ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 13 No. 5
December 2013
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

IMPACT OF SOIL FERTILITY MANAGEMENT PRACTICES ON A MAJOR INSECT PEST INFESTATION AND YIELD OF BEANS (*PHASEOLUS VULGARIS* L.) IN TAITA DISTRICT, KENYA

Ochilo WN[1*], Nyamasyo GH[2] and JH Nderitu[3]

Willis Ochilo

*Corresponding author email: wnochilo@gmail.com

[1]CABI Africa, ICRAF Complex, United Nations Avenue, Gigiri
P.O Box 633-00621, Nairobi, Kenya

[2]University of Nairobi, School of Biological Sciences
P.O Box 30197-00100, Nairobi, Kenya

[3]Mount Kenya University, P.O Box 00515-1282, Nairobi, Kenya.

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 13 No. 5
December 2013
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

ABSTRACT

The common bean is an important food and cash crop in Eastern, Central and Southern Africa. It provides food for more than 100 million people and is a critical source of income for rural households. Common bean yields, however, have declined in the last ten years. This decline is the result of poor soil fertility and nutrient depletion as well as high incidences of insect pests, key among them being the bean stem maggot (BSM). To address soil nutrient depletion and the accompanying declining agricultural productivity, integrated soil fertility management (ISFM) has been adapted as a framework for enhancing crop productivity through combining fertilizer use with other soil fertility management technologies, adapted to local conditions. The current study evaluated the influence of soil fertility treatments on yield and yield components of the common bean. Additionally, to establish the potential links between soil fertility and crop protection, the effect of ISFM interventions on the incidence of the BSM was also assessed. The experiment was carried out in Taita District where agriculture contributes 95% to household income with very little or no fertility inputs in farms. Bean variety Mwezi moja was sown during the wet cropping season. Farm plots were amended with Mavuno fertilizer (a blend of fertilizer containing 11 nutrients); Triple Superphosphate fertilizer with Calcium Ammonium Nitrate (TSP + CAN); cow manure; *Trichoderma* inoculant; *Trichoderma* inoculant with cow manure combination; Mavuno fertilizer with *Trichoderma* inoculants combination; and control (untreated check). Field survey was conducted four weeks after bean emergence to determine the incidence and prevalence of the BSM. Plant survival: dry-seed and and bean straw weight were used as criteria for assessing crop yield. Yield and yield components of common bean were significantly affected by addition of soil ammendments, with Mavuno fertilizer + *Trichoderma* inoculant improving yield by 52.9%. However, the influence of the soil ammendments on the BSM incidence was minimal. These findings point to the fact that soil fertility management interventions increase crop yield. Nevertheless, to maximise yield, there is a strong need to adopt agroecological strategies that not only optimise soil fertilization but also incorporate a pest management dimension.

Key words: Bean, Soil fertility, Beanfly, Yield

INTRODUCTION

The common bean (*Phaseolus vulgaris* L) is an important food and cash crop in Africa, particularly in the eastern, southern, and Great lakes regions of the continent [1]. It is an important source of protein, iron, zinc, fibre, complex carbohydrates, and other dietary necessities that are consumed by families across the region [2, 3, 4]. Moreover, beans improve soil fertility [2, 4] as well as increase household food supplies and income. It is estimated that in Africa, it provides food for more than 100 million people and is a significant and a growing source of income for rural households, with annual African sales worth US$ 580 million being realised [2].

