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Analysis of Efficacy of Integrated Pest Management (IPM) on Bean Aphid Invasion *(Homoptera: Aphididae)* on Bean Crop (*Phaseoli vulgaris* L.*)* in Western Kenya Region

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Abstract: ***Bean (Phaseolus vulgaris) is the most important food legume; however there is an increasing decline in performance 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. 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 beans.***

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

1. Introduction

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)

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

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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 the virus 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 Trans Nzoia 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- Kitale. The area lies at an average altitude of 1,900 meters above sea level at latitude of 1°1'8.72"N and longitude of 35°0'8.3"E. There is a bimodal rainfall in Kitale and averages to 1097 mm, with precipitation even during the driest month. The Köppen-Geiger climate classification is Cfb. The average annual temperature is 18.3 °C (Jaetzold and Schmidt, 1983). The area has a high variation in temperature ranging from 10.5 ºC min –25.5ºC max within the year thus favoring growth of agricultural crops within the area. 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 Trans Nzoia 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;

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- 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 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

3.6.3 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 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 ($P<0.05$).

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.

4.1.1 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

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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)

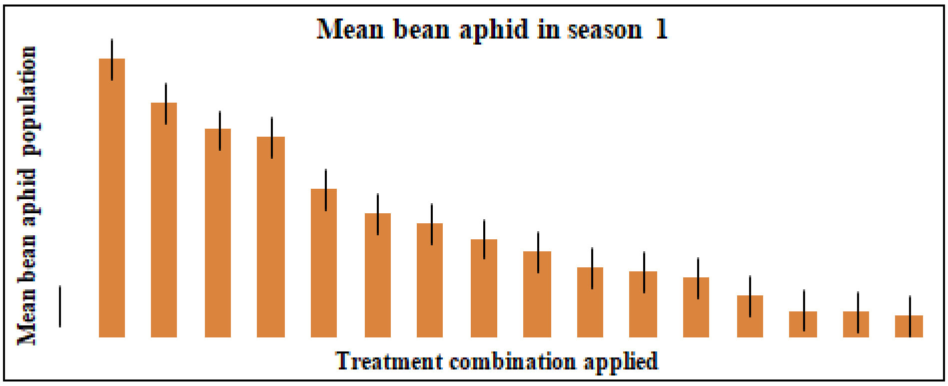

Figure1: Treatment influence on bean aphid in season 1

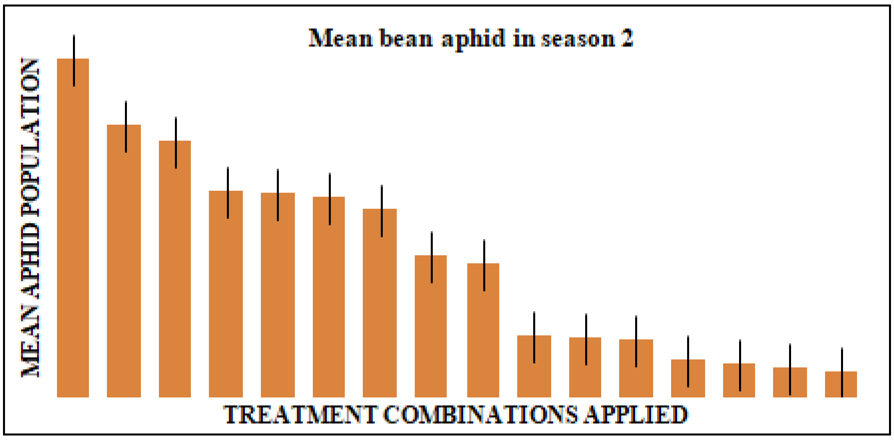

Figure 2: Treatment effect on bean aphid population build up in season 2

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 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).

