African Journal of Rural Development, Vol. 6 (1) January-March 2021:pp.128-149. ISSN 2415-2838

Effects of seed dressing and fertilizer on the common bean yields, bean stem maggot and root rot diseases in Southern highlands of Tanzania

F. KATO,[1] J. LWEHABURA,[2] R.O. SEENGA,[3] D. KABUNGO,[3] M. KILANGO,[3] C. M. MUKANKUSI[1]. and J. C. RUBYOGO[2].

[1]Pathology and Biotechnology Unit, Alliance of Bioversity International and International Centre of Tropical Agriculture (CIAT), P.O. Box 6247 Kampala, Uganda

[2]Department of seed systems, Alliance of Bioversity International and International Centre of Tropical Agriculture (CIAT), P.O. Box 2704 Arusha, Tanzania

[3]National Bean Research Program, Tanzania Agricultural Research Institute – (TARI-Uyole), P.O. Box 400 Mbeya, Tanzania

Corresponding Author:j.c.rubyogo@cgiar.org

ABSTRACT

Common bean (*Phaseolus vulgaris* L.) is an important legume crop mainly for smallholder farmers in Tanzania, for home consumption and cash income. Nevertheless, the bean production in the Southern Highlands of Tanzania which contributes approximately 24.3% of the total bean country production is constrained by both abiotic and biotic factors. Among the most devastating biotic constraints includes the insect pests such as bean fly (*Ophiomyia phaseoli*), bean foliage beetle (*Ootheca bennigseni*) and aphids (*Aphis fabae*) and diseases such as bean root rots (BRR), while among the abiotic factors, the soil fertility was most prevalent. Two hundred- thirty (230) on-farm trials were established in seven bean growing districts to test the effects of seed dressing using an insecticide/fungicide Apron Star and an inorganic fertilizer-Yara Mila on crop performance (diseases, bean stem maggot (BSM) incidence and grain yield) of five popular improved bean varieties and one farmer's preferred variety as a check. BSM and BRR incidences and severities were evaluated at the flowering stage while the yield was done at harvest stage. It was also observed that the incidences of both BRR and BSM in the non-treated plots were significantly ($P < 0.05$) higher than the fertilizer applied alone, seed dressed alone, seed dressed and fertilizer applied plots. Similarly, plots treated with Apron Star and fertilizer combination exhibited the highest total yield of dry weight than the fertilizer alone, seed dresser alone and non-treated plot. All the improved bean varieties performed significantly ($P < 0.05$) higher than the farmers' varieties. Njano Uyole showed better performance in diseases, pest incidence and yield among the improved varieties with or without dressing and fertilizers.

Key words.Apron Star, Bean stem maggot, demonstration plots, incidence, severity

RÉSUMÉ

Le haricot commun (*Phaseolus vulgaris* L) est une légumineuse importante principalement pour les petits exploitants agricoles en Tanzanie, pour la consommation familiale et les revenus monétaires. Néanmoins, la production de haricots dans les hautes terres du sud de la Tanzanie, qui contribue à environ 24,3% de la production totale du pays de haricots, est limitée par des facteurs abiotiques et biotiques. Parmi les contraintes biotiques les plus dévastatrices figurent les insectes ravageurs tels que la mouche du haricot (*Ophiomyia phaseoli*), la chrysomèle du haricot (*Ootheca bennigseni*) et les pucerons (*Aphis fabae*)

Cite as: Kato, F., Lwehabura, J., Seenga, R. O., Kabungo, D., Kilango, M., Mukankusi, C. M. and Rubyogo, J. C. 2021. Effects of seed dressing and fertilizer on the common bean yields, Bean stem maggot and Root rot diseases in Southern highlands of Tanzania. *African Journal of Rural Development* 6 (1):128-149.

Received: 13 Janaury 2020
Accepted: 10 January 2021
Published: 31 March 2021

et les maladies telles que la pourriture des racines du haricot (BRR), tandis que parmi les facteurs abiotiques, la fertilité du sol était la plus répandue. Deux cent trente (230) essais à la ferme ont été mis en place dans sept districts de culture de haricots pour tester les effets de l'enrobage des semences à l'aide d'un insecticide/fongicide Apron Star et d'un engrais inorganique-Yara Mila sur les performances des cultures (maladies, incidence de BSM et rendement en grains) de cinq variétés de haricots améliorées populaires et la variété préférée d'un agriculteur en guise de contrôle. Les incidences et les sévérités de BSM et BRR ont été évaluées au stade de la floraison tandis que le rendement a été fait au stade de la récolte. Il a également été observé que les incidences de BRR et de BSM dans les parcelles non traitées étaient significativement (P < 0,05) plus élevées que l'engrais appliqué seul, les semences traitées seules, les semences traitées et les parcelles appliquées d'engrais. De même, les parcelles traitées avec l'Apron Star et la combinaison d'engrais ont présenté le rendement total le plus élevé en poids sec que l'engrais seul, la préparation de semences seule et la parcelle non traitée. Toutes les variétés de haricots améliorées ont obtenu des performances significativement (P < 0,05) supérieures à celles des variétés paysannes. Njano Uyole a montré de meilleures performances en matière de maladies, d'incidence de ravageurs et de rendement parmi les variétés améliorées avec ou sans traitement et engrais.

Mots-clés : Apron Star, Mouche du haricot, parcelles de démonstration, incidence, sévérité

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is an important legume crop mainly for smallholder farmers in Tanzania, for home consumption, cash income and agro-ecosystems stability (Letaa *et al.,* 2015). Tanzania is the leading bean producer in Africa and seventh in the world (FAO, 2016). The crop is widely grown in the country and, the Southern Highlands of Tanzania (SHT) contributes approximately 24.3% of the country bean production (Letaa *et al.,* 2015). However, the production has been constrained by both abiotic and biotic factors. The most devastating biotic constraints includes the insect pests and diseases such as the foliar and root rots, which affect the crops at both seedling and maturity stages hence compromising with crop yields. Insect pests among which includes the bean fly (*Ophiomyia phaseoli*), bean foliage beetle (*Ootheca bennigseni*) and aphids (*Aphis fabae*) are the most important and common in the farmer fields (Kimani, 2006, Mwanauta *et al.,* 2015). Mwanauta *et al*. (2015) indicated that the highest damage caused by the bean stem maggots is at the seedling stage of the bean plant. Bean root rots (*Fusarium* spp., *Rhizoctonia* spp., *Pythium* spp. and *Sclerotium rolfsii*) have also become a serious constraint in the bean growing areas in the SHT. They cause severe effects such as pre and post seedling damping-off. Incidence and severity of bean root rots are associated with high intensity of bean production and low soil fertility (Wortmann *et al.,* 1998). A study by Binagwa *et al*. (2016) showed that the *Pythium* root rots spp. are the most bean production constraints in the East African region including in the SHT, causing up to 70% yield loss.

In Tanzania, the average bean yield is estimated at 1,038 kg/ha (FAO, 2016). However the potential yield under reliable rain fed conditions is 1500-3000kg/ha, with improved varieties and proper crop and land husbandry (Hillocks *et al.,* 2006). Besides the abiotic and biotic factors, bean yields in Tanzania could remain horizontal for over years due to drought challenges (Hillocks *et al.,* 2006). The same author explained that the major contributions to lower yields by most smallholders are; poor seed quality, poor performance of the local landraces, mainly due to their susceptibility to pests and diseases, low soil fertility, drought and poor crop management, such as late weeding.

However, in Southern highlands of Tanzania, Birachi (2012) attributed the variability in bean yields to declining soil fertility and the increasing pests and disease pressures. In order to increase bean production in the regions and enhance grain yields, the need to alleviate the constraints limiting its production, disseminate and adopt the new technologies to the farmers' level is very important. Goettsch *et al*. (2016) mentioned that the increased management levels and planting bean cultivars tolerant to common bean biotic constraints resulted in improved bean grain yields. A report by Letaa *et al*. (2015) indicated that there is a high adoption rate of inorganic fertilizer in the SHT than other zones in Tanzania. However, this higher adoption rate is largely on higher value crops such as tobacco (*Nicotiana tabacum*), carrots (*Daucus carota*), onions (*Allium cepa*), and tomatoes (*Solanum lycopersicum*) (ESRF, 2014). In comparison, the average adoption rate of inorganic fertilizer in Tanzania was 9 kg/ ha; far below the average fertilizer use of 16 kg/ha in the Southern African Development Community (SADC) and three times less than neighboring Malawi which has an inorganic fertilizer usage rate of 27 kg/ha (Msambichaka *et al.,* 2009). Therefore, more efforts are needed to encourage small scale farmers to adopt the use of inorganic fertilizer for increased bean production. The support to smallholders might include the technical training on production technologies and practices. Adoption rates of technology such as the use of inorganic fertilizers; seed dressing with fungicides/ insecticide properties is relatively low in the bean growing districts of the Southern highlands of Tanzania. In cases where new, proven technologies are introduced which are appropriate for a given agro-ecological conditions, there is evidence of increased farmer adoption (Conley and Udry, 2010; Simtowe *et al.,* 2011).