Over the past ten years, however, common bean yields in parts of Africa have declined significantly [5]. This decline is partly attributed to nutrient depletion and low soil fertility since crops in these regions are grown in marginal environments where soils are poor, with minimal external inputs being used to improve crop growth [5]. In addition, the crop is grown by small-scale farmers, whose land sizes often do not exceed 1 ha and rarely apply fertilizers. Consequently, they do not rotate crops or allow fallow periods [6]. As a result, there is a build up of pests and diseases. Bean stem maggot (BSM), also known as bean fly (*Ophiomyia* spp.) is the most important pest of beans in major bean-growing areas mainly Eastern and Southern Africa with yield losses ranging from 8 to 100% and 37 to 90% respectively being reported from these regions [6, 7]. The adult BSM oviposits in leaves, stems and hypocotyls of young seedlings. Emerging maggots mine their way to the root collar where feeding becomes concentrated between the woody stem and epidermal tissue. Such feeding interfere with nutrient transport and creates entry points for soil borne pathogens such as *Fusarium* spp., *Pythium* spp., etc that use lesions created by the pest to gain access into the plant [5, 6, 8, 9, 10].

To address soil nutrient depletion and the accompanying declining agricultural output, integrated soil fertility management (ISFM) has been adapted as a framework for boosting crop productivity [11, 12, 13]. ISFM refers to the application of soil fertility management practices, and the knowledge to adapt these to local conditions, which maximize fertilizer and organic resource use efficiency and crop productivity [12].

Besides the relation between soil fertility and crop productivity, most soil fertility management methods used by farmers can also be considered pest management strategies and vice versa [14]. Progressively, novel research is showing that the ability of a crop plant to resist or tolerate insect pests and diseases is positively correlated to optimal physical, chemical and mainly biological properties of soils [14]. Soils with high organic matter and active soil biology, for instance, generally exhibit good soil fertility in addition to complex food webs and biological control agents that prevent infection. On the other hand, agronomic practices that result in nutrient imbalances tend to lower pest resistance [15]. In spite of this potential link between soil fertility and crop protection, the advancement of ISFM and integrated pest management (IPM) have proceeded separately. The objective of the current study, therefore, was to evaluate the influence of soil fertility treatments on yield and yield components of the common bean. To establish the potential links between soil fertility and crop protection, the effect of ISFM interventions on the incidence of the BSM was also assessed.

MATERIALS AND METHODS

The study was carried out in Taita Taveta District during the wet cropping season, which occurs between March and May, of 2008 as part of the larger United Nations Environment Programme – Global Environment Facility (UNEP-GEF) funded project: Conservation and Sustainable Management of Belowground Biodiversity (CSM-BGBD) project. The study area is situated southeast of Kenya, 300 km east of Nairobi (latitude 03^0 20' S, longitude 38^0 15' E). The study site was located at the Taita Agricultural Training College (ATC) farm within Wundanyi Division, at altitude 580 m above sea level. The soils are mainly Humic Nitisols that are derived from volcanic rocks. They are deep, well drained, dark brown varying from sandy loam to clay.

The experiment was laid out in a Randomised Complete Block Design (RCBD) with treatments replicated five times. Within each of the five established blocks, seven 3m x 3m plots were set up and in each plot beans were planted as intercrops with maize (local practice) and allocated one soil treatment/ soil amendment except in one plot per block which acted as control. The soil treatment involved application of the following soil amendments: T1 = *Trichoderma* seed coating (seeds were coated with *Trichoderma* at a rate of 2 grams per one kilogram of seeds using gum Arabic as a sticker) – *Trichoderma* is a fungus used in suppressing soil borne plant diseases and promoting plant growth [12]; T2 = Cow manure applied at a rate of 10 tonnes per hectare; T3 = Farmer Practice (TSP + CAN) – Triple Superphosphate fertilizer (44-52% P^2O^5) - 50 kg P/ha combined with Calcium ammonium nitrate (27% N) - 100 kg N/ha; T4 = *Trichoderma* + cow manure; T5 = Control (no soil fertility management intervention was applied); T6 = Mavuno (a compound fertilizer containing 26% potash(K2O), 10% nitrogen , 10% calcium (CaO), 4% sulphur (SO_4), 4% magnesium (MgO) and micronutrient elements like zinc, copper, boron, molybdenum and manganese) - 50 kg P/ha; and T7 = Mavuno fertilizer + *Trichoderma*. The fertilizers were added by broadcasting during planting and top dressing of CAN and Mavuno done after first round of weeding. Maize variety (H516) was sown at a spacing of 90 x 30 cm with two seeds per hole. The bean variety was Mwezi Moja planted at a spacing of 75 x 25 cm and two seeds per hole.

