black method as described Okalebo et al. [24]. Available nitrogen was determined by Kjeldahl method, phosphorus was determined by Brays method and potassium was determined by Flame photometer [25].

Assessment of emergence and stand of common beans in the field

Emergence was determined one week after emergence by counting the number of plants that have emerged while plant stand was determined by counting the plants that survived in each plot six weeks after emergence [9].

Assessment of incidence and severity of root rot of beans in the field

Incidence of root rot on bean seedlings was determined by counting the number of bean seedlings showing root rot symptoms such as yellowing of leaves, wilting, stunted growth, brown discoloration on the roots and death per plot [26]. Root rot severity was determined four weeks after emergence by taking bean samples from either side of the split plot and was based on a scale of 0-5 where; 0-no root discoloration, 1- 1~25% root discoloration, 2- 26~50% root discoloration, 3- 51~75% root discoloration, 4-up to 76% root discoloration, 5- completely dead plants [4].

Isolation of root rot pathogens from bean stems

Roots showing root rot symptoms were washed in running tap water, surface sterilized in 2% sodium hypochlorite for 2 minutes, then rinsed in three changes of sterile distilled water. Cut portions from infected bean roots were plated on potato dextrose agar (PDA) amended with antibiotics. The cultures were incubated at room temperature for 7 to 10 days and the root rot fungi isolated were identified and the frequency of isolation was recorded. The incidence of root rot pathogens was expressed as the total number of isolations from root sections [4]. Morphological and cultural characteristics were used to identify the fungi following general identification keys [27, 28].

Isolation of root rot pathogens from the soil

Soil samples were collected at planting and later six weeks after emergence. A gram of soil sample was dissolved in 10 ml sterile distilled water and shaken for 30 minutes. One milliliter of the soil suspension was transferred into 9 ml of sterile distilled water, thoroughly shaken and the ten-fold dilution repeated up to dilution of 10-3 [29, 30]. One milliliter of the third dilutions was plated on molten PDA medium that was cooled to 450C [30]. The plates were incubated for one week at room temperature after which the numbers of fungal colonies were counted. The different fungal colonies were identified based on colony color, growth type, colony reverse color and color of mycelia [31]. Population of each type of root rot fungi was determined by multiplying the number of colonies by the dilution factor. The different fungi isolated were sub cultured on PDA medium for identification. Fusarium isolates were sub-cultured on SNA (Spezieller Nahrstoffarmer Agar) [32, 33] and on PDA media. Cultures on SNA were incubated under UV light to facilitate conidial sporulation while those on PDA were incubated at the room temperature for 14 days.

Assessment of yield and yield attributes

Yield of beans was determined by sampling 10 bean plants randomly from two central rows in each plot at physiological maturity to measure grain yield (t/ha) [34]. Plant biomass was determined by sampling ten plants from each plot and dried at 50oC for seven days to determine dry weight and data was transformed to biomass per land area [35]. The total yield from each plot was weighed and converted into tons per hectare using the equation by Mwangi et al. [36].

$$\frac{\text{Yield = Field weight per plot (g)} \times 10000 m^2/\text{ha}}{\text{Harvest area } (m^2) \times 1000\ 000 \text{ g / tone}}$$

Statistical analysis

Data was statistically analyzed by Analysis of variance (ANOVA) using Genstat Inc. 15th edition. Means were separated by Tukey's test and significant differences were determined at P≤0.05. Correlation

analysis was performed between root rot severity, disease incidence, and common bean yield attributes.

RESULTS

Soil chemical properties

The analysis of soil samples obtained from the study site indicates notable findings related to soil characteristics (Table 1). Specifically, the analysis indicates strong acidity in the soil. When comparing, the total organic carbon (TOC) across the various treatments, plots treated with green manure had higher TOC than in other treatments and control. There were no significant differences in the levels of available nitrogen. However, there was significant difference in the levels of available phosphorus and potassium (P≤0.05). The available phosphorus was high in untreated plots (25ppm) followed by plots treated with lime and DAP while the levels of potassium was highest (0.47) in plots treated with lablab in rows but least in plots treated with lablab green manure.

Plant stand

The analysis of variance revealed a significant residual impact of various soil amendments on emergence of both bean varieties. Notably, there was significant (P≤0.05) difference between the two experiments, with residual experiment recording higher emergence than the actual experiment. The highest percentage emergence was recorded in plots that were previously treated with lablab green manure (Table 2) while plots that were treated with DAP and those that were not treated recorded the lowest percentage emergence. Variety KK8 had the highest germination percentage in both experiments compared to GLP2. The highest stand count six weeks after emergence was recorded in the plots that were wholly incorporated with green manure and in rows for variety KK8 while for variety GLP2 highest stand count was recorded in plots that were previously treated with DAP.