Landraces of mixed seed types have been reported to be grown in the Southern Highlands (Hillocks *et al.,* 2006), although the yield potential of most of these land races is low, but the provide farmer with a reliable yield under low input. The bean improvement programme embarked on seeking the possibilities for increasing the poor bean yields among smallholders in the Southern Highlands and select high-yielding cultivars (Hillocks *et al.,* 2006). The adoption rate of improved common bean varieties in the SHT was 23.3% and 30.6% in 2012 and 2013, respectively (Letaa *et al.,* 2015). A study by Letaa *et al*. (2015) also showed that farmers who adopted the extensively diffused new improved bean varieties yielded highest with good agronomic strategies. Yet the adoption of improved bean varieties as an indicator of technology transfer would pave way in the increase of yield production among the farm levels with good agronomic practices. Proven inputs such as improved common bean varieties, inorganic fertilizers, and seed dressing chemicals could be effective at enhancing yield and closing the yield gap. Several management strategies to control the root rot diseases and insect pests have been tried and this includes seed treatment among others. A study by Nasirumbi *et al*. (2015) showed that the adoption of improved and resistant common bean varieties, sowing of one seed per hole and application of farm yard manure were the most commonly used in management of the bean root rot disease in the south western region of Uganda. Seed treatment by definition, is the application of the physical, chemical and biological agent to the seeds prior to sowing in order to suppress, control or repel pathogens, insects and other pests (Sharma *et al.,* 2015). This approach has been employed for centuries with great successes reported in the control of plant diseases and pests using the seed treatment fungicides (Sharma *et al.,* 2015). The same author explained that the approach has helped to improve crop yields by providing protection from pre and post-emergent insects and diseases and insurance of a uniform stand across a wide variety of soil types, cultural practices and environmental conditions. With time, various chemical seed treatments fungicides have been developed in response to the type of the plant disease and insect pests. These ranged from the Arsenic, Organo mercury to the new modern fungicide and insecticides, with the Apron Star being among the latter.

Currently seed dressing has been found as a feasible control strategy for plant disease and insect pests. In spite of controlling plant diseases, technique is less toxic to plant and animal life, environmentally friendly and applied at significantly reduced rates. The technique offers protection to the seed prior to sowing. A study by Kivisi (2015) reported that seed treatment approach was ecofriendly with significant reduction of bean roots in the Nandi county, Kenya. Bean yields have been compromised mostly during the tender growth stages of the crop due to pathogens and insect pests, however seed dressing approach has provided added advantages over other integrated crop management (ICM) practices which ranges from crop protection during seedling growth to maximizing crop gains (Sharma *et al.,* 2015). However, for the technology to succeed, there is a need to sensitize small scale farmers about the technology in the SHT regions. Studies have been conducted to test the seed dresser technology in vitro and green house conditions in Kenya and South Africa (Kandolo, 2008; Kivisi, 2015). Evaluation of efficacies of the different products to insect pests and soil borne pathogens is very crucial. A study by Kivisi (2015) showed that seed dressing options significantly differed in their efficacy in reducing incidences of bean root rot infection. The same author reported that seed treatments with Monceren® 125 DS and Click 20sl significantly improved seed emergence, plant stand, and root nodulation, with reduced incidence of root rot, bean fly and aphid infestation in Nandi county, Kenya. The technique has been produced excellent results in small grain cereals (Sharma *et al.,* 2015).

In this study, we used Apron Star which is a fungicide (Metalaxyl–M and Difenoconazole), insecticidal component (Thiamethoxam) incorporated and root growth enhancer. The chemical is produced and commercialized by the Syngenta Company. It was applied as a seed dresser before planting (Salako *et al.,* 2008; Ajeigbe *et al.,* 2009; Yakubu *et al.,* 2011; Syngenta Agro services, 2016) to provide protection to the seed against early seedling attackers at the ratio of 250 g per 100 kg of seeds (Syngenta Agro services, 2016). In Kenya, a commercial company (Elgon) in partnership with Syngenta have already introduced and tried the fungicide traded "Apron star" on common beans. In the northern Tanzania (PABRA, 2017), western Kenya and Uganda Kyomugisha unpublished data). However, preliminary results from these areas showed that the technology was a promising avenue to control bean root rot, BSM and bean root growth and ultimately improve bean production. despite the widespread prevalence and damage by the BSM and root rot in the SHT, the seed dressing technique has not been used extensively.

Soil fertility improvements has also been observed as possible solution to reduce root rot incidences and severities in bean production (Wortmann *et al.,* 1998), however the adoption of the Apron Star seed dressing technology with amendments rich in high Phosphorus and others ICM practices is considered the best approach for maximized bean production. A report by Birachi (2012) indicated that the use of inorganic fertilizers on beans was still scanty with less than 5% of farmers using it, however, the beans only gain when they are intercropped with maize which is usually fertilized.

Bean varietal outputs and releases have gained stability over time in almost all countries in the East and Central African bean research network (ECABREN) (Muthoni and Andrade, 2015). Over time, the genetic improvement strategy has widened its emphasis on the consumer preferences and grain types as a basis for the breeding activities (Muthoni and Andrade, 2015). However, an observation by the same author indicated that if there was increase in area adoption of improved bean varieties, this would suggest that investment in bean genetic improvement within the Great lakes countries could continue to reward handsome dividends. In Tanzania, bean improvement programme was targeted to identify areas of improving the poor bean yields among the small holder farmers in SHT and also select high yielding cultivars (Hillocks *et al.,* 2006). A report by FAO (2011) showed that Tanzania had the highest estimates of adoption of improved bean varieties per area under bean cultivation. Several accessions were introduced during the early years but preliminary screenings reduced the lines to a moderate number that were resistant with suitable agronomic and yield characteristics. Currently, the South African bean research network (SABREN) together with the national agricultural research services (NARS) partners in Tanzania embarked on a strategy to develop improved bean varieties that are resistant to biotic constraints with a major market classes (Hillocks *et al.,* 2006). In this study, the five selected improved bean varieties that were developed for their diverse adapation to the high altitudes agro-ecological conditions with high market acceptability and biotic constraint tolerances were evaluated.

It was hypothesized that Apron Star seed dressing approach supplemented with in organic fertilizers could reduce the incidences and severities of the insect pests and bean root rots in common bean production, and also maximize crop yields. In this study, the approach was sought by training farmers and at the same time allowing them to observe by establishing the mother-baby demonstration trials. Mother-baby trials consist of multisite mother trials experimental design that were replicated in several farms (a set per a farmer) with the primary goal of research and scientific evaluation of technologies and baby trials that consist of three or less selected technologies with the primary purpose of farmer evaluation and bidirectional learning. Therefore, the aim of the study was to evaluate the performance of Apron Star seed dressing with/ without inorganic fertilizers for significant reduction of insect pests and bean root rots incidences and severities with maximized yields, in the seven bean growing districts of the Southern highlands of Tanzania.

RESEARCH APPROACH

Study area and trial establishments. The study was conducted in seven districts of Iringa, Mufindi, Wanging'ombe, Songea, Njombe, Mbozi and Mbeya which constitute the Southern Highlands of Tanzania (SHT) (Fig. 1). In the districts of Iringa, Mufindi, Wanging'ombe, Songea and Njombe, the trial plots were established during the planting period of Nov-Dec, 2015, while for the districts of Mbeya and Mbozi, this was done in the planting period of Feb-Mar, 2017.

