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# Effectiveness of Different Plant Extract for the Control of Black Bean Aphids and Abundance of Beneficial Insects on Common Beans

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***3.0 Abstract***
*Experiment was conducted at Ndugutu village, Morogoro from December, 2020 to August, 2021 to investigate effects of three selected pesticidal plant extracts on the abundance of Black Bean Aphids (BBAs) and beneficial insects on common bean crop. A Randomized Complete Block Design with three replications was used with pesticidal plant species extracts of Dysphania ambrosioides, Vernonia amygdalina and Derris trifoliata leaves with three different concentrations (i.e. 140, 200 and 240) g/L as treatments. Results show that there was a significant difference (p= 0.0001) amongst different treatments. Among other pesticidal plants, V. amygdalina with concentration of 140, 200 and 240) g/L and D. trifoliata 240 g/L were the most effective on the reduction of abundance of aphids and incidence during dry season. The beans yield difference was significant (p = 0.010) across treatment during the two seasons. The second, highest bean yield was recorded in bean plots treated with D. trifoliata and D. ambrosioides with a concentration of 240 g/L each contributing to a mean average of (993.5 and 1165.7) kg/ha whereas lowest being D. trifoliata at 200 g/L with a mean average of (494.7) kg/ha. This study has demonstrated that pesticidal plant extracts have ability to control insect pest population. Therefore, the studied pesticidal plants should be considered in Integrated Pest Management due to their good management efficacy and safety issues for the consumers' and environment.*
***Keywords:*** *Pesticidal plants, Synthetic pesticides, black bean aphids, beneficial insects, common bean*

## 3.1 Introduction
A common bean (*Phaseolus vulgaris* L.) worldwide it creates 50 % of the most common grain legume consumed globally (Singh *et al.*, 2013). According to Binagwa *et al.* (2016), the crop is grown in East and South African countries and it is the second staple food after maize. Common bean contributes to about 38% dietary protein and 12-16% of daily calorific requirements for low-income families in both rural and urban areas (Sibiko *et al.*, 2013). Seventy-eight percent of total legumes are cultivated in Tanzania and more than 75% in rural household families depend on beans for their daily life (Birachi *et al.*, 2021). Tanzania ranks top in Africa and seventh in the world in common bean production (FAOSTAT, 2019). In Tanzania, common beans are mostly cultivated in Southern highland zone, Western zone, Lake Zone and Northern zone (Mwanauta *et al.*, 2015; Birach *et al.*, 2020). The average common beans yield in Tanzania under smallholder farmers ranges from 0.888 to 3 t/h less compared to the world average of 3.9 t/ha (FAOSTAT, 2019; Hillocks *et al.*, 2006; CIAT and World Bank, 2017). This low output is caused by biotic and abiotic factors, poor markets and low production technology (Hillocks *et al.*, 2006). Black Bean Aphids (*Aphis fabae*) has been identified as the main constraints among other factors to common bean production

(Mwanauta *et al*., 2015). Wosula *et al.* (2016) reported that feeding effect of Black Bean Aphids can cause up to 90% of common bean yield losses.

Synthetic pesticides have been generally used to control common bean pest's despite of challenges resulted due to their use comprising environmental biodiversity effect, human health effect and non - target organisms for instance pollinators and natural enemies (Raghavendra *et al*., 2016; Moshi and Matoju, 2017). Moreover, synthetic pesticdes are commonly expensive for smallholder farmers to buy (Grzywacz *et al.*, 2014). This high prices can be a challenging to afford, regardless of high crop yields.

Therefore, an alternative to synthetic pesticides, there are various pesticidal plant extracts which are safer than expensive and harzardous synthetic pesticides which can be used to control various crop insect pests (Dougoud *et al*., 2019). These pesticidal plants extract contain secondary metabolite which offer repellent, attractant and poison chemical substances for the control of various insect pests as described by Regnault-Roger *et al.* (2012); Isman (2016) and Mpumi *et al.* (2016). Other researchers such as (Tembo *et al.* 2018; Mkenda *et al.* 2015) reported that *V. amygdalina* extract was used to control hemipteran and lepidopteran field crop insect pests and coleopteran storage pests. On other hand, Tapondjou *et al.* (2002) reported the use of *D. ambrosioides* for the control of *C. maculatus* on stored cowpeas. Additionally, rotenone extract from *D. trifoliata* has shown effectiveness against wide range of insects including earthworms and fish a report by Peter and Sivasothi (1999) and Tony and Jane (1996). These information paves way for further research to assess pesticidal plants in controlling crop insect pests and their impact on beneficial insects in agricultural production. The aim of this study therefore was to evaluate three pesticidal plants namely *Derris trifoliata*, *Dysphania ambrosioides* and *Vernonia amygdalina* for their effectiveness in controlling insect pests and their impact on beneficial insects for two seasons.

