International Journal of Thesis Projects and Dissertations (IJTPD)
Vol. 6, Issue 2, pp: (8-29), Month: April - June 2018, Available at: www.researchpublish.com

INTEGRATED BEAN APHID MANAGEMENT *(Homoptera: Aphididae)* ON BEAN CROP (*Phaseoli vulgaris)* IN WESTERN KENYA

JACOB. N. MAKILA[1], ROBERT W NYUKURI[2] , ALBERT W. MWONGULA[3]

[1]Department of Biological Sciences, School of Science, University of Eldoret, P.O.Box 1125, Eldoret, Kenya.
[2]Department of Biological Sciences, Kibabii University P.o. Box 1699 Bungoma, Kenya.
[3]Department of Biological sciences, Alupe University College po box 845 Busia, Kenya.

Abstract: **Bean (*Phaseolus vulgaris*) is the most important food legume, however there is an increasing decline in performance and production due to pest attack especially from the aphids. Pest infestation is even higher during the dry season hence causing a serious damage to the crop. Therefore there is an urgent need to come up with methods like integrated pest management in order to control the pest, which destroys the crop by sucking the nutrients, excrete honey dew which attract saprophytic fungi and is also known to transmit a number of viruses to the bean plant. The aim of this study was to: determine efficacy of integrated management on bean aphid infestation and to determine the efficacy of integrated management on bean performance. This was done with an overall aim of increasing the yields of beans. Data collection was done using a 4x2x2 factorial experiment comprising of Bean variety cv. Nyayo ,two rates of seed dressing chemical (with and without) using (Gaucho) *Imidacloprid*, two rates of botanical pesticide (*Tephrosia vogelii*) extract at 0 and 20w/v %) applied as a foliar spray and four rates of inorganic fertilizer Triple Super Phosphate (TSP) –zero rate (no fertilizer), Low rate (TSP at, 50 kg product/ha), medium rate, 75 kg/ha and high 100 kg product/ha). The four factors were combined in a completely factorial arrangement in randomized complete block design replicated three times constituting 16 treatment combination giving 48 experimental plots which were planted in five row field plots measuring 2m by 2.25 m. The experimental design was Randomized Complete Block Design (RCBD) replicated three times. Each experimental plot measured 2.0 M x 2.0 M with inter row and intra row spacing of 45 cm and 20 cm respectively. Clean bean variety seed sourced from local market was used in this study to reflect local farmer's source of planting material. Data collected on all the parameters was subjected to analysis of variance procedure using general linear model of the statistical analysis system (SAS) package (SAS Institute, 1996). However, data on aphid count and number of plants infested by bean aphids were first subjected to a transformation of square root of x+ 1 in order to reduce heterogeneity of the data before being analalysed. Mean separation was done according to Fisher's protected LSD significant difference Test at 5% level of significance. The Pearson's correlation test was performed on the means of the parameters investigated to compare on their relationships. Results showed that the aphid population builds up and damage in bean crop was significantly reduced when combined application of treatments of seed treatment using Imidacloprid at 700 ml/100kg seed was done on bean seed before planting and planting with 100 kg/ha of tsp fertilizer, then followed with a Biopesticide foliar spray of *T. vogelii* at 20%w/v from 30 days after emergence (30DAE) thereafter spraying on a weekly basis better than any other treatment applied. The application of *T.vogelii at* 20%w/v alone on weekly basis significantly reduced bean aphid infestation better than control and application of seed dress alone. Use of seed dressing alone was only temporary measure during seedling stages and should be supported with other control measure one month after crop emergence as it does not provide complete control of bean aphid infestation for the whole season during bean growth. The integration of TSP fertilizer, seed dresser, and application of foliar spray of Tephrosia leaf extract at 20%w/v greatly reduced *Aphis fabae* infestation and population build in bean crop below damaging levels and resulted in improved bean grain yield, Application of TSP fertilizer rates alone did not seem to have effect on bean aphid infestation on bean crop as population build up was observed under all the rates applied. It's therefore recommended to use integrated control in order to increase performance and production of beans.**

Keywords: **Bean, Integrated, *Aphis fabae*, Management, Performance, production.**

1. INTRODUCTION

1.1 Importance of beans

Bean (*Phaseolus vulgaris*) is the world's most important food legume (CGIAR 2009). Global bean production in 2005 was 18 million metric tons harvested from over 25 million hectares (CIAT, 2005). It is the widely grown legume in Kenya, as a staple food (Kiiya, 1997; CIAT, 2006) and is the major source of dietary protein for most people Kenyans (Allen, 1986). Beans are highly nutritious with protein content in the range of 20-28% (Laing *et al.*, 1984). Nutritionally, common bean is characterized as a perfect food because of its high content of protein fiber, complex carbohydrates and micronutrients (CIAT, 2006). A single serving of one cup of bean provides half the recommended daily allowances of folic acid – a vitamin B precursor, 25-30 % of iron magnesium and copper as well as fifteen percent of potassium and zinc (ECABREN 2006). It is eaten in various forms and mixtures with starchy foods such as maize, rice and potatoes. Bean crop residues also have various uses including animal feed and source of organic matter for fertility replenishment. Bean straw ash produces a leachate with tenderizing properties. It widely used in some communities to tenderize dried meat and vegetables. Traditionally, leaves are consumed as vegetable while the seeds are eaten both in green and dried form after boiling. In Africa, in small farms women are the main growers (CGIAR 2009)

1.2 Bean production

Bean production in Africa has been constrained by low soil fertility, lack of improved varieties, poor agronomic practices, insect pests and diseases (Allen *et al.*, 1989, Abate and Ampofo, 1996; Huis, 1989). The diseases include common bean mosaic virus disease, leaf blight, leaf spot, root rot, anthracnose and angular leaf spot (Mbaka *et al.*, 2008). According to CIAT (2006), among the insect pests, farmers singled out, cutworms; bean stem maggot and aphids as a serious pest in bean production. Because of these constraints bean yields in Kenya average a mere 0.4 tons per hectare. The annual production at 200,000 per year tons from about 800,000 hectares falls short of domestic needs by approximately 450,000 tons (Mbaka *et al., 2008,* Paul Macharia *et al.,* 2006). IN Nakuru County, the situation is aggregated due to the fact that rainfall pattern and reliability have changed giving room for long dry spell which favour pest invasions.

To minimize losses farmers rely mainly on recommended synthetic insecticides which have become major concern due to their high cost and potential for causing biotic imbalances and loss of biodiversity.

2. APHIDS (HOMOPTERA: APHIDIDAE) AS CONSTRAINT TO BEAN

The aphid outbreaks in Kenya sometimes occur sporadically and this can cause serious damage before they are noticed during long dry spell following heavy rains (Wanjama 1979). All growth stages of bean crop are very susceptible to black bean aphid infestation and may result in high yield loss if not controlled (Khaemba, *et al*., 2006). Some species of aphids, including black bean aphid, cause extensive destruction of plant tissue through the injection of toxic saliva. Also sugary excretions of aphids (honey dew) attract saprophytic fungi on leaf surfaces which cause accelerated aging and reduced photosynthetic area depriving the growing plant and the developing grains in the pods of nutrients thus causing low yields. (Minks and Harrewijn, 1989, Dickson, 1997). Yield losses of between 50 to 100% have been reported elsewhere.

Aphids are also the most known important insect vectors of plant viruses and transmit the majority of all viruses worldwide (Adane et *al.,* 1995). Even low numbers of aphid can cause significant crop loss if they transmit plant viral disease to bean crop at an early stage of growth. Bean aphid, in particular, transmits bean common mosaic virus disease (BCMVD). Aphids transmit up to 83% of thevirus in *Phaseolus vulgaris.* (Agrios, 1997).

In Kenya high bean aphid infestation has been observed especially during prolonged dry spell during young seedling stages of growth. Complete crop failure has been observed in bean field. Yield losses up to 100% been reported by farmer when infestation starts at seedling stage under low rainfall regimes warm conditions which is usually experienced in most parts in Njoro district, Nakuru county.

The control of pests has relied on the use of synthetic pesticides such as Diamethoate ^{R}, Metasystox^{R} and Karate amongst many available products just to mention a few at recommended rates have been used for controlling insect pests. However, bean being considered as a low input crop in the area, majority of farmers do little to control the pest despite being a threat to bean production. This is due to the fact that farmers are unable to acquire the pesticides at the right time due to the unavailability and their high cost which most of the small scale farmers cannot afford (Ogendo *et al.,* 2013; 210). In addition, the constrained economy of small scale farmers together with the problem of health risks and environmental pollution owing to chemical pesticide, food contamination, inadequate production methods, development of insect resistance to synthetic pesticides, killing of the natural enemies of target pests such as the aphids and occasional unavailability of insecticides makes their use largely incompatible (Indira, 2006). This necessitates the need for integrated management option to avoid overreliance on synthetic insecticides. This study intends to come up with better pest management options which farmers could easily adopt to manage bean pests especially the bean aphid and increase bean grain yields.

3. MATERIALS AND METHOD

3.1 Experimental Sites

The trial site was at KARI- Njoro experimental field which lies between Latitude 00 20'S and Longitude 35^0 56' E and 2166 m above sea level. It is located in the lower highlands (LH_3) with 931 mm and temperature ranges of $7.9^{o\ c}$ to $21.9^{o\ c}$ and a mean of 14.9^o C. The soils are vitric mollic andosols that are well drained, deep to very deep, dark reddish brown, consisting of heavy textured friable silty clay humic top soils (Jaetzold and Schmidt, 1983). However, as a result of over cultivation, leaching and run offs the natural fertility has gone down. The experiment was carried out in two seasons, (long and short seasons) with the first planting taking place during the month of May to August and second planting during the month of October to December, 2013.