Selection and design of the mother demonstration plots. The trial model involved 230 Village Based Agricultural Advisors (VBAAs) with each VBAAs having a mother demo plot. Half of VBAAs (115) did not have baby demonstration plots while 115 VBAAs, each had 150 baby trials (farmer's demonstration plots) to supervise, thus the study had 17,250 baby demonstration plots in total. However, the focus for data collection was based on the mother demonstration plots only.

Mother demonstration plot treatments. Each mother demonstration plot had four treatments; fertilizer applied alone, seed dressed alone, fertilizer applied and seed dressed combination, and non-treated (non-seed dressed and non-fertilizer applied) sub plots. Each sub-plot had measuring dimensions of 5m by 2.5m, separated by 1m apart (Fig. 2).

Fig. 1. A map of Tanzania showing the bean growing areas of the Southern Highlands Region (Adopted from https://fahariyetu.net/region/ 5-04-2017).

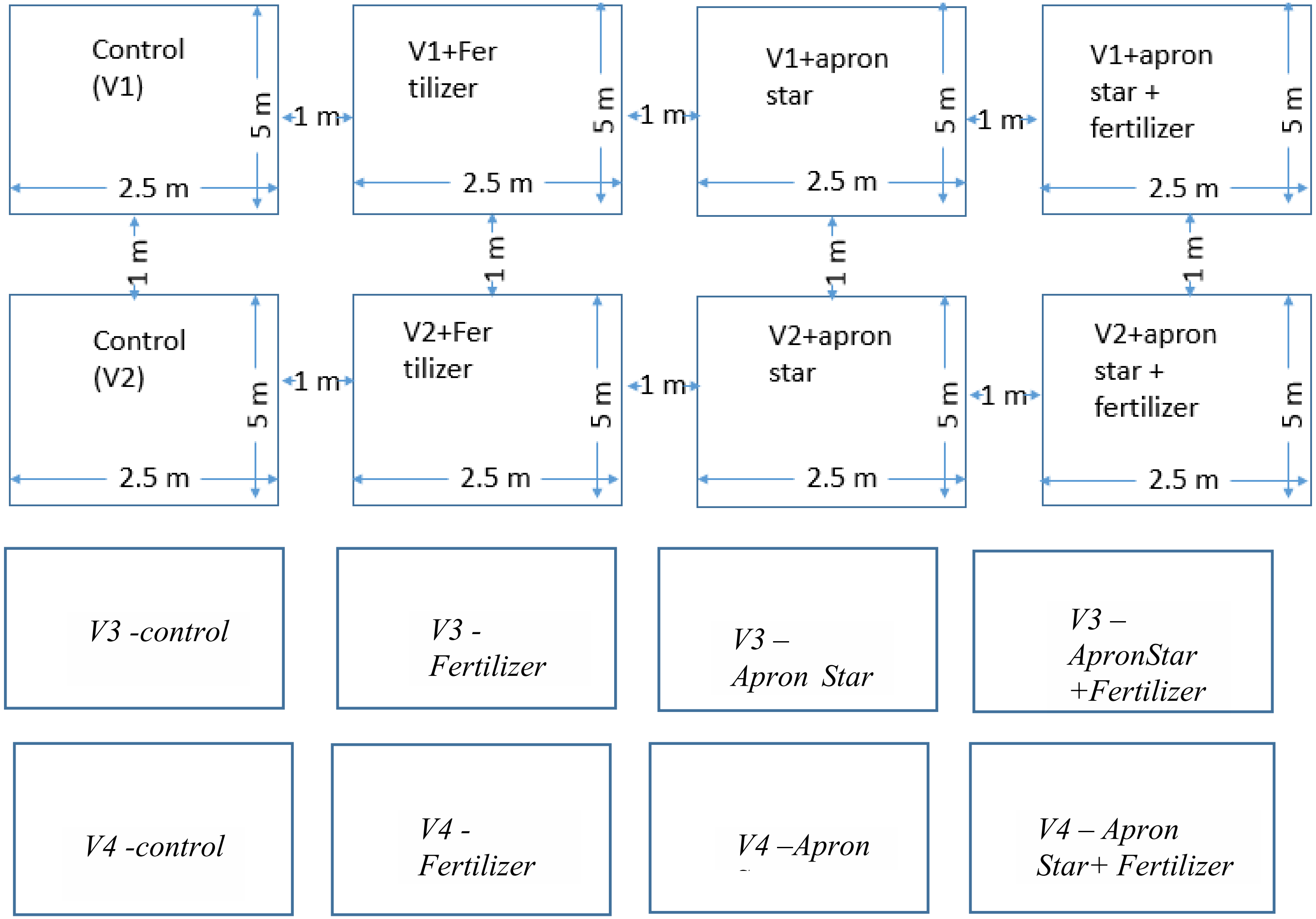

Fig. 2. Description of the mother demonstration plots layout; V1- improved common bean variety 1, V2- improved common bean variety, V3 = improved common bean variety, V4 = Farmer preferred variety.

Selection and distribution of the improved bean varieties. Five improved bean seed varieties recommended by National Bean Research Programme (NBRP) of the Tanzania Agricultural Research Institute (TARI)-Uyole center (Table 1) were selected and distributed to the respective districts based on recommendations provided by NBRP. At each demonstration plot, the VBAA was allowed to plant the local variety of their own choice with respect to the layout of the treatment. All the seven districts received two similar varieties (Njano Uyole and Uyole 96) while the third variety was distributed basing on the district's consumer preference and demand (Table 1).

Application and packaging of the seed treatment fungicide/insecticide. All the improved common bean varieties were seed dressed with Apron Star fungicide/insecticide by the investigators. Each variety was placed in a rolling drum and little water sprinkled over the seeds, followed by the fungicide/insecticide at a rate of (10 g / 4 kg seed). These were rolled thoroughly till the seeds were coated with the fungicide/insecticide. The coated seeds were then spread on a tarpaulin to allow them dry before packing them in the small plastic transparent sachets. Each plastic sachet contained about 100-200 seeds.

Distribution of inorganic fertilizer. The recommended fertilizer brand was YaraMilla Cereal ® fertilizer at a planting ratio of 247.1 kg/ha, with a chemical composition of Nitrogen: Phosphorus: Potassium at a ratio of 23-10-5, and was distributed and tested to all mother demonstration plots.

Bean stem maggot and root rot disease assessment. During the field evaluation exercise, the demonstration plots were checked for the dead, wilted, yellowing and stunted bean plants to record the root rot diseases and insect pest incidences at the above ground assessment. For both the bean stem maggot (BSM) and root rot diseases, each plot was tracked between the rows in "S–shaped" manner to identify the dead, wilted, yellowing and stunted plants. Whilst for the root rot diseases of interest and identified as *Fusarium* spp., *Pythium* spp., *Rhizoctonia* spp and *Sclerotium rolfsii*. In addition, plant damage severity assessment for the BSM and root rot diseases was also evaluated below ground. Five common bean plants were randomly uprooted from each plot to observe the symptoms of the BSM and the root rot pathogens. The plants with BSM symptoms were counted and recorded to obtain the Percentage incidence, while those with the root rot symptoms were scored with a scale of (1-5; one being the lowest damaged and

Table 1. List of the improved common bean varieties distributed at the respective districts in the Southern highlands of Tanzania

District	Improved common bean varieties		
Iringa Rural	Njano Uyole	Uyole96	Wanja
Mufindi	Njano Uyole	Uyole96	Wanja
Wanging'ombe	Njano Uyole	Uyole96	Calima Uyole
Songea	Njano Uyole	Uyole96	Calima Uyole
Njombe	Njano Uyole	Uyole96	Calima Uyole
Mbeya	Njano Uyole	Uyole96	Uyole03
Mbozi	Njano Uyole	Uyole96	Uyole03

five being the highest damaged) as described by Le *et al.* (2012) for *Rhizoctonia* spp. and *S. rolfsii;* and (1-9) for *Fusarium* spp. and *Pythium* spp. as described by CIAT (Abawi and Pastor Corrales, 1990) (Fig. 3). Also during this exercise, mother demonstration plot sizes were re-measured to ascertain the recommended field dimensions.

Crop yield assessment. Due to staggered bean planting period in Southern highlands of Tanzania, the harvesting work was scheduled based on planting time for each district. For Iringa, Mufindi, Wanging'ombe, Njombe, and Songea districts, harvesting work was done in May-June, 2017. While for the districts of Mbeya and Mbozi, it was conducted in late June 2017.