## 3.2 Materials and Methods

### 3.2.1 Description of experimental sites

This study was carried out in Mvomero district in Morogoro Region in Tanzania at Ndugutu village. The experiment commenced from December, 2020 to August, 2021. Ndugutu village lies between latitudes of 7°5'33.8″S and longitudes of 37°34'22.7″ E with elevation of 1625 m.a.s.l which receives bimodal rainfall pattern ranging from 800- 1600 mm per annum with a mean temperature ranging from18$^0$C to 26$^0$C. The short rains start from November to February while long rain are between March to April with relatively short dry spells between mid-May to September (Hashim *et al*., 2018).

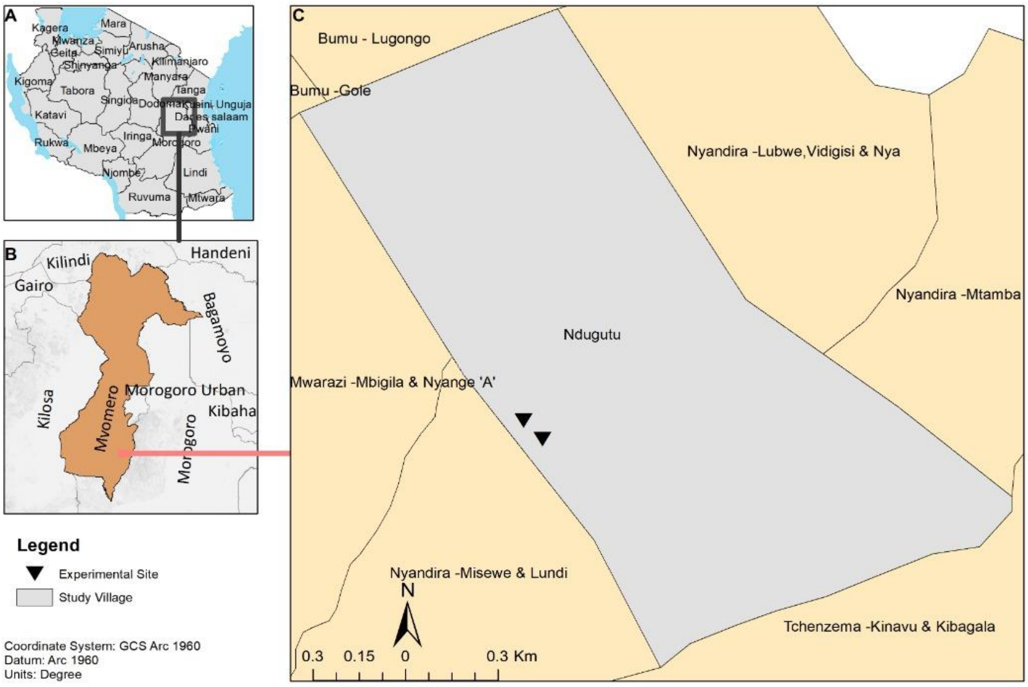


**Figure 3.1: Map of part of Morogoro showing village where the study was conducted**

### 3.3 Materials

#### 3.3.1 Sources of bean seed, botanicals and synthetic pesticide

Common bean known as Kipapri was obtained from local market at Nyandira market. According to Mgeta farmers, they preferred Kipapri because it has a characteristic of high weight, high yield and cook fast and good taste. Pesticidal aqueous solution from Spiny coriander/worm seed (*D. ambrosioides*), Bitter tea (*V. amygdalina*) and three leaf derris (*D. trifoliata*) were applied for the control of Black Bean Aphids.

IMIDA C344SE (Active ingredient; Cypermethrin 144 g/ L +Imidacloprid 200 g/L) as positive control and was bought from Agro dealers in Morogoro Municipal while plots without application of any chemical were treated as a negative control.

#### 3.3.2 Preparation of pesticidal plants leaf aqueous solution

Plate 3.1 shows fresh leaves from *D. ambrosioides* (a), *V. amygdalina* (b) and *D. trifoliata* (a) being processed to final pesticidal leaf extract up to spraying. The part of the plant materials collected were not very old or very fresh in order to acquire high concentration chemical compounds (Stevenson *et al.*, 2016).


**Plate 3.1: Weighing and crushing of pesticidal plant species (a, b and c), Storage of pesticidal extract in containers (d) and Spraying a prepared solution on bean plots (e).**

Source: (Photos: M. Richard – Ndugutu Village, Nyandira Ward, Mvomero –Morogoro).

The leaves were weighed to get (140, 200 and 240 g) of each crude leaf extracts respectively. The weighed leaves were crushed using Mortar and pestle until they are soft. Grinding of pesticidal plants into uniform small size less than 0.5mm was done to increase the extraction efficiency of a required biochemical compunds (Chuo *et al.*, 2022) and then the crushed leaves were soaked into separate plastic containers containing 1litre of water to make concentrations of (140, 200 and 240 g/L) respectively. According to (Belmain *et al.*, 2012; Ikechi–Nwogu and Omeke, 2020) water was used as a universal solvent to extract the required materials from selected pesticidal plants.