Root rot incidence, severity and area under disease progress curve

There were significant (P≤0.05) variations across the experimental treatments with regards to root rot severity between the two experiments and the two bean varieties (Table 3). Highest root rot severity was observed in GLP2 variety when compared with KK8 variety. However, in both sites, plots previously treated with lablab green manure had the highest root rot severity while those treated with DAP had the least incidence. For common bean variety KK8, there was no significant difference between the treatments, however, in Koibem plot treated with lablab green manure had the highest root rot severity while in Kapkerer, all the plots had root rot severity above 50% except for plots treated with DAP fertilizer. The calculation of area under disease progress curve (AUDPC) revealed that plots planted with GLP2 bean variety had the largest AUDPC with a mean of 817 while plots planted with KK8 had lower AUDPC (701). Furthermore, plots treated with lablab green manure in the actual experiment involving GLP2 and those treated with green manure in rows consistently exhibited the largest AUDPC.

Table 1. Effect of treatment applications on soil chemical characteristics.

Treatments	pH	Organic Carbon	Nitrogen	Phosphorus	Potassium
		%		ppm	me%
Control	4.53±0.19	2.20±0.22	0.20±2	25±5.7	0.43±0.03
Incorporated	4.54±0.19	1.83±0.22	0.20±2	10±5.7	0.38±0.03
Between rows	4.80±0.19	2.36±0.22	0.22±2	15±5.7	0.47±0.03
DAP	4.25±0.19	2.38±0.22	0.21±2	20±5.7	0.42±0.03
Lime	4.51±0.19	2.22±0.22	0.20±2	20±5.7	0.45±0.03
LSD	0.24	0.27	0.02	7.1	0.04

LSD - Least significant difference

Table 2. Percentage plant stand count of bean varieties under different soil amendments.

Treatment	Residual Experiment (2017)		Actual Experiment (2016)		
GLP2	Emergence	6 weeks after emergence	Emergence	6 weeks after emergence	% increase in emergence
Incorporated	91.0^{a}	62.0^{a}	60.1^{a}	47.7^{b}	47.6±3.6
Between rows	93.0^{a}	53.3^{b}	54.8^{c}	49.8^{b}	46.4±3.6
No amendment	79.0^{b}	59.0^{a}	62.2^{a}	56.5^{a}	28.5±3.6
DAP	81.0^{b}	62.5^{a}	58.4^{b}	52.8^{ab}	34.8±3.6
Lime	85.0^{b}	60.0^{a}	56.6^{b}	51.5^{ab}	39.4±3.6
Mean	85.8	59.4	58.4	51.6	39.3
LSD (P≤0.05)	7.5	4.7	3.6	4.1	9.9
KK8					
Incorporated	98.7^{a}	64.2^{b}	73.9^{a}	62.0^{a}	37.1±4.1
Between rows	95.8^{a}	78.8^{a}	73.2^{a}	53.3^{b}	44.3±4.1
No amendment	83.8^{b}	71.2^{a}	75.4^{a}	59.0^{a}	29.6±4.1
DAP	78.1^{b}	58.0^{b}	71.3^{b}	62.5^{a}	20.0±4.1
Lime	90.9^{a}	60.5^{b}	70.8^{b}	60.0^{a}	34.0±4.1
Mean	89.5	66.5	72.9	59.4	33.0
LSD (P≤0.05)	10.5	10.5	2.3	4.6	11.3

Values followed by the same letter within the same row are not significantly different between the treatments using Fishers Protected LSD test (P < 0.05).

Table 3. Percent root rot incidence, severity and AUDPC under different green manure incorporation methods.

Treatments	Residual Experiment (2016)			Actual Experiment (2015)		
GLP2	**Severity**	**Incidence**	**AUDPC**	**Severity**	**Incidence**	**AUDPC**
Incorporated	52.2[a]	24.3[a]	467.5[a]	78.3[a]	50.9[a]	1001.3[a]
Between rows	45.8[b]	23.3[a]	410.3[a]	68.7[b]	38.4[b]	751.0[b]
No amendment	47.3[ab]	24.8[a]	449.6[a]	71.0[b]	42.4[b]	809.6[b]
DAP	43.1[b]	21.9[a]	398.7[a]	64.7[b]	38.0[b]	706.7[b]
Lime	47.1[ab]	25.4[a]	471.7[a]	70.7[b]	43.6[ab]	818.0[b]
Mean	47.1	23.9	439.5	70.7	42.7	817.3
KK8						
Incorporated	33.6[c]	13.3[b]	245.4[b]	50.3[c]	34.0[b]	596.2[c]
Between rows	36.2[c]	12.5[b]	242.7[b]	54.3[c]	39.3[b]	820.4[b]
No amendment	34.0[c]	13.1[b]	243.1[b]	51.0[c]	36.6[b]	750.9[b]
DAP	31.1[c]	15.8[b]	303.6[b]	46.7[d]	36.8[b]	766.7[b]
Lime	33.6[c]	11.7[b]	210.1[b]	50.3[c]	27.8[c]	574.1[c]
Mean	50.5	13.3	248.9	33.7	34.9	701.6
LSD (P ≤ 0.05)	6.8	6.9	150.6	6.8	6.9	150.6
CV (%)	23.5	42.5	47.6	23.5	42.5	47.6

Values followed by the same letter within the same row are not significantly different between the treatments using Fishers Protected LSD test (P < 0.05). DAP- Diamonium phosphate.