The fresh weight of the bean pods at harvest was collected from the two middle rows, placed in a bag and weighed per plot or treatment then recorded. The fresh weight of the shelled beans was obtained after threshing the bean pods from the two middle rows, then bean seeds were weighed and recorded. A standard bean sample fresh weight of 200g was obtained from each plot or treatment, weighed and recorded. A dry weight of bean sample was obtained after taking the standard sample weights of 200g at the institute then dried thoroughly (till final constant weight), weighed and recorded.

Data analysis. The data for the variables with in the different districts was then subjected to general analysis of variance (ANOVA). While the data for the all variables across the districts was subjected to the accumulated ANOVA with the unbalanced design using the GenStat regression tool (GenStat 12th Edition, software for bioscience, 2009). All the farmer's preferred varieties were pooled as FarmVar prior to analysis as one variety. The relationships between the variables were obtained using the regression and correlation analysis with the test of significance obtained using the Wald test for dropping terms (GenStat 12th Edition, software for bioscience, 2009). Treatment means were separated using the Duncan's multiple range test.

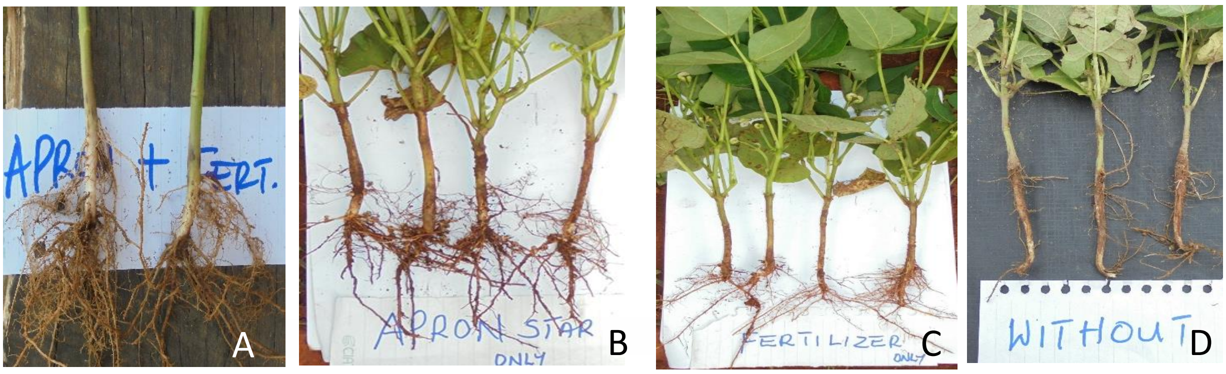

Fig. 3. Shows the extensive root growth for the Apron treated bean plants (A and B), and less root growth and disease infestation (C and D).

RESULTS

Percentage incidences of BSM with in districts

Iringa and Mufindi (zone 1). The percentage incidence of BSM was significantly different between the districts of Mufindi and Iringa (F = 26.03, d.f = 1, P < .001) and treatments (F = 36.63, d.f = 3, P < .001). The district of Mufindi (85.0%) registered the highest incidence of BSM than Iringa (68.0%). While among the treatments, the non-treated plots (90.2%) exhibited the highest incidences of

BSM compared to the fertilizer alone (76.5%), Apron Star and fertilizer combination (60.2%) and Apron Star alone (57.3%) (Fig. 3)

Wanging'ombe, Njombe and Songea (zone 2). The percentage incidences of the BSM was also significantly different among the districts of Wanging'ombe and Songea (F = 42.95, d.f = 2, P < .001) and treatments (F = 14.78, d.f = 3, P < .001). The district of Songea registered the lowest incidences of BSM (38.2%) compared to Wanging'ombe (76.0%) and Njombe (74.2%). While among the treatments, the non-treated plots (76.0 %) exhibited the highest incidences of BSM compared to the fertilizer alone (70.0%), Apron Star and fertilizer combination (51.0%) and Apron Star alone (45.0 %).

Mbeya and Mbozi (zone 3). However, there was no significant difference observed in the Percentage incidences of BSM in the districts of Mbeya and Mbozi (F = 2.83, d.f = 1, P = 0.093), but significant difference among the treatments (F = 42.95, d.f = 3, P < .001) was observed. Among the treatments, the non-treated plots (22.0 %) registered the highest incidences of BSM compared to the fertilizer alone (21.0%), Apron Star and fertilizer combination (5.6 %) and Apron Star alone (4.2%) (Fig.3).

Percentage incidences of BSM across districts. The Percentage incidences of the BSM was significantly different among the districts (F = 100.41, d.f = 6, P < .001), treatments (F = 44.69, d.f = 3, P < .001) and common bean varieties (F = 39.77, d.f = 5, P < .001). Apron Star and fertilizer combination (38.1%) and Apron Star alone (35.0%) registered the lowest Percentage incidences of BSM compared to the non-treated plots (62.0 %) and fertilizer alone (55.3%) (Table 2). A significant relationship was also observed among the districts, common bean varieties and treatments (F = 19.44, d.f = 3, P < .001) (Table 5).

Table 2. Percentage incidence of BSM across seven districts of the Southern Highland of Tanzania

District[1]	Percentage incidence of BSM			
	Non treated plot	Apron Star alone	Apron Star and Fertilizer	Fertilizer alone
Iringa	86.4 ± 4.5	52.5 ± 4.5	56.3 ± 4.5	71.7 ± 4.5
Mufindi	96.4 ± 8.4	80.4 ± 8.4	66.3 ± 8.4	90.0 ± 8.4
Njombe	86.9 ± 6.5	53.5 ± 6.5	72.7 ± 6.5	85.5 ± 6.5
Wanging'ombe	99.5 ± 5.6	55.5 ± 5.6	63.5 ± 5.6	85.0 ± 5.6
Songea	50.3 ± 5.2	26.0 ± 5.2	27.5 ± 5.2	50.8 ± 5.2
Mbeya	29.4 ± 4.9	6.8 ± 4.9	5.4 ± 4.9	24.7 ± 4.9
Mbozi	15.7 ± 5.0	4.1 ± 5.0	7.7 ± 5.0	16.5 ± 5.0
CV%			60.1	

Percentage analyzed using the accumulated analysis of variance at significant level, P < 0.05. CV- coefficient of variation, BSM-bean stem maggot

Percentage disease severity indices of bean root rots within districts

***Fusarium* spp**. The Percentage DSI as a result of *Fusarium* spp. was significantly different between the districts of Mufindi and Iringa (F = 11.69, d.f = 1, P < .001) (Table 3) and treatments (F = 29.47, d.f = 3, P < .001). However, a significant interaction was also observed between the common bean varieties and districts (F = 5.07, d.f = 3, P = 0.002). Among the treatments, the non-treated plots (35.2%) exhibited the highest Percentage DSI compared to the fertilizer alone (30.0%), Apron Star and fertilizer combination (19.5%) and Apron Star alone (20.0%).

Similarly, the Percentage DSI was also significantly different among the districts of Wanging'ombe, Njombe and Songea (F = 3.72, d.f = 2, P = 0.025) and treatments (F = 9.1, d.f = 3, P < .001). The district of Njombe registered a lower Percentage DSI (19.0%) compared to the Wanging'ombe (25.0%) and Songea (25.0%) respectively. While among the treatments, the non-treated plots (28.0 %) and fertilizer alone (28.1%) exhibited the highest Percentage DSI compared to the Apron Star and fertilizer combination (18.0%) and Apron Star alone (19.3 %).

The Percentage DSI was significantly different between the districts of Mbeya and Mbozi (F = 22.46, d.f = 1, P < .001) and among the treatments (F = 3.39, d.f = 3, P = 0.019). The district of Mbeya exhibited the highest Percentage DSI (17.3%) compared to the district of Mbozi (12.4%). While among the treatments, the non-treated plots (16.4 %) and fertilizer alone (16.6%) registered the highest Percentage DSI compared to the Apron Star alone (14.0%) and Apron Star and Fertilizer combination (12.9 %).

***Rhizoctonia* spp.** The Percentage DSI as a result of *Rhizoctonia* spp. was significantly different among the treatments in the districts of Mufindi and Iringa (F = 4.97, d.f = 3, P = 0.002). While it was also significantly different among the districts of Njombe, Wanging'ombe and Songea (F = 34.98, d.f = 2, P < .001).