The materials used included Bean var. Nyayo which was sourced from the local market: This was selected since it is one of the popularly grown varieties in Nakuru County and one of the susceptible cultivar of bean varieties growth. Seed dressing was done using Gaucho 350 FS (Imidacloprid) at two rates of 700 ml per 100 kg seed of bean. A Botanical, *Tephrosia Vogelii*, was used as plants extract at two rates at 20 %w/v 0 %w/v in 20 litres of water

3.2 Preparation of *Tephrosia vogelii* (Hook) extracts solutions

The leaves were harvested from mature *Tephrosia vogelii* plant and weighed using a two kilogram tin (*Gorogoro*). Three such tins of crushed leaves gave approximately 2 kg which was then transfered into a container of ten Litres of water. The mixture was then left standing for twenty four hours before use. It was then squeezed to remove the liquid from the trash. The solution was then filtered into a Knapsack sprayer pump and sprayed at a concentration of 20 %w/v

3.3 Treatment Structure and combination

The study was a **4x2x2** factorial experiment comprising of:

- Bean variety cv. Nyayo
- Two rates of seed dressing chemical (with and without) using (Gaucho) *Imidacloprid*,
- Two rates of botanical pesticide (*Tephrosia vogelii*) extract at 0 and 20w/v %) applied as a foliar spray
- Four rates of inorganic fertilizer Triple Super Phosphate (TSP) –zero rate (no fertilizer), Low rate (TSP at, 50 kg product/ha), medium rate, 75 kg/ha and high 100 kg product/ha)

3.3.1 Treatments combinations

- .A : Tsp. fertilizer at 100 kg/ha;
- AB2: 100 kg/ha + *T. vogelii;*
- AB2S2: 100kg/ha Tsp. + *T. vogelii* at 20%w/v in 20 L of water;
- AS2:100 kg/ha tsp. fertilizer + Seed dressing with Imidacloprid at 700ml/100kg seed50
- B: Control (Zero rates of Tsp fertilizer, T. vogelii and Imidacloprid)
- BB2: application of T. vogelii at 20%w/v in 20 L of water alone;
- BB2S2: *T. vogelii* foliar spray at 20%w/v + seed dressing with *Imidacloprid* at 700 ml per 100 seed;
- BSS2: application of imidacloprid alone;
- C: application of 100 kg Tsp. fertilizer/ha;
- CB2: 75 kg/ha Tsp. fertilizer +*T. vogelii* at 205 w/v;

- CB2S2: 75kg/ha/+ *Vogelii* at 20%w/v + Imidacloprid at 700 ml/100 kg seed;
- CS2: 75 kg/ha tsp fertilizer + seed dressing with imidacloprid at 700 ml/100kg seed;
- D: 50 kg/ha tsp fertilizer alone;
- DB2: 50kg/h Tsp. + *vogelii* at 20%w/v
- DB2S2: 50 kg/ha +*T. vogelii* at 20%w/v + *imidacloprid* at 700ml/100kg seed;
- DS2: 50 kg/ha tsp fertilizer + *imidacloprid* alone

In total sixteen treatment combinations were generated as shown above.

3.4 Experimental design

The four factors were combined in a completely factorial arrangement in randomized complete block design replicated three times constituting 16 treatment combination giving 48 experimental plots which were planted in five row field plots measuring 2m by 2.25 m. The experimental design was Randomized Complete Block Design (RCBD) replicated three times. Each experimental plot measured 2.0 M x 2.0 M with inter row and intra row spacing of 45 cm and 20 cm respectively. Clean bean variety seed sourced from local market was used in this study to reflect local farmer's source of planting material. Experiment was hand planted in a factorial layout.

3.5 Aphid infestation to the plots

During artificial infestation, 5 mature aphids were introduced into the center row on 5 plants chosen at random in each experimental plot. The aphids for infestation were reared in caged potted plants placed in the green house before the start of planting of the experiment. The rearing of aphid was done to ensure there was aphid ready for infestation at the time of infestation in case the natural presence of aphids in the fields failed or delayed.

3.6 Data collection and parameters recorded

Data was collected starting from 30 days after emergence (30 DAE) and this was repeated on weekly basis for a period of nine weeks. The following parameters were recorded:

Germination percentage: The germination percentage was calculated by counting the actual number of plants which germinated per plot and multiplying by 100 and dividing the by total number of plants expected in the plot. The germination in all the plots was above 80%. This was done to ensure uniformity at the time of data collection

3.6.1 Bean aphid count on five randomly selected plants per plot:

The aphid counts on five randomly selected plants in the three inner rows were counted and the total number was divided by five to get mean number of aphids per plant and recorded. This was done in each experimental plot per week for a period of nine weeks.

3.6.2 Plant height of five randomly selected plants per plot:

The plant height was measured using a meter rule by placing a ruler at the stem adjacent to the ground level and taking the plant height up to the growing tip of each plant taken at random on five plants per plot and then getting their mean which was recorded as the mean height. This was done for a period of nine weeks.

3.6.3 Mean number of pods in five randomly selected plants per plot:

Pods were counted on five randomly selected plants within the three inner rows per plot. The total number of pods from the five plants was taken and their average mean recorded. This was repeated for all the plots on weekly basis for a period of nine weeks.

3.6.4 Rating score on stunted plants per plot:

In each experimental plot all bean plants which were stunted in growth were assessed on rating scale of 1-6 as follows: **1** = no stunted growth; **2**= just a few plants stunted; **3**= less than 25% of the plot stunted; **4**= 50% of plants stunted**; 5**=75% of the plots stunted and **6**= more than 75% to 100% stunting of the plants

3. 6.5 Number of plants attacked by bean aphid:

All bean plants showing infestation by bean aphid were counted within the three inner rows and the total number was recorded then the total number was recorded per plot

3. 6. 6 Yield data:

Yield data was collected by harvesting three inner rows as the net plot leaving out the outer rows as the guard rows in each plot. The harvested dry beans were threshed, cleaned and weights taken using electric weighing balance in the laboratory for each plot. This was done for all the 48 plots and the weights recorded.

3.6.7 Number of plants infested by other bean pests per plot:

The presence of other pests attacking bean right from seedling stages up to maturity was closely monitored and recorded on weekly basis. These included cutworms (*Agrotis segetum*), bean fly (*Ophyiomyia phaseoli*). The number of plants attacked by each pest species was counted and recorded.

3. 7 Data analysis

Data collected on all the parameters was subjected to analysis of variance procedure using general linear model of the statistical analysis system (SAS) package (SAS Institute, 1996). However, data on aphid count and number of plants infested by bean aphids were first subjected to a transformation of square root of x+ 1 in order to reduce heterogeneity of the data before being analyzed. Mean separation was done according to Fisher's protected LSD significant difference Test at 5% level of significance ($P<0.05$).The Pearson's correlation test was performed on the means of the parameters investigated to compare on their relationships.

4. RESULTS

Generally, there were more bean aphid population build up and high infestation of *A. fabae* on bean crop compared to season 2. This was because the crop during season 1 was planted in mid-May after the heavy rains had reduced and there was dry spell which favoured high bean aphid infestations and population increase.

During the second season, planting of the experiment was done when it was rainy and the season experienced more rainy days compared to the first season . This resulted in slightly low infestation by bean aphid, better performance of bean crop during season two compared to season one.

4.1 Effects of the efficacy use of integrated management of bean aphid infestation and bean performance

4.1.1 Effects of the efficacy use of integrated management of bean aphid population build up

The aphid population build up was significantly ($p \leq 0.05$) influenced by application of integrated control methods applied in both long and short rainy seasons. During the long rainy season, the highest number of aphid population build up was observed in untreated plots (treatment B (none application of any treatment) while the lowest number was observed under application of treatment AB2S2, (100 kg tsp/ ha + botanical spray +seed dressing with imidacloprid) < BB2S2 (botanical spray + seed dressing with imidacloprid at 700 ml/100 kg seed), < DB2S2 (50 kg tsp/ha + botanical at 20%w/v +imidacloprid at 700 ml /100 kg seed) , < CB2S2 (application of 75 kg tsp /ha + *T. vogelii* leaf extract at 20%w/v + seed dressing with Imidacloprid at 200ml per 100 kg seed of bean) in increasing order respectively during wet and dry seasons . The application of integrated use of *T. vogelii* at 20%w/v, seed dressing with imidacloprid at 200 ml and TSP fertilizer at 50, 75 and 100 kg/ha rates significantly $p<0.05$ different from the control treatment B with (no control measure applied) followed by application of single application of treatments B, A, C and D (0, 100, 75 and 50 kg/ha of TSP singly in decreasing order respectively during both long and short rainy season (Fig.1).

During short rainy season, the highest number of aphid population was observed under application combination of zero rates of *T.vogelii*, imidacloprid and TSP fertilizer (treatment B) while the lowest number was observed under the application of AB2S2: application of integrated use of (Tsp rates of 100 /ha + foliar application of leaf extract of *T. vogelii* at 20 % w\v in 20 litre of water + Imidacloprid at 700 mls per 100 kg seed of bean) which had the lowest aphid population build up (Figures 2)