Root rots pathogens infecting bean stems

Root rot symptoms were evident in all the plots treated with different soil amendments. The main root rot pathogens isolated from the bean stem bases were *Fusarium oxysporum, Fusarium solani* and *Pythium ultimum* (Table 4). Stem bases collected from Koibem had lower incidences of root rot infection compared to those collected from the Kapkerer site. However, Fusarium solani and *Fusarium oxysporum* were the most predominant root rot causing fungal species in both the sites isolated in over 90% of the samples. *Macrophomina phaseolina* and *Rhizoctonia* root rot pathogens were isolated in insignificant incidences from common bean stem bases in both sites compared to other root rot causing fungal pathogens. There were significant differences between the different treatments however, plots previously treated with lablab green manure recorded highest population of root rot pathogens.

Root rot fungal populations isolated from the soil

Fungi isolated included *Fusarium solani, Fusarium oxysporum* and *Pythium ultimum* (Table 5). *Fusarium* spp were the predominant fungi in samples from all the prefectures. They were isolated from nearly all the samples followed by *Pythium ultimum* which had 43% of the samples contaminated. Although all the fungi were isolated from the two sites, their distribution within communes and sectors was uneven. Root rot fungal populations were isolated in small quantities in plots treated with lablab green manure compared to those treated with DAP, Lime and control. However, there was no significant difference between the treatments in fungal populations according to Tukey's test (ANOVA) at (P ≤ 0.05). There was significant difference (P ≤ 0.05) in the incidence of *F. solani* and Pythium across the study sites. Six weeks after emergence, fungi isolated were *Fusarium solani, F. oxysporum* and *Pythium* (Table 6). There were significant differences (P ≤ 0.05) in the incidence of *F. oxysporum* between the treatments and across the sites. However, there were no significant differences among *F. solani* and *Pythium. Fusarium solani* population was highest (56%) compared to other pathogens followed by *F. oxysporum* (28%) and *Pythium* (15%). Soil samples from Kapkerer site had high incidence of root rot pathogens compared to soil samples collected from Koibem.

Yield of common bean

The effect of various treatments on yield attributes of common beans exhibited variations as indicated in Table 7. Specifically, the grain yield ranged from 1.9 to 3.4tha-1. In Koibem, the highest grain yield (3.4tha-1) was achieved in plots previously treated with lablab green manure and lowest in untreated plots (1.9tha-1). Conversely, in Kapkerer site, the highest grain yield recorded was 2.4 t/ha-1 in plots treated with green manure. Notably, highest biomass weight was observed in 2016 than in 2015. In particular, highest biomass weight of 345kg was observed in untreated plots, whereas the least biomass weight was realized in plots previously treated with lablab green manure (243kg) in Koibem. In the year 2015, there were no significant differences between the treatments (P ≤ 0.05).

Correlations among incidence, severity and common bean yield attributes

There was significant negative correlation between plant stand (P≤0.05, -0.5169), Pods per plant (p ≤ 0.05, -0.3665), biomass and total yield (p≤0.05, 0.4618). Total yield displayed significant positive correlation to plant stand (p≤0.05, 0.9233), plant biomass (p ≤ 0.05, 1.00) (Table 8.0), however, there was negative relationship between total yield and root rot incidence (p ≤ 0.05, - 0.4618 and severity (p ≤ 0.05, 0.1516).

DISCUSSION

We evaluated the effect of previously applied lablab green manure and other soil amendments on soil nutrient status, germination and crop establishment. The results herein obtained indicate a slim increase in soil nutrient status following previous application of lablab green manure compared to the other amendments. This may be because of the ability of organic manure to induce changes in chemical properties of soil [36], improvement in soil physical characteristic through improved aggregate stability and decrease in bulk density [37]. Furthermore, the results also showed that plots treated with lablab green manure had improved emergence and stand establishment compared to the previous season. Green manures have substantial carry over residual effect on the succeeding crops in the soil [19]. However, the results are less conclusive, regarding the residual effects of fresh lablab green manure on bean performance and yield since this was a short-term application. Long term application of organic residue improves aggregate stability and decreases bulk density thereby improving soil physical characteristic [37, 38], thus demonstrating the positive impact on the quality and productivity of soil. The residual effects of organic manure include binding heavy metals enhancing their absorption by plants [9] releasing of chelating agents involved in the transformations of insoluble micronutrients.