Pythium spp.* and *Sclerotium rolfsii. There were no incidences of *Pythium* spp. and *Sclerotium rolfsii* in the districts of Iringa and Mufindi. For the districts of Njombe, Wanging'ombe and Songea, there were incidences with no significant observations. In the district of Mbeya and Mbozi, no incidence of *Pythium* spp. was observed, However, with the Percentage DSI as a result of *S. rolfsii,* there was a significant interaction observed between the bean varieties and districts (F = 3.19, d.f = 3, P = 0.024).

Percentage disease severity indices of bean root rots across districts

***Fusarium* spp.** The Percentage DSI as a result of Fusarium spp. was significantly different among the districts (F = 20.32, d.f = 6, P < .001), treatments (F = 33.32, d.f = 3, P < .001) and common bean varieties (F = 9.14, d.f = 5, P < .001) (Table 3). However, a significant interaction was also observed between the treatments and districts (F = 2.11, d.f =18, P = 0.005). While among the treatments, the non-treated plots (26.2%) exhibited the highest Percentage DSI compared to the fertilizer alone (24.0%), Apron Star and fertilizer combination (17.0%) and Apron Star alone (18.0%). A significant relationship was observed among the districts, common bean varieties and treatments (F = 19.57, d.f = 3, P < .001) (Table 5).

***Rhizoctonia* spp.** The Percentage DSI as a result of *Rhizoctonia* spp. was significantly different among the districts (F = 23.03, d.f = 6, P < .001) and treatments (F = 5.08, d.f = 3, P = 0.002) (Table 3). A significant relationship was also observed among the districts, common bean varieties and treatments (F = 5.14, d.f = 3, P = 0.002) (Table 5).

Table 3. Percentage disease severity indices for the *Fusarium* and *Rhizoctonia* root rots across seven districts of the Southern Highland of Tanzania

District [2]	*DSI-Fusarium* spp.				*DSI-Rhizoctonia* spp			
	Non treated plot	Apron Star alone	Apron Star and Fertilizer	Fertilizer alone	Non treated plot	Apron Star alone	Apron Star and Fertilizer	Fertilizer alone
Iringa	34.4 ± 1.9	18.8 ± 1.9	18.4 ± 1.9	29.1 ± 1.9	22.1 ± 0.8	21.3 ± 0.8	21.5 ± 0.8	22.8 ± 0.8
Njombe	20.0 ± 2.8	17.1 ± 2.8	16.8 ± 2.8	21.1 ± 2.8	20.8 ± 0.8	20.3 ± 0.8	21.01 ± 0.8	21.7 ± 0.8
Mbeya	19.8 ± 2.2	15.6 ± 2.2	14.2 ± 2.2	20.7 ± 2.2	23.3 ± 0.9	21.9 ± 0.9	21.4 ± 0.9	21.9 ± 0.9
Mbozi	11.9 ± 2.2	11.9 ± 2.2	12.3 ± 2.2	14.3 ± 2.2	22.3 ± 0.9	19.9 ± 0.9	20.8 ± 0.9	22.4 ± 0.9
Mufindi	42.8 ± 3.7	24.6 ± 3.7	24.6 ± 3.7	33.6 ± 3.7	22.5 ± 1.6	20.3 ± 1.6	21.2 ± 1.6	24.1 ± 1.6
Wanging'ombe	28.7 ± 2.4	20.5 ± 2.4	20.4 ± 2.4	27.8 ± 2.4	30.1 ± 1.1	24.9 ± 1.1	27.1 ± 1.1	28.8 ± 1.1
Songea	31.8 ± 2.3	19.4 ± 2.3	15.8 ± 2.3	31.1 ± 2.3	20.2 ± 1.0	20.1 ± 1.0	20.2 ± 1.0	20.3 ± 1.0
CV%	58.1		24.4					
S.E	12.4				5.4			

Percentage analyzed using the accumulated analysis of variance at significant level, $P < 0.05$. DSI– disease severity index; S.E- standard error of means; CV-coefficent of variation

Pythium* spp. and *Sclerotium rolfsii. There was no significant difference in Percentage DSI among the districts nor treatments (Table 4)., however a significant relationship was observed among the districts, common bean varieties and treatments ($F = 2.62$, d.f = 3, $P = 0.05$). For the *S. rolfsii*, the Percentage DSI was significantly different among the districts ($F = 2.11$, d.f = 6, $P = 0.05$).

Total yields of dry grain weight with in the districts

Iringa and Mufindi (zone 1). Between the districts of Mufindi and Iringa, the total yields of dry grain weight was significantly different among the common bean varieties ($F = 2.8$, d.f = 3, $P = 0.041$) and treatments ($F = 3.55$, d.f = 3, $P = 0.015$). Among the treatments, the Apron Star and fertilizer combination (1841 kg/ha) exhibited the highest yield of dry grain weight than the fertilizer alone (1660 kg/ha), Apron Star alone (1543 kg/ha) and non-treated plots (1316kg/ha). Common bean varieties Nyano Uyole (1796 kg/ha) registered the highest yield of dry grain weight than Uyole96 (1664 kg/ha), Wanja (1565 kg/ha) and Farmer preferred (1334 kg/ha) (Table 6). A significant relationship was observed among the variables ($F = 16.86$, d.f = 4, $P < .001$) (Table 8).

Wanging'ombe, Njombe and Songea (zone 2). Among the districts of Wanging'ombe, Njombe and Songea, the total yields of dry grain weight were significantly different among the common bean varieties ($F = 17.21$, d.f = 3 $P < .001$) and treatments (F =

11.43, d.f = 3, P < .001). Among the treatments, Apron Star and fertilizer combination (1990 kg/ha) exhibited the highest yield of dry grain weight than the fertilizer alone (1690 kg/ha), Apron Star alone (1554 kg/ha) and non-treated plots (1229 kg/ha). While among the common beans, Calima (1934 kg/ha) and NjanoUyole (1806 kg/ha) recorded the highest yields of dry grain weight than Uyole96 (1663 kg/ha) and farmer preferred variety (1058 kg/ha) (Table 6). A significant relationship was observed among the variables (F = 5.18, d.f = 4, P < .001) (Table 8).

Mbozi and Mbeya (zone 3). Between the districts of Mbozi and Mbeya, the total yields of dry grain weight were significantly different among the common bean varieties (F = 5.79, d.f = 3, P < .001) and treatments (F = 7.52, d.f = 3, P < .001). Among the treatments, the Apron Star and fertilizer combination (1503 kg/ha) exhibited the highest yield of dry grain weight than the fertilizer alone (1359 kg/ha), Apron Star alone (1170 kg/ha) and non-treated plots (1009 kg/ha). Common bean varieties Uyole96 (1458.8 kg/ha) registered the highest yield of dry grain weight than Njano Uyole (1282 kg/ha), Uyole03 (1301 kg/ha) and Farmer preferred variety (989.9 kg/ha). (Table 6).

Table 4. Percentage disease severity indices for the *Pythium* and *Sclerotium* root rots across seven districts of the Southern Highland of Tanzania

District [3]	*DSI- Pythium* spp.				*DSI- S. rolfsii*			
	Non treated plot	Apron Star alone	Apron Star and Fertilizer	Fertilizer alone	Non treated plot	Apron Star alone	Apron Star and Fertilizer	Fertilizer alone
Iringa	11.1 ± 0.1	11.1 ± 0.1	11.1 ± 0.1	11.2 ± 0.1	19.9 ± 0.1	19.9 ± 0.12	19.9 ± 0.1	19.9 ± 0.1
Njombe	11.1 ± 0.1	11.1 ± 0.1	11.1 ± 0.1	11.1 ± 0.1	19.9 ± 0.2	19.9 ± 0.2	20.0 ± 0.2	20.0 ± 0.2
Mbeya	11.1 ± 0.1	11.1 ± 0.1	11.1 ± 0.1	11.2 ± 0.1	20.3 ± 0.1	20.5 ± 0.1	19.9 ± 0.1	19.9 ± 0.1
Mbozi	11.1 ± 0.1	11.1 ± 0.1	11.1 ± 0.1	11.2 ± 0.1	20.5 ± 0.1	20.3 ± 0.1	19.9 ± 0.1	19.9 ± 0.1
Mufindi	11.1 ± 0.1	11.1 ± 0.1	11.1 ± 0.1	11.2 ± 0.1	19.9 ± 0.2	19.9 ± 0.2	19.9 ± 0.2	19.9 ± 0.2
Wanging'ombe	11.2 ± 0.1	11.2 ± 0.1	11.1 ± 0.1	11.1 ± 0.1	20.3 ± 0.2	19.9 ± 0.2	20.2 ± 0.2	20.5 ± 0.2
Songea	11.1 ± 0.1	11.1 ± 0.1	11.1 ± 0.1	11.4 ± 0.1	19.9 ± 0.2	20.1 ± 0.2	20.0 ± 0.2	20.0 ± 0.2
CV%	4.3	3.9						
S.E	0.5	0.8						