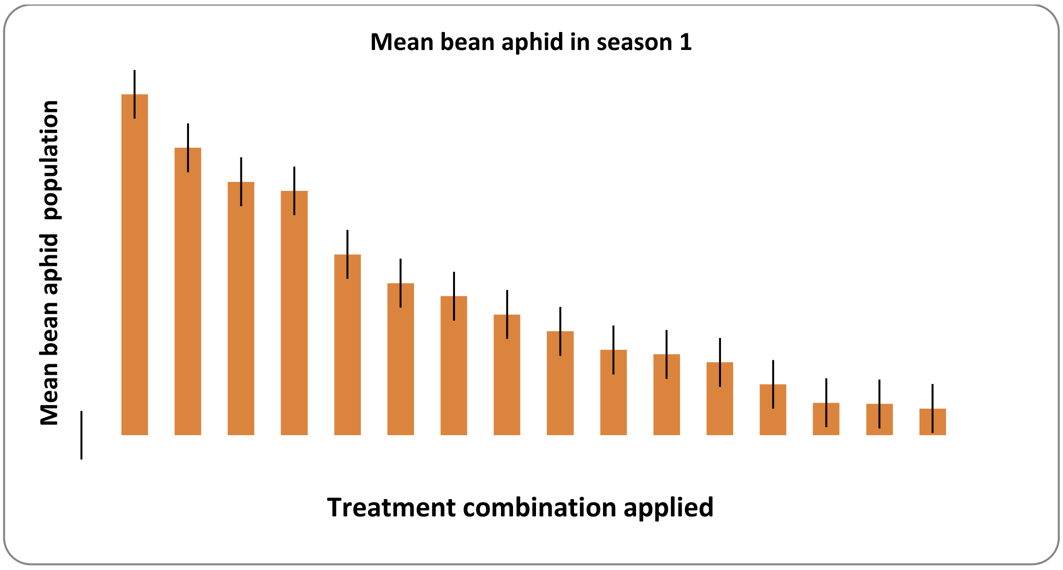

Figure1: Treatment influence on bean aphid in season 1

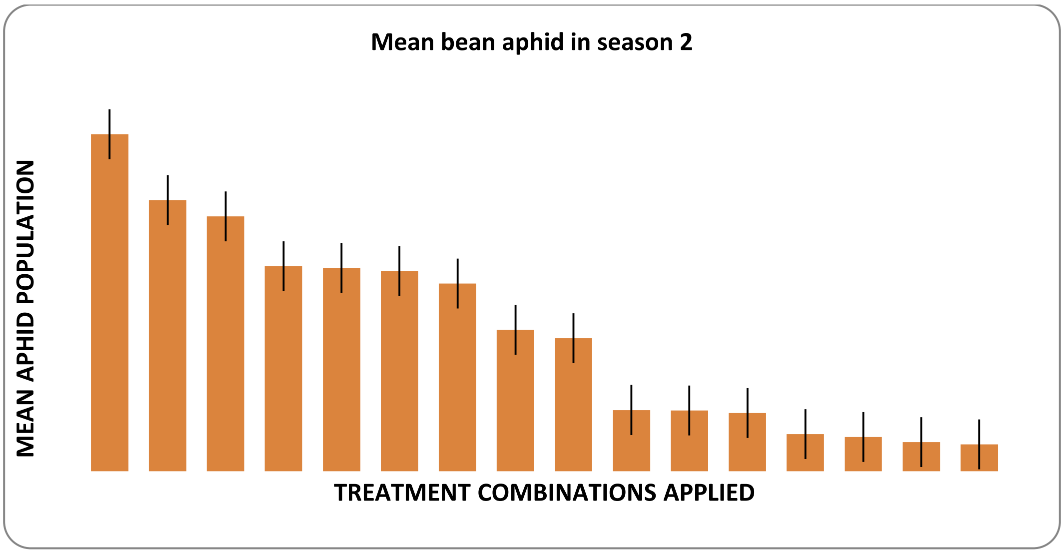

Figure 2: Treatment effect on bean aphid population build up in season 2

Generally, the *A. fabae* population build up observed during the second season was lower than those observed during the first season (figure 1 and 2)

4.1.2 Effect of integrated management on bean plant height growth during wet and dry seasons in 2013.

The applications of integrated use of TSP fertilizer + seed dressing with imidacloprid + botanical spray with *T. vogelii* leaf extract foliar spray significantly<0.05 influenced the mean bean plant height growth. The highest plant height was observed under application of *treatment* AB2S2 (100 kg tsp/ha at planting + *T. vogelii* leaf extract spray at 20%w/v in 20 L of water + imidacloprid dresser before planting at 700 ml/ 100 kg seed of bean) followed by treatments AB2 (100 kg /ha TSP fertilizer at planting + botanical foliar spray *T. vogelii* at 20% w/v in 20 litres of water), CB2S2 (75 kg/ ha TSP at planting + botanical leaf extract spray at 20% w/v + imidacloprid as seed dresser at 70 ml per 100 kg seed) and DB2S2 (50 kg /h TSP fertilizer at planting + botanical spray at 20% w/v in 20 litres of water + imidacloprid as seed dresser at 70 ml/100kg seed of beans) which did not differ significantly. DS2 (50 kg/ha of TSP fertilizer +imidacloprid as seed dresser at 700 ml/100kg seed), BB2S2 (0 kg/ha TSP fertilizer at planting + botanical spray at 20%w/v in 20 litres of water + imidacloprid seed dresser at 100 kg/100 while shortest plant height was observed under application of treatment B (control no treatment applied). This was followed by treatment D, - (application of 50 kg/ha of TSP alone), A-application of 100 kg/ha alone, BS2- (application of 0 rate of TSP and seed dressing with Imidacloprid at 700 ml per 100 kg/ha) (Fig 3 and 4)

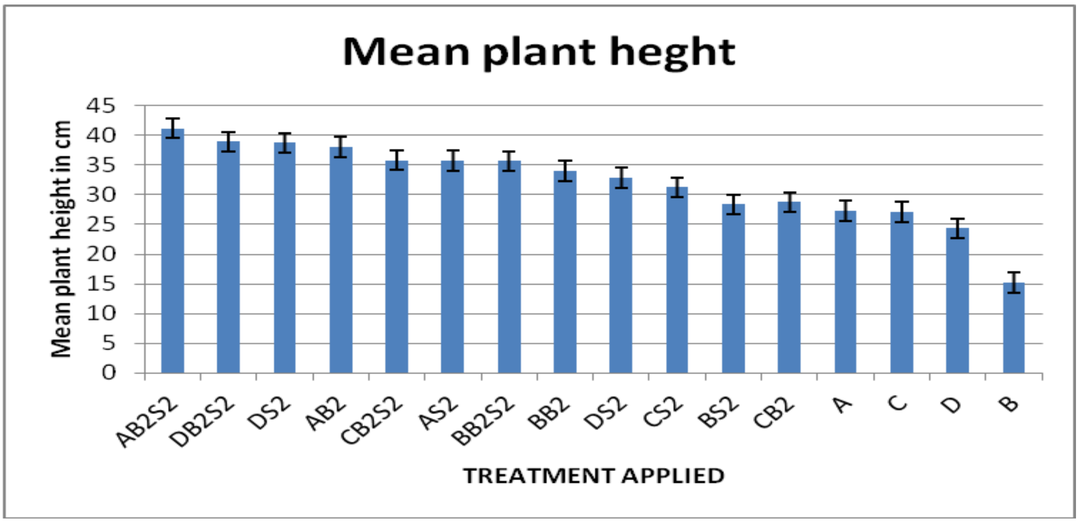

Figure 3: Bean plant height during long rainy season, season 1

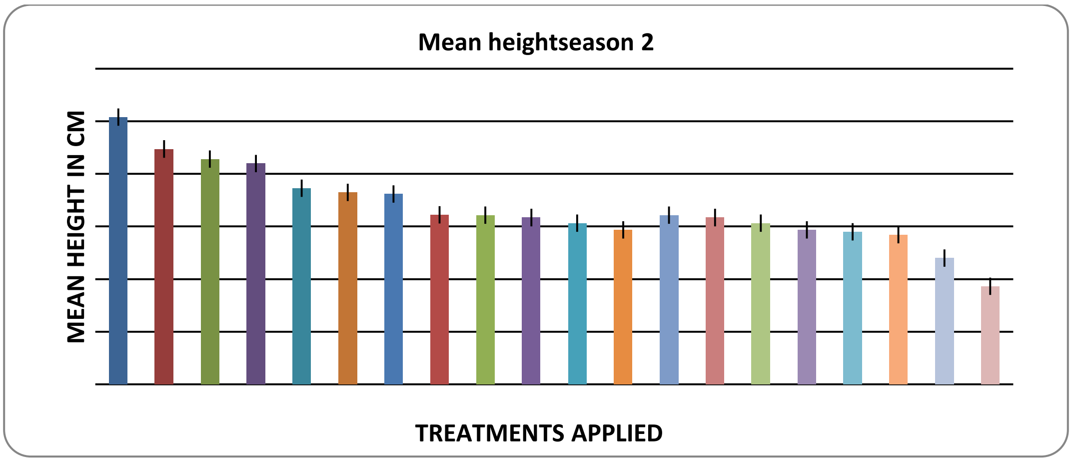

Figure 4: Bean plant height during short rainy season (season 2)

Generally the tallest plant height was observed during the short rainy season compared to that observed during the long rainy season (Figure 3 and 4)

4.1.3 Efficacy of integrated management on mean bean pods formed on bean crop during Long and Short rains in 2013

There was a significant $p<0.05$ relationships between the number of pods and treatment combinations applied during both first and second seasons (Figure 5 and 6). The highest number of pods was observed in plots where treatment AB2S2 (application of TSP fertilizer at 100 kg/ha +foliar spray of *T. vogelii* leaf extract + seed dressing with imidacloprid at 700 ml per 100 kg seed followed by treatments DB2S2 (50 kg/ha tsp + Bio pesticide, *T. vogelii* at 20% w/v + seed dresser, imidacloprid at 700 ml per 100 kg seed), BB2S2 (0 kg tsp fertilizer + foliar spray of *T. vogelii* + seed dresser, imidacloprid). The treatment AB2S2 (100 kg /ha TSP + *T. vogelii* at 20% w/v + imidacloprid as seed dresser) significantly differed from the rest(P< 0.05) in mean number of pods produced per plant whereas treatments DS2 (50 kg/ha TSP + Seed dressing with imidacloprid at 700 ml /100 kg seed), CB2 (75 kg/ha + *T. vogelii* at 20%w/v), BB2S2 (*T. vogelii* at 20%w/v + seed dresser, imidacloprid at 700 ml/100 kg seed), AB2 (100 kg/ha TSP + *T. vogelii* at 20%w/v), DB2 (50 kg/ha + *T. vogelii* at 20%w/v), AS2 (100 kg/ha + imidacloprid at 700 ml/ 100 kg seed), CB2S2 (75 kg/ha + *T. vogelii* at 20%w/v leaf extract + seed dressing with imidacloprid at700 ml per 100 kg of bean seed), CS2 (75 kg/ha + seed dressing with imidacloprid), DS2 (50 kg/ha + seed dressing with imidacloprid), BS2 (seed dressing alone), C (75 kg TSP. fertilizer/ha) , BB2 (0 kg/ ha TSP + biopesticide of *T. vogelii* leaf extract at 20% w/v), D (50 kg/ha tsp. fertilizer alone) in decreasing order respectively with the lowest number of pods being observed on treatment combination of zero rates of tsp. fertilizer, imidacloprid and *T. vogelii,* (treatment B) (Figure 5 and 6). The treatments applied singly had the lowest number of mean pods per plant (Figure 5).