Incidence of bean stem maggot on common beans

A Field survey to determine the incidence and prevalence of BSM was conducted four weeks after bean emergence. From each plot, all the beans were closely examined for symptoms of BSM damage, such as yellowing of leaves, stunted seedlings, mines or cracked stems to determine the number of infested plants [1, 16, 17]. Thirty percent of the infected bean plants were carefully dug up using a shovel. The uprooted bean plants were kept in paper bags and transported in a cooler box to the laboratory for

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 13 No. 5
December 2013
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

analysis. In the laboratory, the plant samples were examined for the presence of BSM. The plant samples were carefully dissected using a scapel blade from hypocotyls to the root to expose the pupae and larvae. The percent number of plants showing the pupae or the larvae of BSM was considered the percent incidence of the plot [16, 18].

Crop yield assessment

Percentages of seedling mortality, plant survival, and dry-seed and and bean straw weight were used as criteria for assessing crop yield. Stand counts were recorded 4 weeks after seeding and dead seedlings were counted in each plot. Seedlings killed by the BSM were rogued to avoid double counting [1]. At harvest, plant stand was recorded for each plot; the number of pods per plot were counted; and dry-seed yield and bean straw yield were also recorded for each plot. Seed weight was determined by weighing all the seeds from each plot.

Statistical analysis

Analysis of variance tests were done to establish the effect of soil amendments on the incidences of the BSM and on crop yield. Fisher's Least Significant Difference (LSD) at $p \leq 0.05$ was used to compare treatment group means.

RESULTS

Incidence of bean stem maggot on common beans

The percentage incidence of the BSM averaged 31.4 ± 3.0% (s.e), and ranged from 20.6 to 40.9%. However, there were no significant (F (6, 28) = 1.19, $p \leq 0.05$) differences among soil fertility management treatments in terms of percent number of plants showing the pupae or the larvae of BSM (Table 1).

Crop yield assessment

There were no significant ($p \leq 0.05$) differences among the treatments in terms of plant stand at emergence and at harvest as well as plant mortality (Table 1). However, soil amendments positively influenced yield parameters such as the number of bean pods per plot, dry-seed yield, and total bean dry matter (DM) (dry-seed and bean straw yields) (Table 2). The highest yielding treatments were Mavuno + *Trichoderma* (T7), Mavuno alone (T6) and Farmer Practice (T3). These three treatments showed differences that were significantly ($p \leq 0.05$) different from the untreated control (T5).
Total DM showed highly significant ($p \leq 0.05$) differences among the treatments. The highest yield of 1,133.33 kg/ha was obtained with Mavuno + *Trichoderma* treatment, as compared with 533.33 kg/ha for the control, a 52.9% difference in yield.

DISCUSSION

Bean stem maggot incidence

All the plots were infested with the BSM. This indicates the importance of BSM as a significant pest of beans in Taita District. The manifestation of the BSM symptoms could be attributed to the association between the BSM and the occurrence of root rot pathogens such as *Fusarium solani* fsp *phaseoli*, *Rhizoctonia solani* and *Pythium* species [6, 9, 16]. Studies have shown that BSM predispose plants to infection by root rot pathogens [19]. These pathogens in turn, indirectly affect beans by reducing their efficiency in using soil nutrients. In addition, they make roots susceptible to an increased range of stresses such as temperature variation, drought, and many biological stresses. Aboveground symptoms in a field with severe incidence of root diseases include poor seedling establishment, uneven growth, chlorosis, and premature defoliation of severely affected plants [20, 21].