Table 4. Incidence of root rot pathogens isolated from common bean stem bases treated with different soil amendments.

Treatments/Koibem	*Fusarium oxysporum*	*Fusarium. solani*	*Macrophomina phaseolina*	*Pythium ultimum*	*Rhizoctonia solani*
Incorporated	54.4^{a}	47.5^{b}	8.3^{a}	26.5^{ab}	8.6^{c}
Between rows	48.3^{ab}	48.9^{b}	8.1^{a}	33.5^{a}	6.4^{c}
No amendment	48.6^{ab}	45.8^{b}	10.8^{a}	29.4^{ab}	18.9^{b}
DAP	43.9^{b}	42.8^{b}	13.3^{a}	25.8^{ab}	6.9^{c}
Lime	42.2^{b}	50.0^{b}	11.1^{a}	28.1^{ab}	10.6^{c}
Kapkerer					
Incorporated	59.4^{a}	60.0^{a}	14.7^{a}	21.5^{b}	12.5^{bc}
Between rows	50.0^{a}	57.5^{a}	13.9^{a}	25.7^{b}	31.9^{a}
Removed	58.3^{a}	57.5^{a}	11.4^{a}	28.6^{ab}	18.9^{b}
No amendment	54.4^{a}	61.9^{a}	13.9^{a}	37.6^{a}	7.8^{c}
Lime	54.2^{a}	58.9^{a}	14.7^{a}	28.7^{ab}	5.6^{c}
Mean	55.3	53.1	12.0	28.5	12.8
LSD (P ≤ 0.05)	10.8	9.9	8.1	10.7	7.4
CV (%)	45.2	40.2	145.2	80.8	124.1

Values followed by the same letter within the same row are not significantly different between the treatments using Fishers Protected LSD test (P < 0.05).

Table 5. Population (CFUs/g) of fungal pathogens isolated from soils sampled in Koibem and Kapkerer before planting.

Treatments	Root rot Pathogens (10^4)		
Koibem	***Fusarium oxysporum***	***Fusarium solani***	***Pythium ultimum***
Incorporated	1.2_{a}	3.0_{ab}	0.3_{c}
Between rows	1.4_{a}	1.9_{b}	1.1_{bc}
No amendments	1.8_{a}	2.6_{ab}	1.0_{bc}
DAP	1.6_{a}	2.8_{ab}	1.3_{bc}
Lime	2.5_{a}	2.9_{ab}	0.8_{c}
Mean	1.7	2.7	0.8
Kapkerer			
Incorporated	1.5_{a}	2.7_{ab}	1.6_{ab}
Between rows	2.4_{a}	4.0_{a}	2.5_{a}
No amendments	1.4_{a}	3.0_{ab}	2.4_{a}
DAP	1.8_{a}	3.2_{ab}	1.4_{bc}
Lime	1.9_{a}	3.6_{ab}	1.8_{ab}
Mean	1.8	3.3	1.9
LSD (P ≤ 0.05)	0.9	1.2	0.9

Values followed by the same letter within the same row are not significantly different between the treatments usingFishers Protected LSD test (P < 0.05). DAP- Diamonium phosphate

Table 6. Population (CFUs/g) of fungal pathogens isolated from soils sampled in Koibem and Kapkerer six weeks after emergence

Treatments	Root rot Pathogens (10^4)		
Koibem	*Fusarium oxysporum*	*Fusarium solani*	*Pythium ultimum*
Incorporated	1.3_{ab}	2.3_{a}	0.5_{a}
Between rows	1.8_{ab}	2.7_{a}	0.7_{a}
No amendments	0.8_{b}	2.8_{a}	0.8_{a}
DAP	1.4_{ab}	2.3_{a}	1.0_{a}
Lime	0.8_{b}	2.7_{a}	0.8_{a}
Mean	1.2	2.6	0.78
Kapkerer			
Incorporated	1.3_{ab}	3.2_{a}	0.7_{a}
Between rows	1.2_{ab}	3.4_{a}	0.2_{a}
No amendments	1.7_{ab}	3.1_{a}	1.2_{a}
DAP	2.6_{a}	3.1_{a}	1.4_{a}
Lime	1.3_{ab}	3.2_{a}	1.2_{a}
Mean	1.6	3.2	0. 9
LSD (P ≤ 0.05)	0.8	1.2	1.07

Values followed by the same letter within the same row are not significantly different between the treatments usingFishers Protected LSD test (P < 0.05). DAP- Diamonium phosphate