During the short rainy season, the highest number of pods was formed under application of treatment AB2S2 (combined application of 100 kg/ha of TSP fertilizer + *T. vogelii* at 20%w/v+ seed dressing with Imidacloprid at 700 ml per 100 kg bean seed) whereas the lowest number of pods was obtained under treatment B – zero application of treatments (controls) (Table 2). The application of treatment *AB2S2* (combined application of 100 kg/ha of Tsp. fertilizer + *T. vogelii* leaf extract at 20% w/v + seed dressing with Imidacloprid at 700 ml per 100 kg bean seed)

significantly *p<0.05* differed from application of 0 rates of all the treatments that is treatment B (the control) in the number of pods realized (Figure 6)

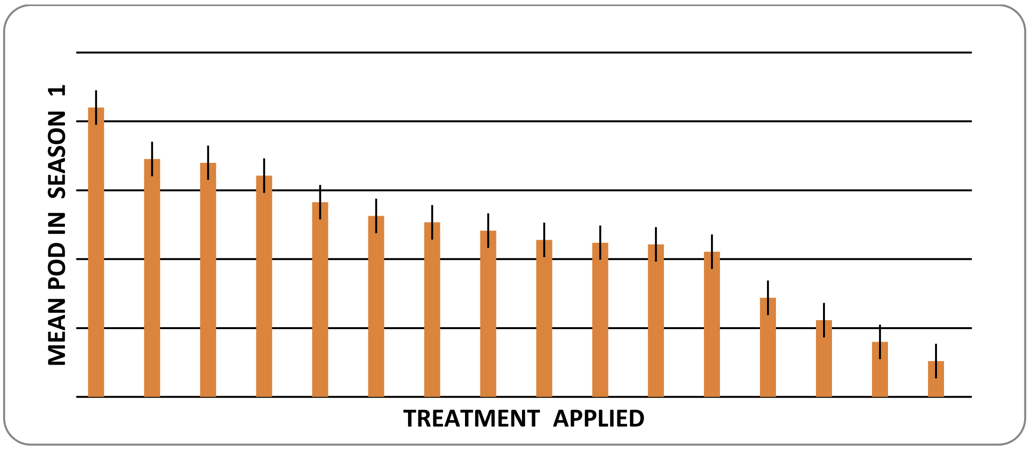

Figure 5: Integrated management on mean bean pod crop during May-August, 2013, season 1

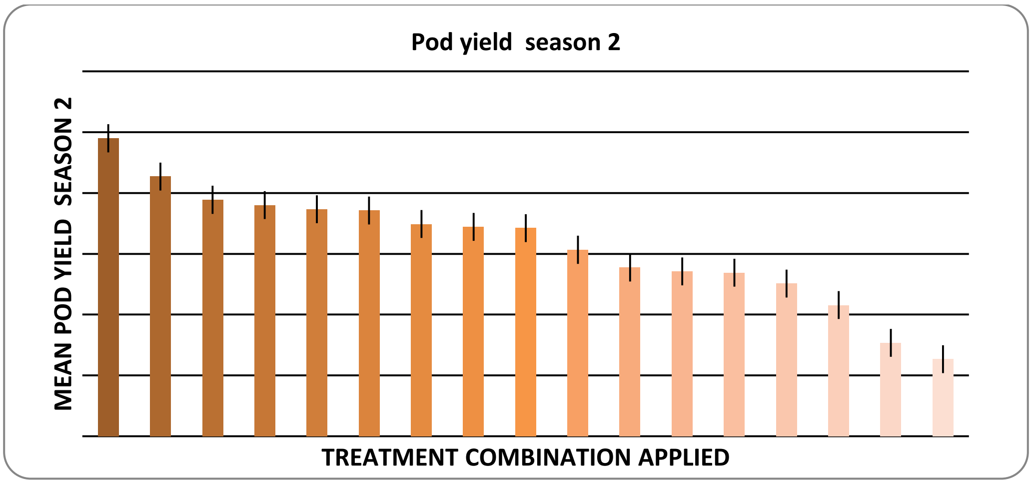

Figure 6: Bean plant height during short rainy season (season 2)

Generally, more pods were formed in second season compared to those formed in second season compared to the first season (figure 5 and 6). The table and figures should be placed immediately after the text for ease of reference.

4.1.4 Effect of efficacy of integrated use of fertilizer, seed dressing, and bio-pesticide spray on bean plant stunting rating scores during season 1 and 2

Bean stunting score rating was significantly p<0.05 influenced by the various treatments applied singly or in combinations during both long and short rainy seasons. The highest rating score on scale of 1-6 was observed under treatment B (0 rates of TSP fertilizer +Imidacloprid + *T. vogelii*) while the lowest rating score was observed under application rates of treatment AB2S2 (TSP fertilizer application at 100 kg/ha + *T. vogelii* at 20%w/v leaf extract + Seed dressing with imidacloprid at 700 ml per 100 kg seed (Figure 7).

During the short rainy season, the application of various treatments on bean crop significantly p<0.05 influenced stunting of bean plants. The highest rating score on stunting was observed under application of treatment B (zero rate of *T. vogelii* at 20 %w/v + seed dressing with imidacloprid at 700ml per 100 kg seed while the lowest rating score was observed under application of treatment AB2S2 (100kg/ha. of TSP fertilizer +*T. vogelii* at 20 %w/v + Seed dressing bean seed with Imidacloprid at 700 ml). Generally, the highest rating score of bean stunting was recorded during season 1 compared to season 2 (Figure 8)

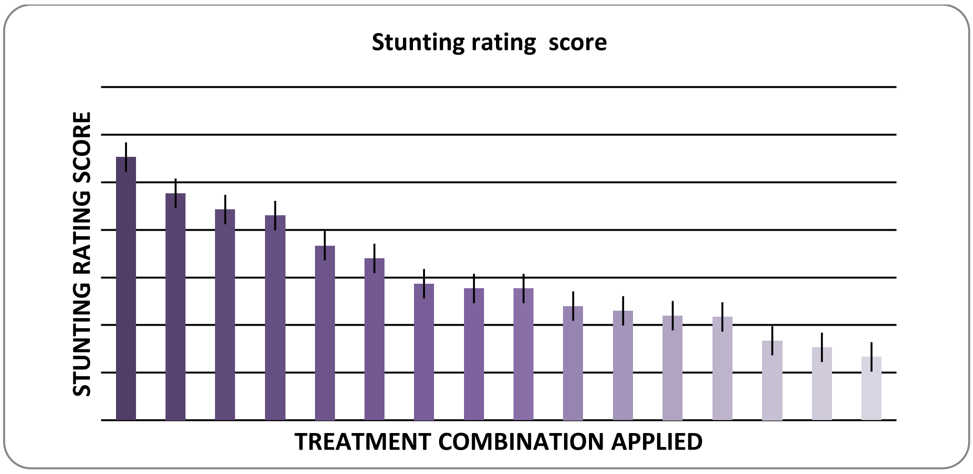

Figure 7: Treatment effect Bean plants stunting rating score season 1

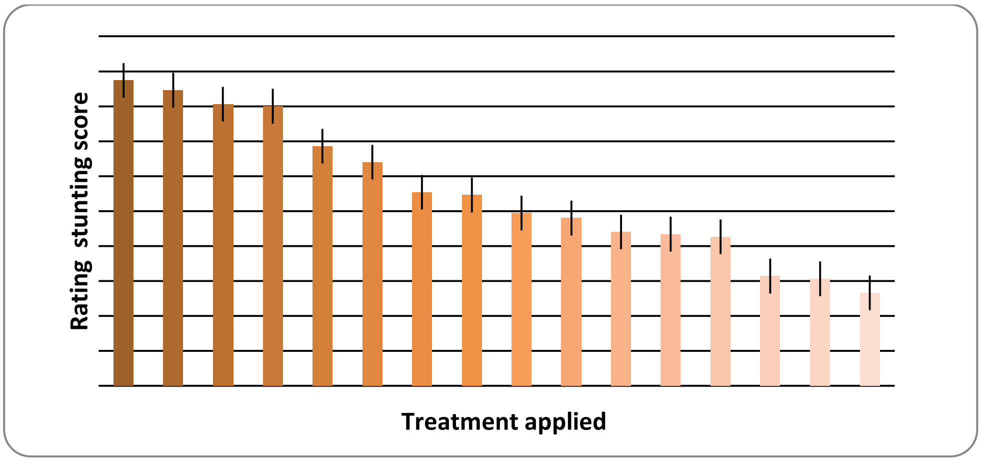

Figure 8: Bean plants stunting rating score season 2

4.1.5 Efficacy of integrated management on number of bean plants infested by bean aphid, *A. fabae* on bean crop during long and short rainy season, May-August, and October- December, 2013.

The number of plants affected/ infested by bean aphid was significantly P<0.05 influenced by application of treatments applied during both long and short rainy seasons. The highest number of bean plants infested by bean aphid (*A. fabae*) was higher in untreated plots (application of treatment B) (application of combinations of zero rates of treatments and those applied singly while the lowest number of plants infested was observed under application of integration of Triple single phosphate fertilizer at 100 kg/ha + *T. vogelii* at 20%w/v + seed dressing bean seed with imidacloprid at 700 ml per 100 kg seed before planting (Figure 9).

During the short rainy season, the highest stunting rating score on bean common was observed under treatment B (0 rate of application of *T. Vogelii* + Imidacloprid + tsp. fertilizer while the lowest rating score was observed under treatment AB2S2 -the application of 100 kg/ha of Tsp. fertilizer +20%w/v of *T. vogeli*. + seed dressing with Imidacloprid at 700 ml per 100 kg seed during both seasons 1 and 2. All the treatments applied singly were observed to have high *A. fabae* infestation (Figure 10).