Addition of soil ammendments did not influence the incidence of the BSM and its associated plant mortality. This observation is in agreement with previous findings which reported that enhanced soil fertility had no effect on the levels of BSM infestation [6]. When it comes to the influence of soil ammendments on plant mortality, the observed results are at variance with the same findings highlighted above which reported that enhanced soil fertility reduced plant mortality due to BSM. This implies that soil ammendments or soil fertility status do not protect plants against BSM infestation and their associated plant mortality. This outcome is in conformity with earlier findings advocating for Integrated Pest Management (IPM) as an alternative approach to exclusive focus on individual pest control strategies [22].

Crop yield

Blending of *Trichoderma* inoculum and Mavuno fertilizer performed better in comparison to the other treatments that included single application of either mavuno fertilizer or inoculum and untreated control. *Trichoderma* has been shown to directly influence plant growth by solubilizing plant nutrients and increasing plant nutrient uptake [23], and by promoting growth of primary root and root branching in beans [24[. The root system is critical for plant fitness where it provides anchorage, absorbs water and mineral nutrients, and synthesises various essential comounds such as growth regulators [24, 25]. In addition to influencing plant growth, *Trichoderma* has abilities to control plant pathogenic fungi [23, 24]. Among the mechanisms proposed for plant-pathogenic fungi control by *Trichoderma* include direct effects upon target fungi through antibiosis, mycoparasitism and competition [23]. Addition of fertilizer has the effect of providing substrate for the proliferation of *Trichoderma* spp thus enhancing its overall performance [24]. Also, application of fertilizer on responsive soils boosts crop yield and enhances the agronomic efficiency (AE) [26]. AE is the extra crop yield obtained per unit of nutrient applied [27].

Effect of manure on crop yield was low compared to mineral fertilizer probably due to its quality and the short time during which the trial ran [24]. Whilst organic inputs are an important source of nutrients, their nitrogen, phosphorous, magnesium and calcium content is only released following decomposition – unlike potassium which is released rapidly from manure since it is contained in the cell sap [28]. Additionally, the amount of nutrients contained in manure may not have been sufficient to sustain crop productivity [28].

CONCLUSION AND RECOMMENDATIONS

The study has showed that ISFM practices influence crop yield as expected. Three treatments improved yield by 50%. For this reason, and contrary to the popular myth that legumes should not be fertilized or supplied only in minimal amounts, the best soil management system for enhancing bean yield entails strategic application of mineral fertilizer to improved seed coated with *Trichoderma*. The ability of Mavuno + *Trichoderma* to produce the highest yield indicates that, whilst mineral fertilizer (Mavuno fertilizer) offers a key entry point for improving productivity of cropping systems, *Trichoderma* - a fungus used for the biological control of fungal root pathogens – is equally important, and combining both components of ISFM ensures maximum yield. On the other hand, the failure of Manure and *Trichoderma* separately, and a combination of the two (Manure + *Trichoderma*) to influence yield parameters suggests that organic inputs, soil biota and a combination of the two should not be used exclusively (without mineral fertilizer) in crop nutrient management.

The study has also revealed that ISFM interventions have little effect on the BSM incidence, and its associated plant mortality is minimal. This failure suggests that, although soil amendment is important within ISFM, it cannot be relied upon as a means of managing the BSM.

From these results, it is clear that improved soil fertility influences crop yield even for legumes such as beans. Nevertheless, to maximise yield through reducing incidences of the BSM and the consequent plant mortality, there is a strong need to adopt holistic management approaches that integrates soil fertility and pest management.

ACKNOWLEDGEMENTS

We acknowledge the project on Conservation and Sustainable Management of Belowground Biodiversity (CSM-BGBD), a UNEP/GEF project number GF/2715-02, for financial support. The University of Nairobi is acknowledged for providing laboratory equipment and space.