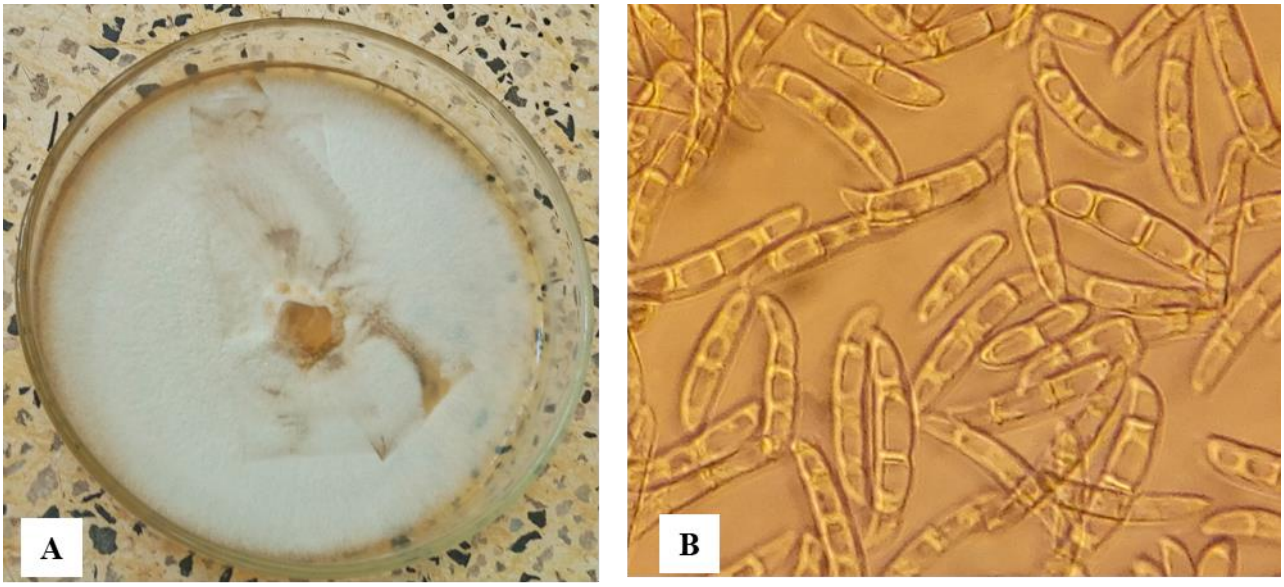

Fig. 1. A – Culture of *Fusarium solani* and B – macroconidia of *Fusarium solani*

Table 7. Bean seed yield and biomass (Kg ha-1) under different soil amendments methods in Nandi south

Treatment	Residual Experiment (2016)		Actual experiment (2015)	
	Biomass (Kg)	Yield (t/ha)	Biomass (Kg)	Yield (t/ha)
Incorporated	243.5c	3.4a	276.5a	2.4a
Between rows	257.2bc	3.2a	267.9a	2.0a
No amendment	345.4a	2.7a	265.7a	2.2a
DAP	343.6ab	3.4a	260.5a	1.9a
Lime	320.3ab	2.7a	298.0a	2.6a
Mean	302.0	2.9	273.7	2.2
LSD (P ≤ 0.05)	117.4	1.4	170.8	1.7
CV (%)	25.7	27.9	34.9	33.8

Values followed by the same letter within the same row are not significantly different between the treatments using Fishers Protected LSD test (P < 0.05). DAP- Diamonium phosphate

Table 8. Correlation coefficients among root rot disease incidence, severity, and yield parameters

	Incidence	Severity	stand	Pods	100 swt	biomass	Yield ha
Incidence	-						
Severity	0.2350	-					
Plant stand	-0.5169*	-0.1702	-				
pods plant	-0.3665*	-0.0622	0.0425	-			
100 SWT	0.0532	0.0239	-0.0725	-0.0539	-		
Final biomass	-0.4618	-0.1516	0.9233**	0.0003	0.2962	-	
Yield ha	-0.4618	-0.1516	0.9233**	0.0003	0.2962	1.00**	-

*significant ** highly significantly, swt – seed weight

Residues may also possess high amounts of macro and micronutrients which supplements the nutrients in the soil [39]. According to Tedla, [38] the considerable residual effect observed when organic manure is applied demonstrates the stability of manure derived from various organic matter with potential to improve soil quality and stability.

The major root rot pathogens isolated were *F. solani, F. oxysporum* and *Pythium ultimum*. High incidences were reported in 2016 when compared to 2017. Application of lablab green manure could have had an effect and enhanced the population of root rot pathogens [9]. Root rot pathogens cause high yield losses to bean plants under stressful environmental conditions such as low nutrient status. The differences in isolation frequency of root rot fungi reflect the influence of soil factors on colonization of bean roots by the pathogens identified in this study [40]. Variety, GLP2 had the highest infection rate compared to KK8 and this is due to the ability of KK8 variety to resist infection by root rot pathogens [41]. The severity of root rot disease is greater due to synergistic effect of various root rot pathogens [42]. In this study, *F. solani* was the predominant fungus isolated from majority of root samples, followed by *F. oxysporum*. The ability of *Fusarium* spp. to grow fast, sporulate abundantly and degrade cellulose explains why the pathogen was more dominant in comparison to other pathogens identified in the present study [43]. This agreed with previous findings by Mwang'ombe et al. [44] on major root rot pathogens of bean common across Kenya.