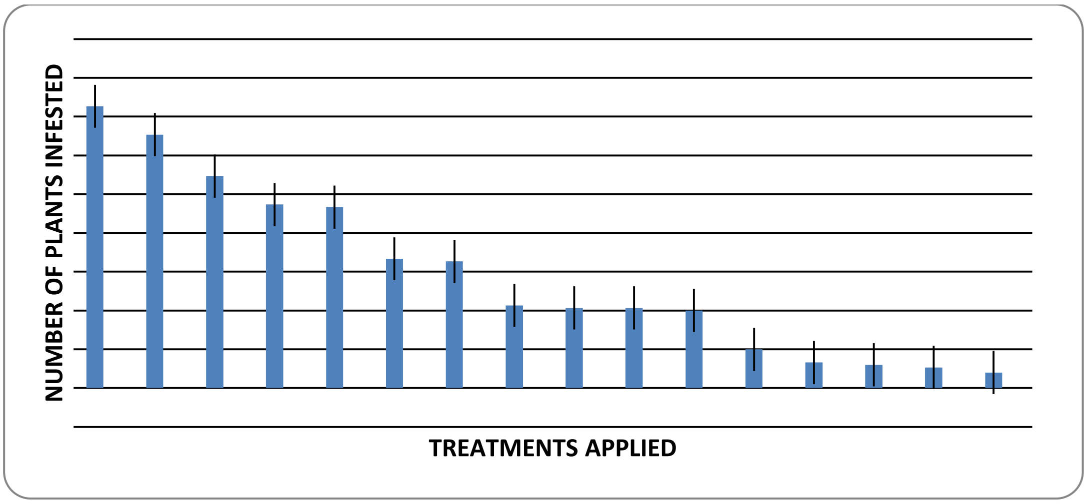

Figure 9: Number of bean plants infested by *A. fabae* in season 1

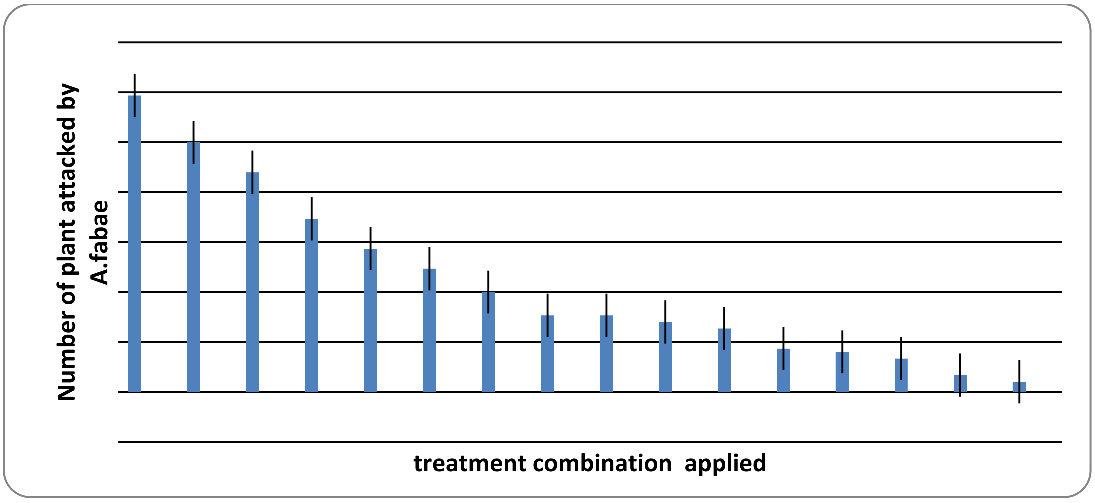

Figure 10: Number of bean plants infested by *A. fabae* in season 2

Generally, more bean plants were attacked by bean aphid, *A. fabae* during the long season compared to those attacked during the short rainy season (Figure 9 and 10)

4.1.6 Efficacy of integrated management on bean yield during long and short rainy seasons.

There was a significant (p<0.05) relationship between the integrated treatments applied and bean grain yield during both long and short seasons. Treatment AB2S2: (integrated application of TSP fertilizer at 100 kg/ha + T. *vogelii* at 20%w/v + seed dresser, imidacloprid at 700 ml per 100 seed short rains with the highest yield obtained during season 1 whereas the lowest yield was obtained under application of treatment B (control) (figure 11). There was a significant difference between treatment AB2S2, (integrated application of T. *vogelii* at 20%w/v + TSP fertilizer at 100 kg/ha + seed dressing with 700 ml of Imidacloprid per 100 kg seed) and AB2 (100 kg/ha tsp. fertilizer + bio pesticide, *T. vogelii* at 20% w/v) and CB2S2 (application of Tsp rate of (75 kg/ha + *T. vogelii* at 20%w/v leaf extract spray in 20 litres of water and application of seed dresser, (imidacloprid) at 700 ml per 100 kg seed respectively) at p<0.05 Table 1 and (Figure 11 and 12).

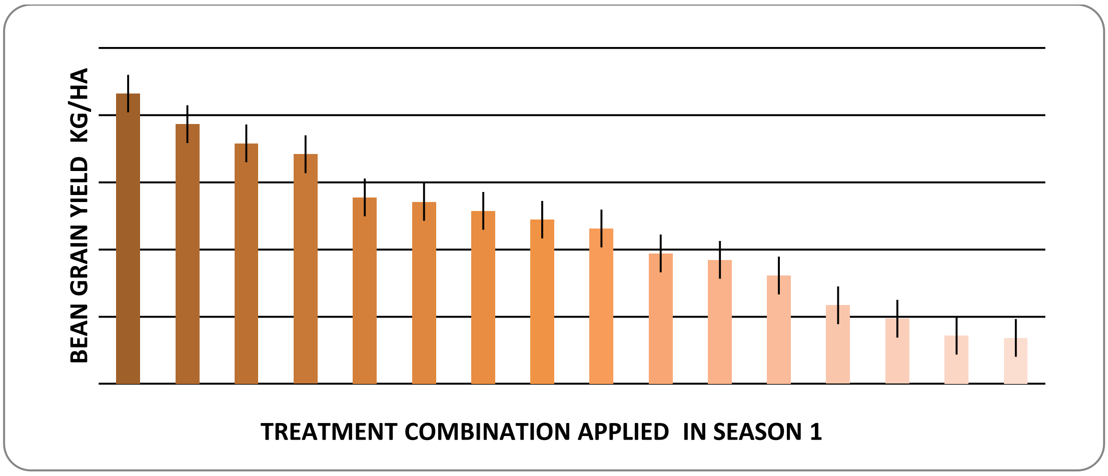

Figure 11: Bean grain yield in season 1

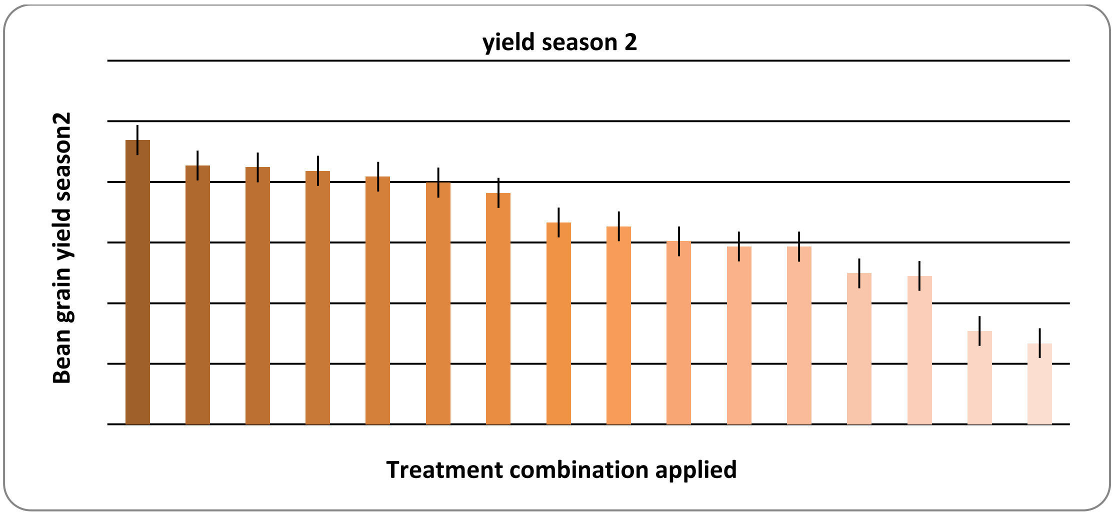

Figure 12: Bean grain yield during season 2

Generally a high yield was observed during the short rainy season compared to that observed during long rainy season (Figures 11 and 12)

Pearson's correlation coefficient analysis

The Pearson Correlation Coefficients analysis also indicated that integrated management of bean aphid using combined application of 100 kg/ha of tsp fertilizer + *T. vogelii* at 20%w/v of spray + seed dressing with imidacloprid at 700 ml per 100 kg seed was highly significant $p<0.05$ but negatively correlated to aphid population build up, the number of plants attacked by aphid and stunted bean plants rating score while it was positively correlated to mean number of pods formed and grain yield produced. The application of Imidacloprid as seed dresser was significant $p<0.05$ and negatively correlated to *A. fabae* population built up, number of plants attacked by *A. fabae* and had symptoms of bean common mosaic virus disease. However, it was highly significant $p< 0.05$ and positively correlated to plant height and mean number of plants per plant realized. It was also significant $p<0.05$ influenced bean yield.

During the second season, the aphid population build up was highly significantly $p<0.05$ and negatively correlated to bean plant height growth, mean number of pods formed, and bean grain yield obtained but was positively correlated to stunting growth observed and the number of bean plants that were infested by *A. fabae*. The plant height was highly significant $p<0.05$ and positively correlated to mean number of pods formed and bean grain yield realized but was negatively correlated to stunting rating sores and the number of plants that were infested by *A. fabae*

Mean bean pods produced was significant $p< 0.05$ and positively correlated to yield obtained but was negatively correlated to bean plants stunting rating score and to the number of bean plants that were infested by *A. fabae*. Bean plants stunting rating score was highly significant $p<0.05$ positively correlated to number of bean plants that were attacked by *A.*

fabae and the aphid population build up but was negatively correlated to bean plant height , number of mean pod set and bean yield obtained. The number of bean plants that were infested by *A. fabae* was highly significant p<0.001 and negatively correlated to bean grain yield realized .

5. DISCUSSION

5.1.1 Effects of integrated management on bean aphid infestation and population build up on bean crop.

The result of this study showed that there was a low infestation and population build up under integrated management combining TSP fertilizer, seed dressing with imidacloprid and foliar spray of *T. vogelii* leaf extract at 20 %w/v compared to control (B-no application of any treatment) at all sampling dates during both long and short rainy seasons **(Fig.1 and 2**). Treatment (AB2S2) combination of 100 kg/ha of tsp + *T. vogelii* at 20%w/v in 20 litres of water + imidacloprid at 700 ml /100 kg seed recorded the lowest *A. fabae* population build up. Reduction of insect population in an integrated management has been reported in previous studies. Indira Gandhi and Gunesakeran (2006), reported minimum population of sucking leaf hoppers, (*Amiruka bigutulla* Ishunda) and cotton aphid, *Aphis gossippi* (Glover) in Okra seedlings planted from treated seeds with Neem oil. Abate and Ampofo (1996) reported good control of bean fly, *Ophiomyia phaseoli* (Tyron) infestation by use of seed dressing chemical before planting. Kumar *et al.*, 2001; Endersby and Morgan 1991 recommended use of seed dressers as an alternative to chemical against sucking pests since they have systemic action after being taken through the root system. This kept the young seedlings of beans free from attack by the *A. fabae* (Mhan and Gujar, 2003). Macharia (1990) reported reduction in cereal aphids infestation in wheat treated with carbofuran before planting followed with application of systemic insecticide after six weeks leading to reduced cereal aphids infestation hence reduced Barley Yellow Dwarf Virus (BYDV) infection on wheat crop.