Percentage analyzed using the accumulated analysis of variance at significant level, P < 0.05. DSI– disease severity index; S.E- standard error of means; CV- coefficent of variation

Table 5. Relationships between the districts, bean varieties and the treatments on incidences of bean stem maggot and root rots

	District	Treatment	Bean varieties	BSM	DSI_P	DSI_S	DSI_R	DSI_F
District	-							
Treatment	1	-						
Bean varieties	0.001***	1	-					
BSM	0.0051***	0.001***	0.7017 NS	-				
DSI_P	0.0647 NS	0.1195 NS	0.076 NS	0.0762 NS	-			
DSI_S	0.2594 NS	0.7041 NS	0.11 NS	0.1855 NS	0.1641 NS			
DSI_R	0.0963 NS	0.001***	0.9144 NS	0.001***	0.8505 NS	0.8994 NS		
DSI_F	0.2714 NS	0.001***	0.3794 NS	0.001***	0.0141**	0.0664 NS	0.0214 **	

NS-not significant, ***-Highly significant at 0.001, **-significant at 0.05; DSI_P = disease severity index for *Pythium* spp.; DSI_S = Disease severity index for *S. rolfsii*; DSI_R = Disease severity index for *Rhizoctonia* spp.; DSI_F = Disease severity index for *Fusarium* spp. Correlations was a two-sided test different from zero

Total yields of dry grain weight across districts. The total yield of dry grain weight was significantly different among the common bean varieties (F = 12.66, d.f = 5, P = < 0.001) and treatments (F = 18.82, d.f = 3, P = < 0.001). Common bean variety Calima Uyole was observed to produce the highest total yield of dry grain weight (1856 kg/ha) than the five other common bean varieties. It was noted that all the improved common bean varieties expressed higher total yield of dry grain weights than the farmer preferred variety. Among the improved common bean varieties, Calima Uyole still exhibited the highest total yield of dry grain weight than the other four common bean varieties (Table 7).

Table 6. Total yield of dry weight (kg/ha) for the six common bean varieties with in the different regions in the southern highlands of Tanzania

Regions[4]	Treatments	Common bean varieties			
		Njano Uyole	Uyole 96	Wanja	Farmer preferred variety
Zone 1					
(Iringa and	Apron Star & Fertilizer	2031.0	1885.0	1930.0	1517.0
Mufindi)	Apron Star alone	1746.0	1688.0	1373.0	1365.0
	Fertilizer alone	1931.0	1541.0	1723.0	1446.0
	Non-treated	1477.0	1544.0	1236.0	1007.0
	CV%	58.7			
	S.E	934.0			
		Njano Uyole	Uyole 96	Calima Uyole	Farmer preferred variety
Zone 2					
(Njombe,	Apron Star & Fertilizer	2259.0	2012.0	2387.0	1301.0
Songea and	Apron Star alone	1770.0	1668.0	1996.0	782.0
Wanging'ombe)	Fertilizer alone	1779.0	1767.0	1986.0	1227.0
	Non-treated	1417.0	1207.0	1366.0	924.0
	CV%	51.7			
	S.E	835.3			
		Njano Uyole	Uyole 96	Uyole 03	Farmer preferred variety
Zone 3					
(Mbozi and	Apron Star & Fertilizer	1727.0	1587.7	1497.3	1183.3
Mbeya)	Apron Star alone	1169.6	1483.1	1208.5	877.6
	Fertilizer alone	1258.9	1587.6	1406.9	1169.6
	Non-treated	1048.7	1144.8	1094.0	728.4
	CV%	53.0			
	S.E	668.2			

[4] Data was analyzed at significant level, P < 0.05. S.E- standard error of means; CV-coefficent of variation

Table 7. Total yield of dry weight (kg/ha) obtained from the six common bean varieties across the four treatments in the seven districts of the Southern Highland of Tanzania

Treatment 5	Common bean variety					
	Calima Uyole	Njano Uyole	Uyole 03	Uyole 96	Wanja	Farmer preferred variety
Apron Star & Fertilizer	2309 ± 193.5	2014 ± 116.7	1702 ± 199.5	1833 ± 116.7	1803 ± 216.6	1323 ± 117.9
Apron Star alone	1918 ± 193.5	1538 ± 116.7	1413 ± 199.5	1612 ± 116.7	1247 ± 216.6	983.0 ± 117.9
Fertilizer alone	1908 ± 193.5	1651 ± 116.7	1611 ± 199.5	1640 ± 116.7	1597 ± 216.6	1269 ± 117.9
Non-treated plot	1288 ± 193.5	1312 ± 116.7	1298 ± 199.5	1286 ± 116.7	1109 ± 216.6	881.0 ± 117.9
CV%	57.6					
S.E	858.0					

[5] Data was analyzed at significant level, $P < 0.05$.

Table 8. Relationships between the districts, common bean varieties, treatments and field size on the total yield of dry weight

	District	Field size	Treatment	Common bean varieties
District	-			
Field size	<0.001***	-		
Treatment	<0.001***	<0.001***	-	
Common bean varieties	<0.001***	<0.001***	0.2157NS	-

***- Highly significant at 0.001; NS-not significant

DISCUSSION

In this study the percentage incidences of the BSM and bean root rot diseases differed significantly across the seven bean growing districts in the Southern highlands of Tanzania. This indicated that there was a high prevalence of BSM and bean root rots across the regions. The high prevalence of BSM and root rots was observed to be more in the on-farm plots that were established early in the districts of Iringa, Mufindi and Wanging'ombe depending on the locations. This finding agrees with the report by Ochilo and Nyamasyo (2011) who observed the high prevalence of BSM and black bean aphids in the on-farm plots than on-station plots in the Taita district of Kenya. Similarly, low incidences of bean stem maggot were also observed in fields where the bean were intercropped with maize in Tanzania (Peter *et al.,* 2009).

It was observed that the district of Mufindi exhibited the highest percentage of BSM incidences than the districts of Iringa, Wanging'ombe, Njombe and Songea. Infestation of BSM may be influenced by geographical location and climatic conditions and crop seed systems. High incidences of BSM are aggravated by warmer weather conditions and poor soil fertility, which was different from the other districts as Mufindi receives the highest rainfall pattern among the three districts. A report by Nderitu *et al*. (1997) also agrees with the findings that BSM infestation are aggravated by the presence of soil borne pathogens and declining soil fertility. However, on a contrary a report by Ochilo and Nyamasyo (2011) indicated that location did not have a significant effect on the BSM incidences, and these districts in the Southern Tanzania are at higher altitudes than the northern regions, so soil fertility is slightly lower than the low lands with high prevalence of pathogens due to favorable environmental conditions.

In this study, it was also observed that there was significant variation in the percentage incidences of the BSM and bean root rots infestation across the four treatments. The incidences of both constraints in the non-treated (neither seed dressed nor fertilized) were higher than the fertilizer applied, seed dressed and seed dressed and fertilizer applied plots. The high incidences of BSM and root rots in the non-treated plots was due to lack of the antagonistic chemical agent that is applied pre sowing to reduce the pest damage at the early seedling stages or the fertilizer that minimizes the pest population build up as they crop grows very fast before the damaging pest stages is reached. The low incidences of BSM and root rots in the seed dressed and fertilizer treatment are attributed to the seed dresser insecticide and fungicide that is applied to the seeds before sowing such that they provide protection to the seedling to the early seedling attackers such as the BSM and soil borne pathogens. Seed dresser insecticide and fungicide traded "Apron Star" was applied on the seed prior to sowing. It comprises of three active ingredients (difenoconazole, thiamethoxam, and mefenoxam) that targets both the BSM and root rot pathogens affecting the seedlings at an early stages of growth. Seed dressing has been considered as an efficient control strategy against insect pests and soil borne pathogens (Sharma *et al.,* 2015). Studies by Kandolo (2008) and Kivisi (2015) experimented the application of chemical fungicides as seed dressers to manage the bean insect pests, root rots and improvement of germination rate in maize crop under laboratory conditions. A study by Kivisi (2015) reported a reduction in the incidence of root rot, bean fly (*Ophiomyia* spp.) and aphid (*Aphis* spp.) infestation in beans in the Nandi county, Kenya. A study by Khalid and Aymen (2017) who evaluated the efficacy of Apron Star 42 WS as seed dresser against seedbed diseases and insect pests, reported a significant reduction of damping off of wheat (*Triticum aestivum* L.) seedlings and yield loss than the untreated control at Hudiaba Research Station Farm (River Nile State, Sudan).