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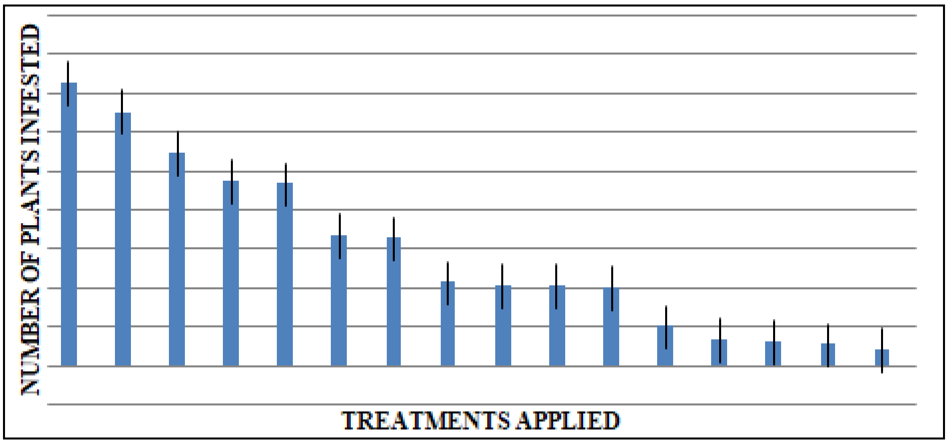

Figure 9: Number of bean plants infested by *A. fabae* in season 1

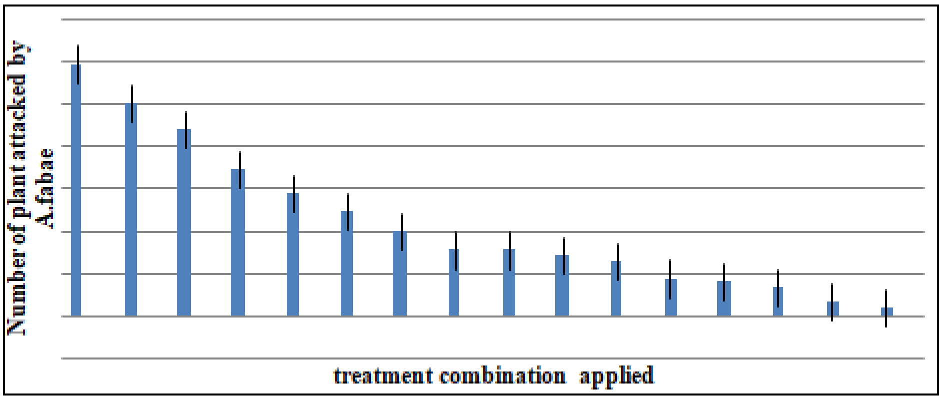

Figure 10: Number of bean plants infested by *A. fabae* in season 2

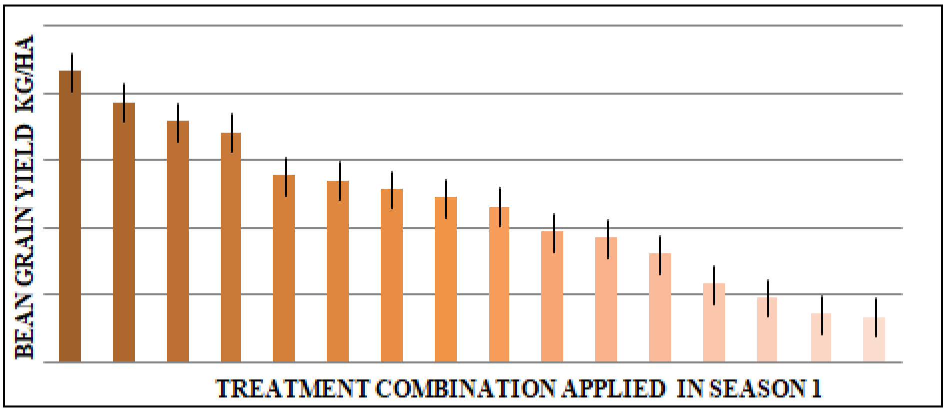

Figure 11: Bean grain yield in season 1

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)

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

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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

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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 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 9 and 10). 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)

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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