Continued reduction of *A. fabae* infestation in bean crop on plots under AB2S2 treatment (combination of tsp fertilizer at 100 kg/ha + seed dressing with imidacloprid at 700 ml per 100 kg bean seed + foliar spray of *T. vogelii* leaf extract at 20% w/v on weekly basis) was likely due to health condition of the bean plants as a result of high rate of fertilizer application, seed dressing with Gaucho 350 FS 350 and pesticide effect of the *T. vogelii*. Phosphorus element is needed for proper growth especially in enhancing root development and nodulation in the roots, increase in biomass and yield as was observed in soy bean, cowpea when it was supplied (Seith kai Tague *et al*., 2010). Phosphorus (P) is also essential for sustained productivity of oil crop plants. It is also known to enhance nodulation for nitrogen fixation by leguminous plants (Mhagadhkar *et al.*, 2000. When 100 kg of tsp was applied in integration with seed dressing and foliar spray with *T. vogelii* resulted in high reduction of *A. fabae* population build up.

T. vogelii (Hook) contains retinoid in leaves which are effective in killing numerous pests and its toxicity is lost after five to six days (Barnes and Frayre, 1987). It has been used as an insecticide in various parts of the world (Gaskin *et a*l., 1972). The leaves contain different chemicals which are effective against fish and various insects, these compounds include: rotenone, degualin and tephrosin. Rotenone is a selective non- systemic insecticide containing some acaricide properties. Rotenoid is highly toxic to numerous insects. However, it is of relatively low toxicity to most mammals and is highly biodegradable (Endersby, 1991). In addition to insecticide compounds leaves of *T. vogelii* also contain methoxyisolonchocarpin which is highly effective antifendant as reported by Fukam *et al.*, 1970. It has been used to control maize stalk borer, *Busseola fusca*, (Ogendo *et al.*, 2010). The leaves also forms very good source of manure since it is rich in nitrogen. These properties of *T. vogelii* could have been reasons of low bean aphid population build up when applied.

High bean aphid infestation was observed under treatment A (application of 100, 75 and 50 kg/ ha of TSP only). This means that application of P alone regardless of rate used did not result in reduction of bean aphid infestation and population build up effectively. One of the possible reasons could have been due to due lack of synergy of potassium. In legumes potassium application has been reported to increase root weight together with P. In the absence of potash, plants have been reported to be more susceptible to pests, diseases, salinity, high temperature and dry conditions (Mhgadhkar *et al.*, 2000). This might have been seasons leading to high susceptibility to *A. fabae* infestation when 100 kg /ha of TSP was applied as a treatment alone. The addition of P alone during planting appears not to have protected young bean seedling from *A. fabae* infestation without other controls (Figures 1 and 2). This also indicates that the integration of Treatment A (100 kg of TSP with seed dresser, imidacloprid and application of botanical spray with *T. vogelii* when integrated proved to control bean pests better than those treatments applied singly.

The highest population of aphid infestation on bean crop was observed under treatment B (control Plots) (**Fig.1**). This means that with no control measure put in place bean aphids, (*A. fabae)*, was able to infest its favored host, feed and multiply into big colonies. Under lack of application of control measure, bean aphid was able to multiply faster and infest bean crop and cause extensive destruction to bean crop. P during planting and lack of any control measure resulted in weak plants which were more vulnerable to pests attack. The infestation by aphid on bean crop was higher in the first season compared to the second season (Fig.1). This could have been attributed by the weather conditions on aphid population dynamics. In the first season (May to August 2013), the bean crop was planted late in the season after heavy rains when little rain was realized and prolonged warm dry weather which favored the rapid multiplication and spread of bean aphids. Wanjama (1986) observed that aphid population increase is favoured by warm long dry spell which favours their extreme reproductive capacity up to 10 offspring per day and short life cycles results in several generations of (3 - 4) in one month. This particular behavior could have been the reason for high population builds up observed in the untreated plots. The cool and rainy conditions that prevailed during September, October and November led to slow and late infestation when crop had already established in the field could have been the reasons of slow multiplication of aphids in second season (appendix 1). Heavy rainfall realized during the second season especially during sampling dates reduced infestation of aphids by dislodging them from the plants. This study is in agreement with the findings of the study by Wanjama (1979) who reported high cereal aphid infestation and population increase during prolonged dry spell that followed heavy rainfall. The third sampling week experienced the highest aphid population, thereafter that population started declining. This could have been attributed to the fact that at a high population the aphid colonies were disrupted either due to the feed exhaustion, death due to physical factors such as high temperatures and some might have migrated after developing wing buds and becoming alatae and taking off to new niches so as to survive. This decrease in aphid colonies agrees with the findings of Nyaanga (2002), who reported a decreased number of cereal aphids (*Rhopalosiphum padi, Rhopalosiphum maidis* and *Metopolophium dirhodum)* after overcrowding resulting in development of winged forms, *Alatae*, which are able to take off to new habitats. The sudden decline later in the season could have been also due to sudden death (due to unfavourable conditions, lack of food and migration Stem *et al.*, (1959). In the current study, the decline in aphid infestation could have been attributed to treaments applied depleted host plant, wing development as a result of overcrowding and changes in the environmental condition which many not have favoured their survival in control plots. The early infestation by *A. fabae* on bean seedlings resulted in weak and stunted plants with drying leaves. Destruction by *A. fabae* has been reported by several authors. Bean aphid, *(Aphis fabae)*, injects some toxic chemicals into the plant which hinders its normal growth and development. The puncturing of the tissue by stylets and the covering of plant leaves by sticky substance, honeydew, produced by the aphids on which fungi grow1 causing a ‘’sooty mold’’ which further distort growth by reducing the photosynthetic activity and subsequent tissue formation (Dobson *et al*., 2002). The extent of damage caused the *A. fabae* depends upon the time; size and duration of aphid infestation in relation to the stage of plant growth. When this is repeated several times it may cause death of seedlings. Sucking of sap deprives the plant of assimilates and water, which is required for growth and development (Girouse *et al.,* 2005). Bajwa and Kogan, 2002; CIAT, 2005; Mbaka, 2008) reported a high multiplication rates in aphids occurs due to parthenogenesis and viviparity. Their infestations often result in complete crop loss (The most affected plant stages are seedling stage, vegetative growing stage and flowering stage (Mbaka, *et al.,* 2008). All these factors could have leads to high aphid population built up resulting in stunted growth and death of bean plants.

5.1.2 Effect of efficacy of integrated management on bean plant height during wet and dry seasons.

The shortest plant height was observed in control plots where high bean aphid populations were observed and the tallest was observed under treatment AB2S2, integrated management (application of TSP fertilizer at 100 kg/ha +seed dress at planting with imidacloprid at 700 ml per 100 kg of bean seed + application of foliar spray *T. vogelii* at 20%w/v concentration on weekly basis) in both seasons. The bean plant height continued to increase throughout the experimental periods. The growth generally follows the normal growth curve under favorable growth conditions. In this study the plant height was generally dictated by the treatments applied (fig 6.and 7) The shortest plant was observed in plots where combinations of zero rates of seed dresser- imidacloprid and weekly spray of *T. vogelii* leaf extract spray were applied (fig. 6 and 7). The aphid population was also high in these plots causing stunted growth and malformed leaves hence decreased plant height growth observed. Poor leaf and development under insect pest pressure has been reported. Dobson *et al.*, (2002) reported that under high pest pressure, leaves of plants become crinkled and of poor quality. The quality of plant is obtained when crop has adequate nutrients (right quantities of macro-elements, somewhat genetically controlled aspect (Tisdale *et al.,* 1985). This is even accelerated by under fertilization or over fertilization since some elements may turn to be toxic, causing imbalance in soil nutrients leading to physiological disorders or increase of pest pressure (Tidale *et al.*, (1985). In this study, bean height growth in controlled plots under (treatment B) became stunted in growth and had decreased height compared to plants that received or more treatments two or more control measures (**Fig. 6 and** 7 Decreased plant growth has been reported. Aphids affect plant growth directly through nutrient drain by sap sucking, especially when they are present in large numbers, causing affected plants to have lower water potential, low carbon dioxide assimilation, low soluble carbohydrates and low proteins synthesis hence poor growth (Cabrela *et al.*, 1995).

The high plant height was realized when 100 kg/ha of TSP was combined with seed dressing with imidacloprid at 700 ml per 100 kg bean seed + foliar spray with *Tephrosia leaf extract* at 20% w/v on weekly basis. This implies that application of 100 kg of TSP fertilizer in combination with other control measures helped in reduction of aphid population build up. Dressing seeds with *Imidacloprid* at planting protected seedling from early seedling pests and aphids infestation during early seedling stage. Thereafter, weekly spray using *Tephrosia leaf* extract solution at 20% w/v protected bean crop from serious attack bean aphid. Application of integrated management of pests has been reported. Cornel, (2004), reported reduction of pests in vegetables through integrated approach. P has been reported to stimulate or enhance nodulation for N -fixation. Abate (1991) recommended use of seed dressing insecticides for control of bean fly, *Ophiomyia phaseoli (Tyron*). Jackai (1995), recommended Integrated Pest Management (IPM) in management of pod borers in cowpea by using seed dresser and foliar spray and reported reduction of damage by both bean fly and borers in cowpea vegetables (Kumar *et al.*, 2001; Enders by and Morgan 1991) recommended use of seed dressers as an alternative to chemical against sucking pests since they have systemic action after being taken through the root system. The present study agrees with their findings since all the plots planted with seeds treated with *Imidacloprid in* combinations of TSP fertilizer at *100 kg/ha + T. vogelii at 20o% w/v* had reduced incidences of both BSM (*Ophiomyia phaseoli)* (Tyron) and *Agrotis segetum* infestations and bean aphids, *A. fabae.* All these pests heavily infested all the plots which were not given any control measure and plant heights were significantly reduced (Figures 6 and 7).