Bean root rot pathogens such as *Fusarium* spp, *Rhizoctonia* spp., *Pythium* spp. and *Sclerotium rolfsii* were present but these varied during the field surveys across all the bean growing districts. This observation indicated that these pathogens are widely distributed with *Fusarium* spp. and *Rhizoctonia* spp. being the most predominant. This observation agrees with the study by Kivisi (2015) who reported the prevalence of root rot pathogens such as *Fusarium* spp., *Macrophomina* spp. and *Rhizoctonia* spp. in all agro ecological zones in the Nandi county, Kenya. However, there was variation among zones in respect to soil borne pathogens with *Fusarium* spp. being the most common root rot pathogen isolated in both soil and seeds. The effects of bean root rots are thought to be either mutualistic or synergistic mode of relationship. This hypothesis agrees with the report by Nzungize *et al*. (2011) which stated that the prevalence of bean root rots is caused by one or more soil-borne pathogens acting either alone or as a complex of two or more pathogens depending on environmental conditions.

Since in this study the beans were sown in a monoculture system, it was thought that the lower incidences and prevalence of the root rots could have been attributed to the cropping system employed. This observation agrees with the statement by Burgress *et al*. (2008) which stated that the level of the *Fusarium* spp. in the soil depends on the cropping system and soil type. The infield diagnosis of the *Fusarium* and *Rhizoctonia* root rots was based on the red to purple discoloration of the root cortex. This method was used by Vendelbo (2017) in the northern Tanzania to assess the infield diagnosis of root rots however it was reported that the method was flawed with uncertainties with the visible symptoms inflicted.

However, it was also observed that one of the most economically important soil borne pathogen (*Pythium* spp.) was not predominant in the regions. The absence of the pathogen may be due to the climatic conditions and soil types. However, in this study, the soil pH was not taken into consideration. Binagwa *et al*. (2016) reported that the high incidence and distribution of *Pythium* spp. were observed in soils with a pH range of 5.03 to 5.95. Secondly the failure to observe the pathogen could have been attributed to the timing of the disease diagnosis. It is well understood that this pathogen attacks the seedlings at an early stage of growth, when the plants are very tender during the first three weeks after sowing in a contaminated soils causing damping off and death. This was not the case with this study as the pathogens were diagnosed at the reproductive stage of the crop growth. Failure to observe the *Pythium* organisms at the reproductive stage of growth agrees with Burgress *et al*. (2008) who stated that the *Pythium* spp. rarely causes death in older plants.

In this study, the total yield of dry grain weight was significantly varying among the common bean varieties and treatments across all the seven bean growing districts in southern highlands of Tanzania. Common bean variety Njano Uyole (Iringa and Mufindi), Calima Uyole (Wanging'ombe, Njombe and Songea) and Uyole 96 (Mbozi and Mbeya) districts registered the highest total yields of dry weight in those respective districts. However, Calima Uyole exhibited the highest total yield of dry weight in the plots treated with both fungicide and fertilizer. All the five common bean varieties were improved to the prevailing ecological constraints. Studies have indicated that these improved bean varieties were adopted for their high yielding, palatability, tolerance to diseases and market preference (Hillocks *et al*., 2005). It has been noted that under moderately good growing conditions, these improved bean varieties yield highly with a stable productivity (Wortmann *et al*.,1998).

The total yield of dry grain weight was also significantly varying among the treatments/ plots. Plots treated with Apron Star and fertilizer combination exhibited the highest total yield of dry grain weight than the fertilizer alone, Apron Star alone and without. The combination of the insecticide and fungicide and fertilizer was observed to be very essential in that it provided protection to the seedling as well as promoting and nourishing the plant during its growth hence higher yields. This observation agrees with the findings by Muthomi *et al*. (2007) who reported that the combination of the seed dresser fungicide and bacterial inoculation was beneficial in the root rot management and enhanced nodulation in the food legumes in Kenya. Khalid and Aymen (2017) also reported from their study the application of Apron Star at medium and higher tested rates that effectively reduced aphid and termite infestation and increased grain yield compared to the untreated and standard treatments. The fungicide product has been tried on cereals in southern Sudan and South Africa Maize (*Zea mays* L.): Kandolo, 2008) (Wheat: Khalid and Aymen, 2017, however in western part of Kenya and Northern bean corridors of Tanzania, it has been tried on common beans. Addition of inorganic fertilizers rich in phosphorus and nitrogen is important for common bean production. The YaraMila cereals fertilizer that was applied in the study comprised of Nitrogen: Phosphorus: Potassium at a ratio of 23-10-5. Plots that comprised of fertilizer resulted in high grain yields than the without fertilizer treatments. Although high nitrogen and high phosphorus are very crucial for high bean productivity, in the current study the inorganic fertilizer composition was relatively lower than the recommended rates. A study by Wondimu and Tana (2017) showed higher grain yields of 3127 kg/ha when fertilizer at a ratio of 27 kg Nitrogen and 69 kg phosphorus per hectare was applied in Mechara, Eastern Ethiopia. Similarly, a study by Negash and Rezene (2015) also reported higher grain yields when fertilizer rich in nitrogen and phosphorus at rate of 45 kg N /ha and 69 kg P_2O_5/ha were applied in Areka, Ethiopia. Although the same author explained that the higher nitrogen did not supersede the grain yield from the preceding lower rates of 36 and 27 kg N/ha.

CONCLUSION

From this study, it was observed that there were minimal infestation levels of the bean stem maggots and bean root rots in seed dressed treatment alone and seed dressed and fertilizer applied combinations. Similarly, there was an increase in grain yield in the improved common bean varieties than the farmer preferred varieties. Therefore, it was recommended that the adoption of both seed dressing and fertilizer combination in the farmer's fields on improved common bean varieties would be the best option to reduce the BSM and bean root rot infestations and maximize crop yields. There is a need to carry out financial analysis and return of farmers and input value chain actors to build business case for wider use of these two inputs. A beneficial return on farmers' investments will provide them with incentives to use dressed seed and by default farmers will be renewing seed regularly rather than recycling seed. This will be translated into a vibrant and responsive seed industry. The commercialization of Apron Star fungicide to control the soil borne pathogens should first target the districts with higher pathogen prevalence.

ACKNOWLEDGEMENT

We thank the United States Agency for International Development (USAID) for funding this study through the Sustainable Intensification Innovation Laboratory (SIIL) and the Michigan State University (MSU). We also acknowledge the contribution from other donors particularly the Bill and Melinda Gates Foundation, Swiss Agency for Development Cooperation, Global Affairs Canada and Government of Tanzania through the Pan-Africa Bean Research Alliance (PABRA). We are indebted to the technical support provided by the Farm input promotion services (FIPS)- Africa, District agricultural, irrigation and cooperative officers (DAICOs) from the respective districts where the studies were conducted. We are further indebited to Syngenta- Africa and YaraMila Inc. for providing the (Apron Star) fungicide/insecticide products and the Yaramila cereals inorganic fertilizers, respectively.

STATEMENT OF NO-CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

REFERENCES

Abawi, G. S. and Pastor-Corrales, M. A. 1990. Root rots of beans in Latin America and Africa: Diagnosis, research methodologies and management strategies. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colomba.

Adebisi, M. A., Daniel, I. O. and Ajala, M.O. 2004. Storage life of Soybean (*Glycine max* L. Merril) seed after seed dressing. *J. Trop Agric*. 42 (1-2): 3-7.