There was no significant difference between the treatments in terms of root rot populations isolated from the soil. Root rot pathogens survive for long time in colonized plant residues [45]. The effect of various amendments applied on soil microbial population lasted for relatively short period, however, microbes enhanced by application of organic manure contribute to biological changes of the soil [46]. Some soil organic amendments induce soil suppressive through enhancement of antagonists in soil leading to a decrease in viable root rot pathogen inoculum. It's been suggested that the soil type determines the type and activity of microbes in the soil [47]. Thus, these sites originally contained high population of root rot pathogens. Organic manure improves soil physical and chemical properties thus enhance microbial activity and subsequent release of organic chelating agents which increase stability of micronutrients [47]. Plots previously amended with lablab green manure recorded the highest yield compared with other treatments. Significant residual effect of lablab green manure on bean yield could be attributed to improvement in soil biological and fertility status thereby enhancing yields. This result is supported by Murwira and Kirchmann, [48] where there was increased yield even after discontinuation of manure use. Manure addition can have significant carry over effect for several seasons. All assessed yield attributes were influenced by the treatments, except for the number of pods per 100 seed weight which has high genetic control and may therefore not respond to changes in environmental variations [49]. Application of both organic and inorganic fertilizers showed effect on the increase of biomass and in general common bean yield but the treatment interaction effect was not evident though generally residual effect was found to improve production. Eghball et al. [50] reported positive residual effects of manure on yields of several crops in his studies with a minimum of 3 years of manure application; the results indicated a significant increase in soil nutrient status that was responsible for improved crop production.

CONCLUSION

In conclusion, overall responses of amendments previously applied were positive on soil nutrients and germination thus enhanced crop yield however, the responses to root rot pathogens was not positive, suggesting that judicious use of organic and inorganic fertilizers may maintain soil productive capacity and quality but should also incorporate management practice aimed at reducing the quantity of root rot inoculum in the soil.

CONFLICT OF INTEREST

Authors have declared that no competing interests exist

ACKNOWLEDGEMENTS

This research was funded by the McKnight Foundation under the project "Multipurpose legumes and management strategies for reinvigorating and maintaining the health and productivity of smallholder mixed farming systems".

AUTHOR'S CONTRIBUTIONS

OOO, designed the study and gathered the relevant information and wrote this document while JWM, JO and JHN reviewed and gave insightful comments. All authors read and approved the final manuscript.

REFERENCES

1. Akibode CS, Maredia MK. Global and regional trends in production, trade and consumption of food legume crops. 2012.
2. Rady MM, Semida WM, Hemida KA, Abdelhamid MT. The effect of compost on growth and yield of *Phaseolus vulgaris* plants grown under saline soil. Int J Recycl Org Waste Agric. 2016;5:311–21. http://dx.doi.org/10.1007/s40093-016-0141-7.
3. De Ron AM, Rodiño AP, Gioia T, Brezeanu C, Burzo I, van Rensburg BJ, et al. Common bean genetics, breeding, and genomics for adaptation to biotic stress conditions. In: Genomic Designing for Biotic Stress Resistant Pulse Crops. Cham: Springer International Publishing; 2022. p. 1–116.
4. Naseri B, Younesi H. Beneficial microbes in biocontrol of root rots in bean crops: A meta-analysis (1990-2020). Physiol Mol Plant Pathol. 2021.
5. Ngoya ZJ, Mkindi AG, Vanek SJ, Ndakidemi PA, Stevenson PC, Belmain SR. Understanding farmer knowledge and site factors in relation to soil-borne pests and pathogens to support agroecological intensification of smallholder bean production systems. Front Sustain Food Syst. 2023;7. http://dx.doi.org/10.3389/fsufs.2023.1094739.
6. Mourice SK, Tryphone GM. Evaluation of common bean (*Phaseolus vulgaris* L.) genotypes for adaptation to low phosphorus. ISRN Agron. 2012; 2012:1–9. http://dx.doi.org/10.5402/2012/309614.
7. Gossen BD, Conner RL, Chang K-F, Pasche JS, McLaren DL, Henriquez MA, et al. Identifying and managing root rot of pulses on the northern Great Plains. Plant Dis. 2016;100(10):1965–78. http://dx.doi.org/10.1094/PDIS-02-16-0184-FE.
8. Naseri B. Linkages of farmers' operations with *Rhizoctonia* root rot spread in bean crops on a regional basis. J Phytopathol. 2013;161(11–12):814–22. http://dx.doi.org/10.1111/jph.12140.
9. Otsyula RM, Buruchara RA, Mahuku G, Rubaihayo P. Inheritance and transfer of root rots (*Pythium*) resistance to bean genotypes. African Crop Science Socety. 2003; 6:295–8.
10. Kumar S, Sukul P. Blum LEB, Rodriguez-Kabana R. Effect of organic amendments on sclerotial germination, mycelial growth, and Sclerotium rolfsii-induced diseases. Fitopatol Brasil. 2004; 29:66–74.
11. Kumar S, Samiksha, Sukul P. Green manuring and its role in soil health management. In: Soil Biology. Cham: Springer International Publishing; 2020. p. 219–41.
12. Zaccardelli M, Perrone D, Pane C, Pucci N, Infantino A. Control of Corky root of tomato with compost and role of spore-forming bacteria to inhibit *Pyrenochaeta lycopersici.* Acta Hortic. 2011;(914):393–6. http://dx.doi.org/10.17660/actahortic.2011.914.74.
13. Pane C, Villecco D, Zaccardelli M. Short-time response of microbial communities to waste compost amendment of an intensive cultivated soil in southern Italy. Commun Soil Sci Plant Anal. 2013;44(15):2344–52. http://dx.doi.org/10.1080/00103624.2013.803566.
14. Ren F, Sun N, Xu M, Zhang X, Wu L, Xu M. Changes in soil microbial biomass with manure application in cropping systems: a meta-analysis. Soil Tillage Res. 2019.
15. Gunapala N, Scow KM. Dynamics of soil microbial biomass and activity in conventional and organic farming systems. Soil Biol Biochem. 1998;30(6):805–16. http://dx.doi.org/10.1016/s0038-0717(97)00162-4.
16. Gautam, Roshana, Chandeshwor Prasad Shriwastav, Sarita Lamichhane, and Bandhu Raj Baral. "The residual effect of pre-rice green manuring on a succeeding wheat crop (*Triticum aestivum* L.) in the rice-wheat cropping system in Banke, Nepal." Int J Agron. 2021 (2021): 1-10.