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 13 No. 5 December 2013 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Table 1: Effect of soil amendments on mean incidence (%) of the BSM and on bean plant performance

Treatment	Mean incidence of Bean stem maggot (%)	Plant stand at:		Plant Mortality (%)
		Emergence	Harvest	
T1	20.6a	31ab	26ab	12.25a
T2	22.4a	27ab	24ab	11.15a
T3	26.8a	28ab	26ab	9.34a
T4	30.7a	32a	27a	13.9a
T5	38.1a	30ab	25ab	16.76a
T6	40.3a	21b	18b	16.43a
T7	40.9a	31ab	28a	10.28a

*Means, within a column, followed by the same letter are not significantly different from each other at $p \leq 0.05$ (Fisher's Least Significant Difference Test)

T1 – *Trichoderma*; T2 – Manure; T3 – TSP + CAN; T4 – *Trichoderma* + Manure; T5 – Control; T6 – Mavuno; T7 – Mavuno + *Trichoderma*

Table 2: Effect of soil amendments on bean yield in Taita District

Treatment	Pod/plot	Seed yield in kg/ha	Bean straw yield in kg/ha[1]	Total bean dry matter (dry-seed and bean straw yields) in kg/ha
T1	156a	344.44a	211.11a	555.56a
T2	185abc	455.56abc	233.33a	688.89ab
T3	247bc	622.22bcd	377.78a	1000.00bc
T4	177abc	433.33ab	255.56a	688.89ab
T5	156a	300.00a	233.33a	533.33a
T6	177abc	588.89bcd	455.56a	1044.45c
T7	256cb	722.22d	411.11a	1133.33c

*Means, within a column, followed by the same letter are not significantly different from each other at $p \leq 0.05$ (Fisher's Least Significant Difference Test)

T1 – *Trichoderma*; T2 – Manure; T3 – TSP + CAN; T4 – *Trichoderma* + Manure; T5 – Control; T6 – Mavuno; T7 – Mavuno + *Trichoderma*

REFERENCES

1. **Abate T and JK Ampofo** Insect Pests of Beans in Africa: their Ecology and Management. *Annual Review Entomology ,* 1996; **41**: 45-73.

2. **Pyndji MM and P Trutmann** Managing Angular Leaf Spot on Common Beans in Africa by Supplementing Farmer Mixtures with Resistant Varieties. *Plant Diseases ,* 1992; **76** (**11**): 1144-1147.

3. **Blair, MW, Fregene SE, Beebe SE and H Ceballos** Marker-Assisted Selection in Common Beans and Cassava. In F. a. Nations, *Marker-Assisted Selection: Current Status and Furure Perspectives in Crops, Livestock, Forestry and Fish.* Rome, 2007.

4. **Singh SR** Fighting Insect Damage to Legumes. Retrieved July 25, 2009, from http://www.anancy.net/tpl/fulltext.tpl.php?file_id=1088&language=english&access=1

5. **Ochilo W and G Nyamasyo** Pest Status of Bean Stem Maggot (Ophiomyia spp.) and Black Bean Aphid (Aphis fabae) in Taita District, Kenya. *Tropical and Subtropical Agroecosystems ,* 2011; **13:** 91-97.

6. **Ampofo JK and SM Massomo** *Some Cultural Strategies for Management of Bean Stem Maggots (Diptera: Agromyzidae) on Beans in Tanzania.* Retrieved July 23, 2009, from http://www.bioline.org/

7. **Okoko EN, Kidula N, Mwangi G, Munyi D, Ngoze S, Ombese and H Siro** *Grow Beans for Food and Higher Income.* Retrieved JULY 23, 2009, from http://www.kari.org/fileadmin/Publications/Legume_Project/Legume_Leaflets/GrowBeans_020506/pdf

8. **Minja E** *IPM Learning and Practicing Guide - Farmer-to-Farmer Dissemination of Bean IPM Technologies: Approach, Processes and Tools.* Arusha: CIAT, 2006.

9. **Greathead DJ** Study in East Africa of the Bean Flies (Dipt., Agromyzidae) Affecting Phaseolus vulgaris and their Natural Enemies, with the Description of a New Species of Melanogromyza Hend. *Bulletin of Entomological Research* , 1966; 541-561.