In season I, infestation started early in seedling stages of crop growth. Infestation by *A. fabae* during seedling stages resulted in slow and stunted growth and drying of bean seedlings realized in the control plots. The tall plants were realized under treatment AB2S2, combined application of tsp. fertilizer, seed dressing using Imidacloprid and weekly spray of foliar spray of *T. vogelii* at 20%w/v. on weekly basis starting from 30 days after emergence (30 DAE) kept insect pests pressure below economic injury level (EIL) and improved growth was realized.

The tall plants realized under treatment AB2S2, could have been as result of reduction in pest pressure from aphids, bean fly and cutworm reduction through application of seed dresser*, (Imidacloprid)* at 700ml per 100 kg seed before planting followed by weekly application of Biopesticide (Tephrosia leaf extract at 20% w/v) from 30 days after emergence (30 DAE). This kept the pest pressure low and allowed suitable environment for growth (**Fig 10 and 11**)

High pressure of infestation by aphids, realized during the initial stages of growth in season 1 June – July in the control plots might have lowered the general rate of growth especially in the control plots (control) and treatment 2 (application of *T. vogelii* leaf extract spray at 20%w/v concentration) (**Fig. 10**). The decreased plant height in control plot and some in treatment 2in both seasons could have resulted in reduction in rate of nutrient absorption and poor photosynthesis since leaves turned yellowish reducing absorption of light necessary for photosynthesis. Aphids have also been reported to affect plant growth directly through nutrient drain by sap sucking, especially when they are present in large numbers, causing affected plants to have lower water potential, low carbon dioxide assimilation, low soluble carbohydrates and low proteins synthesis hence poor growth (Cabrela *et al.*, 1995). These could have been reasons for poor growth and short plans observed under plots that received zero rates of all treatments applied (the controls).

The highest plant height was observed under application of treatment AB2S2, the combined application of 100 kg TSP/ha at planting + *T. vogelii* leaf extract spray at 20 %w/v in 20 L of water + seed dressing bean seed with imidacloprid before planting at 700 ml/ 100 kg seed of bean followed by treatments AB2 (100 kg /ha TSP fertilizer at planting + botanical foliar spray *T. vogelii* at 20% w/v in 20 litres of water). The plant height growth is usually follows normal curve under favorable growth conditions. In this study the plant growth was generally dictated by the treatments applied. The shortest plants were observed in the plots where no treatment was applied, under treatment B, (controls). The aphid population was also high in these plots causing slow growth, stunting and malformed leaves. Poor leaf development under insect pressure has been reported. Dobson et al., 2007 reported that under high insect presser, leaves of plant become crinkled and of poor quality. The quality of plant is obtained when crop has adequate nutrients (right quantities of micro-elements, somewhat genetically controlled aspect (Tidale *et al*., 1985)

Treatment CB2S2 (75 kg/ ha tsp at planting + botanical leaf extract spray at 20% w/v + imidacloprid as seed dresser at 70 ml per 100 kg seed), and DB2S2 (50 kg /ha TSP fertilizer at planting +botanical spray at 20% w/v in 20 litres of water + imidacloprid as seed dresser at 70 ml /100kg seed of beans) which did not differ significantly. DS2 (50 kg /ha of TSP fertilizer +imidacloprid as seed dresser at 700 ml /100 kg seed), BB2S2 (0 kg/ha TSP fertilizer at planting + botanical spray at 20%w/v in 20 litres of water +imidacloprid seed dresser at 100 kg/100 while shortest plants height was observed under application of treatment B (control no treatment applied). This was followed by treatment D, (application of 50 kg/ha of TSP alone), A- application of 100 kg/ha alone, BS2- (application of 0 rate of Tsp and seed dressing with Imidacloprid at 700ml per 100 kg/ha) while the shortest bean height was observed under application of treatment B (control- none application of treatment). The two rates applied differed significantly $p<0.05$ in the mean number of aphid population build up observed (Figures 6 and 7)

Generally the tallest plant height was observed during the short rainy season compared to that observed during the long rainy season (Figure 7). This could have been as a result of weather conditions which were more favourable for plant growth compared to first season. More rain during second season, low aphid pressure due cold conditions resulting in better utilization of available nutrients could have helped the plant height growth observed.

In the untreated plots, heavy infestation of aphids and high disease symptoms rating scores were recorded. This resulted in stunted growth, with reduced and malformed leaves, poor root formation and reduced nutrient and water absorption. The high intensity was observed in control plots in which high rating scores was achieved **(Fig.12)**. IT has been reported elsewhere that seeds from infested plant will carry on the infection to the bean planted from the same seed.

The use of both indigenous and scientific knowledge on pest management has been reported. Facknath (2000) reported the use Neem leaf extract as foliar spray in controlling Cabbage pests successfully in Mauritius. Mihale *et al.,* 2009; Mugishe- Kamatenesi *et al.,* (2004) reported the use of botanicals in control of pests by farmers in field crops. Ogendo *et al*., 2003a, reported application of *Lantana camara*, *T. vogelii* as an alternative to chemical application in storage when ground to powder form and mixed with grain. *Tephrosia vogelii* leaf extract has been used to control maize stalk borer, *Busseola fusca* in maize crop (Shiberu T, 2013). Namugu (2013) reported the ability of *T. vogelii* in control of field and storage pests of pigeon pea *Cajan us cajan*. In the current study, the application of *T. vogelii* leaf extract at 20%w/v concentration resulted in reduction of mean population of *A. fabae* to low numbers compared to the control plots which had no treatment applied to them. *T. vogelii* as botanical Bio pesticide shrub, (plate) contains rotenone which is poisonous to most insects and has been used in various parts of the world (Gaskin *et al.,* 1972). Rotenoids present in its leaves are effective in killing numerous pests yet its toxicity is lost in five to six days (Barnes and Freyre, 1966). This resulted in reduction in the numbers of *A. fabae*. Weekly spray appeared to have reduced/ disrupted progressive increase in numbers. Sinzoga *et al.,* 2006 in a inefficacy study of various plant extract reported a reduction in incidence and damage of cotton bollworm in cotton when Neem seed extract at 6 kg/ha was used in bollworm gossippiela spp management.

5.1.3 Effect of efficacy of integrated management on bean pod formation during wet and dry seasons in 2013.

The highest number of pods was observed in plots under treatment AB2S2 (application of 100 kg/ha TSP + seed dressing with imidacloprid + foliar spray of *T. vogelii* leaf extract at 20%w/v at concentration applied on weekly basis). The high number of pods realized under treatment AB2S2 led to the control of bean aphids below damaging levels. The application of imidacloprid as seed dresser before planting controlled bean pests during the early seedling stage hence better growth and high pod set realized under treatment AB2S2. The seed dresser was able to keep the bean seedlings free from aphids for the first one and a half months when they are vulnerable to the pests while application of tsp provided P needed for root development. The *Imidacloprid*, the active ingredient of Gaucho^{R}, is a systemic stomach poison, was able to kill the aphids feeding on the sap of bean plant. The chemical is usually translocated into the plant system during germination and this makes the plant sap poisonous to the sucking and chewing pests. Thereafter, the applications of *T. vogelii* leaf extract foliar spray on weekly basis continued to keep the pest population below economic damaging levels. Reduction in pest in an integrated management has been reported by Adebayo *et al.*, (2007) whose results indicated a reduction of pest population density and damage caused in cowpea by insect pest prevalent in many experimental sites in southern Guinea of Nigeria. The use of *T. vogelii* in controlling pest was ranked equal to that of synthetic Decis in pest reduction (KARI, 2006)

Under application of *Imidacloprid* alone, treatment BS2, it was able to keep bean plants free of pests for the first one and a half month then the population of aphids started increasing and low pod set especially in season 1. So the number of pods formed was lower than those formed under treatments AB2S2.

Low pods were produced under treatment B (controls-untreated plots) during both first and second seasons. This could have been attributed by the high aphid infestation which resulted in stunted with distorted growth; thin plants experiencing poor pod formation. Another factor which could have resulted in low pod set was due to seedlings attack by other pests such as bean fly. This resulted in loss of plant population especially in the control plots. Lack of P led to poor root development, inadequate water and nutrients absorption leading to poor plant growth and development.

It has also been reported that potassium application increases pods per plant, number of grains per pod, straw yields and total dry matter. In the absence of potash, plants are more susceptible to Pests, diseases, salinity, high temperature and dry conditions (Mhgadhkar *et al.,* 2000). These conditions could have resulted to reduction in plant growth and bean aphid infestation leading to low pod formation.

In season 2, high number of pods was formed under treatment AS2B2 (planting of treated seeds with 700 ml of imidacloprid +100 kg /ha of tsp fertilizer followed with weekly spray of *T. vogelii* at 20%w/v on weekly basis started 30 days after emergence (30 DAE). The high number of pods realized could have been due to low aphid infestation which was generally realized in the season. This created healthy environment for bean plants growth to full potential hence the production of more pods. The cool environment and generally wet season which prevailed ensured low aphid infestation. The seed treatment protected the plants from early bean aphid attack. The plants high pod production could have been resulted from other abiotic and biotic factors such as weather conditions like temperature and rainfall and absorption of necessary nutrients, low pest incidence respectively during flowering and pod set respectively. The lowest number of pods obtained under treatment B (untreated plots) was due to poor plant stand, poor nutrient supply resulting in weak plants which were easily attacked by the pests. The high aphid attack realized caused sap drain, flower abortion and death of some plant which resulted in poor pod set and development.

Generally, more pods were formed in season 2 compared to those formed in season 1 **(Fig 5 and 6**). The constant availability of rains in season 2 may be one of the reasons of low aphid infestation during seedling stages hence less damage was caused by pests on bean crop growth. It has also been reported that potassium application increases pods per plant, number of grains per pod, straw yields and total dry matter. In the absence of potash, plants are more susceptible to pests, diseases, salinity, high temperature and dry conditions (Mhgadhkar *et al.,* 2000).