17. Yang, H., Niu, J., Tao, J., Gu, Y., Zhang, C., She, S., Yin, H. 2016. The impacts of different green manure on soil microbial communities and crop health. 10.20944/preprints201609. 0056.v1.
18. Hoque, Tahsina Sharmin, Farhana Akter, Md Rafiqul Islam. Residual effects of different green manures on the growth and yield of wheat. Asian J Med Biol Res. 2017;624-630.
19. Singh, Priyanshu, Anand Singh, Vijay Kant Singh, and Omkar Singh. "Green manuring for sustainable agriculture." In Encyclopedia of Green Materials, pp. 1-6. Singapore: Springer Nature, 2023.
20. Ansari, Meraj A, Burhan U. Choudhury, Jayanta Layek, Anup Das, Rattan Lal, and Vinay K. Mishra. Green manuring and crop residue management: Effect on soil organic carbon stock, aggregation, and system productivity in the foothills of Eastern Himalaya (India). Soil Tillage Res 218 (2022): 105318.
21. Batjes NH. A world dataset of derived soil properties by FAO–UNESCO soil unit for global modelling. Soil Use Manage. 1997;13(1):9-16.
22. Kiplagat JK, Okalebo JR, Serrem CK, Mbakaya DS, Jama B. Determination of appropriate rate and mode of lime application on acid soils of western Kenya: Targeting small scale farmers. In: Challenges and Opportunities for Agricultural Intensification of the Humid Highland Systems of Sub-Saharan Africa. Cham: Springer International Publishing; 2014. p. 177–86.
23. Pfenning LH, Abreu D. Saprophytic and plant pathogenic soil fungi. In: Husing J, Bignel DE, Fatima M, editors. A hand Book of Tropical Soil Biology. London; 2008.
24. Okalebo JR, Gathua KW, Woomer PL. Laboratory methods of plant and soil analysis.
25. Motsara MR, Roy RN. Guide to laboratory establishment for plant nutrient analysis. Rome: Food and Agriculture Organization of the United Nations. 2008; 19:45–64.
26. Medvecky B, Ketterings Q. Relationships among soil borne bean seedling diseases, *Lablab purpureus* L. and maize stover residue management, bean insect pests and soil characteristics in Trans Nzoia district, Kenya. App Soil Ecol. 2007; 35:107–19.
27. Okumu O, Muthomi J, Ojiem J, Narla R, Nderitu J. Effect of time after incorporation of lablab green manure on root rot pathogens and establishment of common bean. 2018.
28. Barnett HL, Hunter BB. Illustrated genera of imperfect fungi. The American Phytopathological Society. St Paul, MN; 1998.
29. Okumu OO, Muthomi JW, Ojiem J, Nderitu JH, Narla R. Effect of Lablab green manure on population of soil microorganisms and establishment of common bean (*Phaseolus vulgaris* L.). Am J Agric Sci. 2018;5(3):44–54.
30. Saravanan, S., Sivakumar, T., Thamizhmani, R., and Senthilkumaran, R. Studies on Microbial Diversity in Marine ecosystem of Parangipettai, Tamil Nadu. India. Int J Curr Microbiol App Sci. 2013; 2: 20-32.
31. Nurbaya K, Kuswinanti T. Growth rate and identification of Fusarium spp. associated with *Aquillaria* spp. from Nunukan regency, North Kalimantan. Int J Curr Res Acad Rev. 2014;2(11):7–17.
32. Nirenberg HI. A simplified method for identifying Fusarium spp. occurring on wheat. Can J Bot. 1981;59(9):1599–609. http://dx.doi.org/10.1139/b81-217.
33. Okumu OO, Muthomi JW, Mutegi CK, Wagacha JM. Resistance of Kenyan wheat germplasm to Fusarium head blight and deoxynivalenol contamination. Int J Agron Agric Res. (2):22–35.