Binagwa, P. H., Bonsi, C. K., Msolla, S. N. and Ritte, I. I. 2016. Morphological and molecular identification of *Pythium* spp. isolated from common beans (*Phaseolus vulgaris* L.) infected with root rot disease. *African J. Plant Sci*. 10 (1):1-9.

Birachi, E. 2012. Value chain analysis of beans in Eastern and Southern Africa: Building partnerships for impact through research on sustainable intensification of farming systems. IITA publishing. www.africarising.net.

Burgess, L. W., Knight, T., Tesoriero, L. and Phan, H. T. 2008. Diagnostic manual for Plant diseases in Vietnam.' ACIAR Monograph 129. Australian Centre for International Agricultural Research: Canberra.

Conley, T. G. and Udry, C. R. 2010. Learning about a new technology: Pineapple in Ghana. *American Economic Review* 100: 35-69. doi:10.1257/aer.100.1.35.

Economic and Social Research Foundation (ESRF). 2014. Economic Transformation for Human Development report, Dares salaam, Tanzania. Website: http://www.esrf.or.tz, http://www.thdr.or.tz.

Food and Agriculture Organisation (FAO). 2011. FAOSTAT. Food and Agriculture Organization of the United Nations. http://faostat.fao.org/default.aspx.

Food and Agriculture Organisation (FAO) . 2016. FAOSTAT. Food and Agriculture Organization of the United Nations. http://faostat.fao.org/default.aspx.

Goettsch, L. H., Andrew,W. L., Russell, S. Y., Ebby, S. L., Onesmus, S., Moses, T. and Robert, E. M. 2016. Improved production systems for common bean on Phaeozem soil in South-Central Uganda. *Afri.J.Agric. Res.* 11 (46): 4796-4809. https://doi.org/10.5897/AJAR2016.11760.

Hillocks, R. J., Madata, C. S., Chirwa, R., Minja, E. M. and Msolla, S. 2006. Phaseolus bean improvement in Tanzania,1959-2005. *Euph*.150(1-2):215-231.https://doi.org/10.1007/s10681-006-9112-9.

Kandolo, S. D. 2008. Effect of fungicide seed treatments on germination and vigour of maize seed. MSc Thesis, University of Pretoria, South Africa.

Khalid, E. H. and Aymen, E. A. 2017. Evaluation of the efficacy of Apron Star 42 WS as seed dresser against seedbed diseases and insect pests on wheat. *J. Agric. and Vet. Sci*. 10 (1): 41-50.

Kimani, P. M. 2006. Snap beans for income generation by small farmers in east Africa [on line]. Centro Internacional de Agricultura Tropical (CIAT), Kampala, UG. 2 p. (Highlights: CIAT in Africa no. 31).

Kivisi, F. A. 2015. Bean diseases inoculum in soil and seeds in Nandi County and management of Bean Root by seed dressing. *Journal of Chemical Information* *and Modeling* 53 (9):1689-1699. https://doi.org/10.1017/CBO9781107415324.004.

Le, C.N., Mendes, R., Kruijt, M. and Raaijmakers, J. M. 2012. Genetic and phenotypic diversity of *Sclerotium rolfsii* in groundnut fields in central Vietnam. *J. Plant Dis*. 96: 389-397.

Letaa, E., Kabungo, C., Katungi, E., Ojara, M. and Ndunguru, A. 2015. Farm level adoption and spatial diffusion of improved common bean varieties in Southern Highlands of Tanzania. *Afri. Crop Sci. Journal* 23 (3): 261-277.

Msambichaka, L., Mashindano, O., Luvanda, E. and Ruhinduka, R. 2009. Analysis of the performance of Agriculture Sector and its contribution to economic growth and poverty reduction: A draft Report Submitted to the Ministry of Finance and Economic Affairs, Dar es Salaam, Tanzania.

Muthoni, R. A. and Andrade. R. 2015. Performance bean improvement programmes. pp. 147-163. In: Walker, T. and Alwany, J. (Eds.). Crop improvement, adoption and impact of improved bean varieties in Sub Saharan Africa. CABI, Wallingford, Oxfordshire, United Kingdom.

Muthomi, J. W., Otieno, P. E., Chemining'wa, G. N., Nderitu, J. H. and Wagacha, J. M. 2017. Effect of legume root rot pathogens and fungicide seed treatment on nodulation and biomass accumulation. *Journal of Biological Sciences* 7 (7):1163-1170.

Mwanauta, R. W., Mtei, K. M. and Ndakidemi, P. A. 2015. Potential of controlling Common Bean Insect Pests ; Bean Stem Maggot (*Ophiomyia phaseoli*), Ootheca (*Ootheca bennigseni*) and Aphids (*Aphis fabae*) using agronomic, biological and botanical practices in field. *Agricultural Sciences* 6 (5): 489-497. https://doi.org/10.4236/as.2015.65048

Nasirumbi, S. L., Ugen, M. A., Opio, F., Mugagga, J. I. and Namayanja, A. 2015. Uptake of resistant varieties and integrated management packages for bean root rot disease in western Uganda, South Western Uganda through Packages for Bean Root Rot Disease, Technology Transfer Fund (MATTF) 16 (1):1-18.

Negash, F. and Rezene, Y. 2015. Nitrogen and phosporus fertilizers rate as affecting common bean production at Areka, Ethiopia. *J.Agric. and Crops* 1(3): 33-37.

Nderitu, J. H., Anyango, J. J. and Ampofo, J.K.O. 1997. A survey on insect pests and farmers control measures of snap beans in Kirinyaga District, Kenya. CIAT, Occasional Publications Series No. 23.

Nzungize, J. R., Lyumugabe, F., Busogoro, J. P. and Baudoin, J. P. 2011. Pythium root rot of Common bean: Biology and control methods. A review. *Biotechnology Agronomy, Society and Environment* 16 (3): 405-413.

Ochilo, N. W. and Nyamasyo, G. H. 2011. Pest status of Bean stem maggot (*Ophiomyia* spp.) and Black bean aphid (*Aphis fabae*) in Taita district, Kenya. *Tropical and Subtropical Agroecosystems* 13 (1): 91-97.

Pan African Bean Research Alliance (PABRA). 2017. Lessions from the field day in Tanzania. http://www.pabra-africa.org/lessons-field-day-Tanzania

Peter, K. H., Swella, G. B. and Mushobozy. D. M. K. 2009. Effect of plant populations on the incidence of Bean Stem Maggot (*Ophiomyia* spp.) in Common Bean intercropped with Maize. *Plant Prot. Sci*. 45 (4): 148-155.

Salako, E.A., Anjorin, S.T., Garba, C.D. and Omolohunnu, E.B. 2008. A review of neem biopesticide utilization and challenges in Central and Northern Nigeria. *Afric. J. Biotech*. 7 (25): 4758-4764.

Sharma, K. K., Singh, U. S., Sharma, P., Kumar, A. and Sharma, L. 2015. Seed treatments sustainable agriculture-A review. J. *Appl. and Natural Sci*. 7 (1): 521-539.

Simtowe, F., Kassie, M., Diagne, A., Silim, S., Muange, E., Asfaw, S. and Shiferaw, B. 2011. Determinants of agricultural technology adoption: the Case of improved pigeon pea varieties in Tanzania. *Quarterly J. Internat. Agric*. 50 (4): 325-345.

Vendelbo, N. M. 2017. Effect of cropping system design on severity of biotic stresses in Common bean (*Phaseolus vulgaris*) and Maize (*Zea mays*) in Northern Tanzania. M.Sc Thesis. Wageningen University, The Netherlands.

VSN International. 2009. Gen Stat for Windows 12th Edition. VSN International, Hemel Hempstead, United Kingdom.

Wondimu, W. and Tana, T. 2017. Yield Response of Common Bean (*Phaseolus vulgaris* L.) Varieties to Combined Application of Nitrogen and Phosphorus Fertilizers at Mechara, Eastern Ethiopia. *Journal of Plant Biology and Soil Health*, 4 (2): 1-7.

Wortmann, C. S., Kirkby, R. A., Eledu, C. A. and Allen, D. J. 1998. Atlas of Common Bean Production in Africa. Second edition. 195pp.

Yakubu, H., Buji, I. B. and Sandabe, M. K. 2011. Effects of seed-dressing fungicides on germination, nodulation, N2-Fixation and yields of two groundnut varieties in Semi-Arid Region of Nigeria. *International J. Appl. Agric. Res.* 6 (2): 121-129.