5.1.4 Effect of efficacy of integrated management on bean plant stunting rating scores during season 1 and 2.

The highest rating score on scale of 1-6 was observed under treatment B (0 rates of tsp fertilizer +Imidacloprid + *T. vogelii*) while the lowest rating score was observed under integrated application of treatment AB2S2. (Figure 8 and 9)

During season 1 infestation started early in seedling stages of crop growth. Infestation by *A. fabae* during seedling stages resulted in slow and stunted growth realized in the control plots. In the plots where no treatment was applied, that is combinations of zero rates of tsp fertilizer + *T. vogelii* and imidacloprid, high aphid population build up was realized. The high aphid resulted in stunted growth. High pressure of infestation by aphids, realized during the initial stages of growth in season 1 June – July in the control plots might have lowered the general rate of growth especially in the control plots (control) and treatment 2 (application of *T. vogelii* leaf extract spray at 20%w/v concentration) (**Fig. 8 and 9**). The decreased plant height in control plot in both seasons could have resulted in reduction in rate of nutrient absorption and poor photosynthesis since leaves turned yellowish reduced absorption of light necessary for photosynthesis. Aphids have also been reported to affect plant growth directly through nutrient drain by sap sucking, especially when they are present in large numbers, causing affected plants to have lower water potential, low carbon dioxide assimilation, low soluble carbohydrates and low proteins synthesis hence poor growth (Cabrela *et al.,* 1995). These could have been reasons for poor growth and short stunted bean plants observed under plots that received zero rates of all treatments applied.

During the short rainy season, the highest rating score on stunting was observed under application of treatment B (zero rate of *T. vogelii* at 20 %w/v + seed dressing with imidacloprid at 700 ml per 100 kg seed. This implies that under zero rates of all treatments applied, the bean aphid, *A. fabae* was able to infest the bean plants and cause stunting symptoms observed while the lowest rating score was observed under application of treatment AB2S2 (100kg/ha. of TSP fertilizer +T. vogelii at 20 %w/v + Seed dressing bean seed with Imidacloprid at 700ml) (figure 9)

Generally, the highest rating score of bean stunting was recorded during long rainy season compared to the short rainy season (figure 8 and 9). This could have been as a result of late planting. The bean crop was planted in the mid may when rains had subsided and pest population pressure had started building up. The pest population build up during warm dry spell following heavy rainfall has been reported. (Wanjama, 1979), reported high wheat aphid population build up during warm dry spell following heavy rainfall. In this study, high *A. fabae* population build observed during seedling stage of bean crop which resulted in nutrient depletion and stunted growth in the plots which did not receive any treatment.

5.1.5 Effect of efficacy of integrated management on number of bean plants infested by bean aphid, *A. fabae* during long and short rain seasons.

The highest number of bean plants attacked by bean aphid (*A. fabae*) was higher in plots under treatment B (zero rates of TSP fertilizer, imidacloprid and *T. vogelii* and in all plots given single application of treatments while the lowest number of plants infested was observed in plots under application of integration management including Tsp fertilizer at 100 kg/ha + *T. vogelii* at 20%w/v + seed dressing bean seed with imidacloprid at 700 ml per 100 kg bean seed before planting (Figure 10 and 11). The highest number of plants attacked by *A. fabae* observed under 0 rate of treatments applied implies that plants that with no control measure put in place, bean aphid is able to infest bean crop rapidly causing poor growth. Also else where it has been reported that plants not supplied with nutrients become weak and usually succumb to pressure from pests attack (Mhagadhkar *et al., 2000*). The importance proper nutrient to plants for better growth has been reported. Dobson *et al*., 2002 reported that under high insect pest pressure, the leaves become crinkled and of poor quality. On the other hand quality plants are obtained when crop has adequate nutrients, (right quantities of macro-elements somewhat genetically controlled aspect (Tisdale *et al.,* 1985). Over fertilization or under fertilization with either of the elements may be toxic, causing imbalance in soil nutrients leading to physiological disorders or may lead to increase in pest pressure. In this study, the high number of plants attacked in an untreated plot indicated that the plants that were not supplied with P. lacked nutrients and therefore became vulnerable to pest attack at an early stage compared to those supplied with P and least control measures under taken.

The low number of plants attacked under the use of two or more control measures in combination implies that application of two or more control measure against bean aphids was able keep the bean aphids at low population better than those treatments applied singly against bean aphid. Low pest infestation has been reported in an integrated pest management.

During the short rainy season, the highest stunting rating score on bean common was observed under treatment B (0 rate of application of *T. Vogelii* + Imidacloprid + tsp fertilizer while the lowest rating score was observed under treatment AB2S2 -the application of 100 kg/ha of Tsp fertilizer +20%w/v of *T. vogeli*. + seed dressing with Imidacloprid at 700 ml per 100 kg seed during both seasons 1 and 2. All the treatments applied singly were observed to have high A. fabae infestation (figure 11). Generally, more bean plants were attacked by bean aphid, *A. fabae* during the long season compared to those attacked during the short rainy season (Figures 10 and 11)

5.1.6 Effect of efficacy of integrated use of fertilizer, seed dressing, and bio-pesticide spray on bean yield during long and short rainy seasons

Low yield was observed in untreated plots during season 1, compared to season 2 (Fig 12). The unfavorable growth conditions such as high warm temperatures coupled with dry spell favoured multiplication and development of bean aphid population build up. In control plot, under treatment B bean leaves crinkled due to high pest pressure and pronged dry spell in mid-season 1. The heavy aphid infestation then resulted in drying and stunted growth of bean plants. The bean fly infestation resulted into the death of some plant hence reduction in numbers of plants in control plots. The high aphid population build up with increased infestation resulted in low flower set and abortion resulting in low yield realized. Low crop yields due to insect pest have been reported. Aphid species cause extensive destruction of plant tissue through the injection of toxic saliva. Sugary excretions of aphids (honey dew) attract saprophytic fungi on leaf surfaces which cause accelerated aging and reduced photosynthetic area (Mink and Harrenwjn, 1989; Dixon, 1997). All Aphids affect plant growth directly through nutrient drain by sap sucking, especially when they are present in large numbers, causing affected plants to have lower water potential, carbon dioxide assimilation, soluble carbohydrates and proteins (Cabrela *et al.*, 1995). Since these nutrients are needed for plant growth, aphid infestation slows the rate of stem elongation and leaf production and decreases flower production. Aphid feeding may also cause substantial water loss with subsequent wilting and collapse. Damage on plants is done by both adults and nymphs which pierce plant tissue to suck sap thereby transmitting virus which results in stunted growth, distortion of leaves and. reduction in yield. Bean aphid, *(Aphis fabae)*, injects some toxic chemicals into the plant which hinders its normal growth and development. Further puncturing of the tissue by stylets and the covering of plant leaves by sticky substance produced by the aphids called honeydew on which fungi grow causing a ‘’sooty mold’’ which further distort growth by reducing the photosynthetic activity and subsequent tissue formation (Dobson *et al*., 2002). The extent of damage caused the *A. fabae* depends upon the time; size and duration of aphid infestation in relation to the stage of plant growth. When this is repeated several times it may cause death of seedlings. Sucking of sap deprives the plant of assimilates and water, which is required for growth and development (Girouse *et al.,* 2005). Due to parthenogenesis and viviparity, aphids have a high multiplication rate. Their infestations often result in complete crop loss (Bajwa and Kogan, 2002; Mbaka, 2008). The most affected plant stages are seedling stage, vegetative growing stage and flowering stage (Mbaka, *et al.*, 2008). All these factors may have resulted in very low yields realized under zero application of treatments.

High yield was realized under treatment AB2S2, (integrated application of 100 kg/ha tap + seed treatment with Imidacloprid + foliar spray with *Vogelii* at 20%w/v leaf extract). The weekly spray of *Tephrosia Vogelii* leaf extract at 20% w/v after initial application of *Imidacloprid* as seed dresser kept the bean pests population at low levels. The integration of three treatments appeared to have improved the capacity of plant to grow well and was able to absorb nutrient. It has been reported that P is needed for proper productivity usually added as inorganic phosphates because free inorganic P in soil solution plays a central role in P-cycling and plant nutrition. It is needed for increased plant growth by allowing proper root development hence better nutrient uptake. Abate, (1991) recommended use of seed dressing insecticides for control of bean fly, *Ophiomyia phaseoli (Tyron*). Jackai (1995) recommended Integrated Pest Management (IPM) in management cow pea borers using seed dresser and foliar spray and reported reduced damage by both bean fly and cowpea borers. In this study, application of tsp at 100 kg/ha plus seed dressing bean seed with imidacloprid at planting significantly reduced pest infestation in bean crop for the first 30 days after emergence (30 DAE). The use *Biopesticide, (Tephrosia leaf extract* at 20% w/v) also reduced aphid incidence. The combined use of both *Imidacloprid* and *Tephrosia vogelii (*Hook) *leaf extract* was able to reduce bean aphid (*A. fabae)*, cutworm (*Agrotis segetum*, and bean fly (*Ophyomia phaseoli*) pressure on bean crop resulting in high yield compared to untreated bean plots (controls) that is plots that received zero rates of treatments applied.

Generally a high yield was observed during the short rainy season compared to that observed during long rainy season

6. CONCLUSIONS

Based on the findings of this research, it can be concluded that:

- The aphid population builds up and damage in bean crop was significantly reduced when combined application of treatments of seed treatment using Imidacloprid at 700 ml/100kg seed was done on bean seed before planting and planting with 100 kg/ha of TSP fertilizer, then followed with a Biopesticide foliar spray of *T. vogelii* at 20%w/v from 30 days after emergence (30DAE) thereafter spraying on a weekly basis better than any other treatment applied.
- The application of *T.vogelii at* 20%w/v alone on weekly basis significantly reduced bean aphid infestation better than control and application of seed dress alone.
- Use of seed dressing alone is only temporary measure during seedling stages and should be supported with other control measure one month after crop emergence as it does not provide complete control of bean aphid infestation for the whole season during bean growth.
- The integration of TSP fertilizer, seed dresser, and application of foliar spray of Tephrosia leaf extract at 20%w/v greatly reduced *Aphis fabae* infestation and population build in bean crop below damaging levels and resulted in improved bean grain yield
- Application of TSP fertilizer rates alone did not seem to have effect on bean aphid infestation on bean crop as population build up was observed under all the rates applied.

7. RECOMMENDATIONS

- This experiment could be repeated in a controlled environment such as greenhouse in which other pests and variation in environmental factors could be minimal
- The experiment could be repeated using NPK fertilizer at the recommended rate but vary the rates of *T. vogelii* concentration rates to determine whether lower rates such as 5%, 10%, 15% w/v could still control bean pest.
- The bean aphid migration and seasonal movement is not well understood in Kenya. This calls for study on their seasonal movement using traps placed strategically in the field to monitor their presence in the fields. This will help in determining the populations build up circle and avoid sudden pest infestations on bean crops.

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