10. **Abate T, van Huis A and J Ampofo** Pest Management Strategies in Traditional Agriculture: An African Perspective. *Annual Review Entomology,* 2000; **45**: 631-659.

11. **Odendo M, Obare G and B Salasya** Factors Responsible for Differences in Uptake of Integrated Soil Fertility Management Practices Amongst Smallholders in Western Kenya. *African Journal of Agricultural Research ,* 2009; **4** (**11**): 1303-1311.

12. **Sanginga N and PL Woomer** eds *Integrated Soil Fertility Management in Africa: Principles, Practices and Developmental Process.* Nairobi: Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture, 2009.

13. **Buresh R, Sanchez P and F Calhoun** eds. *Replenishing Soil Fertility in Africa.* Madison: Soil Science Society of America, 1997.

14. **Altieri M and C Nicholls** Soil Fertility Management and Insect Pests: Harmonising Soil and Plant Health in Agroecosystems. *Soil and Tillage Research ,*2003; **72**: 203-211.

15. **Magdoff F and H van E**s, *Building Soils for Better Crops* (2nd Edition ed.). Washington: SARE, 2000.

16. **Mwang'ombe A, Thiong'o G, Olubayo F and E Kiprop** Occurence of Root Rot Disease of Common Bean (Phaseoulus vulgaris L.) in Association with Bean Stem Maggot (Ophiomyia sp.) in Embu District, Kenya. *Plant Pathology Journal* , 2007; 141-146.

17. **Davies G** Pest Status and Ecology of Bean Stem maggot (*Ophiomyia* spp.: Diptera: Agromyzidae0 on the Niassa Plateau, Mozambique. *International Journal of Pest Management*, 1998; **44**:215-223.

18. **Nderitu J, Nyamasyo G and J Kasina** *Agricultural Entomology: Learning by Practice* (1st Edition ed.). Nairobi, 2008.

19. **Medvecky B, Ketterings Q and E Nelson** 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. *Applied Soil Ecology ,*2007; **35**: 107-119.

20. **Okoth S and E Siameto** Suppression of Fusarium spp. in a Maize and Beans Intercrop by Soil Fertility Management. *Yeast and Fungal Research ,*2010; **1**: 035-043.

21. **Schwartz H and M Pastor-Coralles** *Bean Production Problems in the Tropics.* Cali: CIAT, 1980.

22. **Ogecha J, Ampofo J and J Owuor** *Development of an Integrated Pest Management Strategy for Controlling Bean Stem Maggot in South Western Kenya.* Retrieved July 2009, 23, from http://www.kari.org/fileadmin/publications/Legume_Project/Legume2Conf_2000/45.pdf

23. **Harman G, Petzoldt R, Comis A and J Chen** Interactions Between Trichoderma harzianum Strain T22 and Maize Inbred Line Mo17 and Effects of These Interactions on Diseases Caused by Pythium ultimum and Colletotrichum graminicola. *Phytopathology,* 2004; **94**: 147-153.

24. **Okoth S, Otadoh J and J Ochanda** Improved Seedling Emergence and Growth of Maize and Beans by Trichoderma harzianum. *Tropical and Subtropical Agroecosystems,* 2011; **13**: 65-71.

25. **Kramer P and J Boyer** Roots and root systems. In: E. Science, ed. *Water Relations of Plants and Soils.* California: s.n., pp. 115-166.

26. **Vanlauwe B, Chianu J, Giller K, Merckx R, Mokwunye U, Pypers P, Shepherd K, Smaling E, Woomer P and N Sanginga** Integrated Soil Fertility Management: Operational Definition and Consequences for Implementation and Dissemination *19th World Congress of Soil Science, Soil Solutions for a changing world*. - Brisbane : [s.n.], 2010.

27. **Vanlauwe B and K Lopez** . *IITA R4D Review.* IITA, 2012.

28. **Fairhurst T** *Handbook for Integrated Soil Fertility Management*, Nairobi: Africa Soil Health Consortium, 2012.