34. El-Naim AM, Jabereldar AA, Ahmed SE, Ismaeil FM, Ibrahim EA. Determination of suitable variety and plants per stand of cowpea (*Vigna unguiculata* L. Walp) in the sandy soil, Sudan. Sudan Adv Life Sci. 2012; 2:1–5.
35. Talgre L, Lauringson E, Makke A, Lauk R. Biomass production and nutrient binding of catch crops. Žemdirbystė Agric J. 2012;98:251–8.
36. Mwangi SN, Deng AL, Kamau AW. Response of Kenyan varieties of common bean, *Phaseolus vulgaris* L., to infestation by *Aphis fabae* Scopoli. Afr Entomol. 2008;16(2):196–202. http://dx.doi.org/10.4001/1021-3589-16.2.196.
37. Adekiya AO, Ejue WS, Olayanju A, Dunsin O, Aboyeji CM, Aremu C, et al. Different organic manure sources and NPK fertilizer on soil chemical properties, growth, yield and quality of okra. Sci Rep. 2020;10(1):16083. http://dx.doi.org/10.1038/s41598-020-73291-x.
38. Diacono M, Montemurro F. Long-term effects of organic amendments on soil fertility. A review. Agron Sustain Dev. 2010;30(2):401–22. http://dx.doi.org/10.1051/agro/2009040.
39. Direct and residual effects of organic and inorganic fertilizers on soil chemical properties, microbial components and maize yields under long term crop rotation. 2001.
40. Mandisi MM, Ngaka SG, Oghenetsavbuko ET. Effects of different soil amendments on soil ph and heavy metals content in maize (*Zea mays* [L.]). Agric Forest Fisher. 2016; 5:141–50.
41. Miklas PN, Kelly JD, Beebe SE, Blair MW. Common bean breeding for resistance against biotic and abiotic stresses: from classical to MAS breeding. Euphytica. 2006; 147:105-31.
42. Okumu OO, Muthomi JW, Ojiem J, Narla R, Nderitu J. Effect of Time after Incorporation of Lablab Green Manure on Root Rot Pathogens and Establishment of Common Bean (Phaseolus *vulgaris* L). World J Agric Res. 2018; 6:113–21.
43. Schwartz HF, Pastor-Corrales MA. Bean production problems: disease, insect, soil and climatic constraints of *Phaseolus vulgaris*. Cali: Centro Internacional de Agric Tropical. 1989.
44. Pascual I, Avilés M, Aguirreolea J, Sánchez-Díaz M. Effect of sanitized and nonsanitized sewage sludge on soil microbial community and the physiology of pepper plants. Pant Soil. 2008; 310:41–53.
45. Mwang'ombe AW, Thiong'o G, Olubayo FM, Kiprop EK. Occurrence of root rot disease of common bean (*Phaseolus vulgaris* L.) In association with bean stem maggot (*Ophyiomia* spp). In: Embu District. Kenya; 2007. p. 141–6.
46. Mandic L, Djukic D, Beatovic I, Jovovic Z, Pesakovic M, Stevovic V. Effect of different fertilizers on the microbial activity and productivity of soil under potato cultivation. Afr J Biotech. 2011;10(36):6954–60.
47. Shuman LM, Llargrover WL. Effect of tillage on the distribution of manganese. Copper, iron and zinc in soil fractions. Soil Sci Soc America J. 1985; 49:1117–21.
48. Murwira HK, Kirchmann H. Nitrogen dynamics and maize growth in a Zimbabwean sandy soil under manure fertilization. Commun Soil Sci Plant Anal. 1993; 24:2343–59.
49. Dos Passos AMA, De-Rezende PM, Carvalho ER, Aker AM. Residual effects of the organic amendments poultry litter, farmyard manure and biochar on soybean crop. Agric Sci. 2014; 5:1376–83.
50. Eghball B, Ginting D, Gilley JE. Residual effects of manure and compost applications on corn production and soil properties. Agron J. 2004;96(2):442–7. http://dx.doi.org/10.2134/agronj2004.4420.