Two milliliter of potash based soap was added in each liter of solution to aid in extraction of chemical compound and as adjuvant (Kaputa *et al.*, 2015). Each individual concentration of pesticidal aqueous solution was soaked in water for 24 hours in a tight covered container at a room temperature ($25^0$C). The solution was filtered using muslin cloth. One milliliter of IMIDA C344SE (Active ingredient; Cypermethrin 144 g/L + Imidacloprid 200 g/ L) per 1liter of water at application rate of 0.5L/ ha was used as a positive control and without application of any pesticide was treated as a negative control. Pesticidal extracts were prepared each time of application early in the morning or late in the afternoon in order to avoid photo degradation nature of pesticidal plant extracts (Onunkun, 2012). The prepared concentrations at every 15 days' interval of application were immediately sprayed after filtration using 1liter hand sprayer at after 30 days since sowing and was repeated three times.

### 3.3.3 Methods and experimental design

An experiment was laid down in split plot layout under Randomized Complete Block Design (Gomez and Gomez, 1984) with three replications. The experiment had two factors "Main factors" and "Sub factors". Main factors were treated in the main plot with three concentrations (140, 200 and 240 g/L) of pesticidal plants. Sub factors consisted of three treatments of *D. ambrosioides*, *V. amygdalina*, *D. trifoliata,* IMIDA C344SE and control. A bean crop field was established measuring a total area 2184 $m^2$. The main and subplots were separated by two and one meters, respectively. Kipapri common beans was planted at 50 cm x 20 cm spacing in each plot. Each plot had four-meter square with five rows consisting 10 plants per row. All recommended agronomic practices were carried out as required such as Diammonium Phosphate (DAP) fertilizer five grams per hole was used as basal dressing and five grams of Sulphate of Ammonia (SA) was applied as top dressing, weeding and Master King fungicides was applied every week due to high rainfall, relative humidity which favour development of fungal diseases.

**Table 3.1: General treatment structure**

| Botanicals | Concentration | | | | |
|---|---|---|---|---|---|
| 1. *D.trifoliata* | *D. trifoliata-1* | *D. trifoliata-2* | *D. trifoliata-3* | Synthetic | Control |
| 2. *D.ambrosioides* | *D.mbrosioides-1* | *D. ambrosioides-2* | *D.ambrosioides-3* | Synthetic | Control |
| 3. *V.amygdalina* | *V. amygdalina-1* | *V. amygdalina-2* | *V. amygdalina-3* | Synthetic | Control |

*Derris trifoliata* 1, 2, 3- Concentration of 140 g, 200 g and 240 g
*Dysphania ambrosioides* 1, 2, 3- Concentration of 140 g, 200 g and 240 g
*Vernonia amygdalina* 1, 2, 3- Concentration of 140 g, 200 g and 240 g
IMIDA C344SE – One milliliter/L of water and Control- Without any chemical application

## 3.4 Data Collection

### 3.4.1 Abundance of aphids and beneficial insects

Number of aphids were counted from six randomly selected plants from second plant subsequently every fourth plant in third middle rows inside the $4m^2$ in each plot at 5 and 10 days from 5 cm apical twig of sample plant before the next spraying, this is a newly growing part of the plat where most of aphids prefer. Incidence of Black bean aphids was recorded as either zero (0) for absence or one (1) for presence of aphids and then expressed as percentage of plants with aphids over total number of plants sampled in each plot. Aphid count for damage and severity was done by visual inspection and by using magnifying hand lens (x30-21mm) as designed by El Fakhouri *et al.* (2021). Number of aphids per $4m^2$ were recorded for their abundance and severity of damage in a weekly basis by using scale of 0 - 5 as described by Wosula (2016); Mkenda *et al.* (2015).

**Table 3.2: Abundance and severity scoring scale**

| Abundance | Severity of damage (%) |
|---|---|
| 1 = 1- 150 | 1 = 1-5 |
| 2 = 151 - 300 | 2 = 6 -25 |
| 3 = 301 – 450 | 3 = 26 -50 |
| 4 = 451 - 600 | 4 = 51 -75 |
| 5 = Over 601 | 5 = 76 -100 |

The lowest abundance ranging from one to over 601 were used to denote the low to high level of aphid's abundance and percentage raging from one to 100 denote low to high severity of damage of aphids.

### 3.4.2 Beneficial insects

Yellow and green colour pan traps and pitfall traps (Plate 3.2) were used to capture the number of beneficial insects. Sampling insects per trap was done based on their species level in each plot as described by Awal *et al.* (2015). A yellow and green plastic dish of 6 cm height and 12 cm diameter having a mixture of water with 2% mild detergent which breaks the surface tension of the water were placed above the ground level. A total of one hundred twenty-six yellow and green pan traps were used in two experimental units. The traps were set weekly in two replicates in each plot for a period of 24 hours. Flying insects landing on the surface of the water in the traps were trapped, collected and preserved in a small plastic bottle filled to half with 70% ethanol for both methods. Similarly, a total of one hundred twenty-six pitfall traps having 10 cm diameter and 18 cm deep were used to trap at ground level for two experimental units. Two traps were placed in each plot and mouth of each pot was kept at the ground level so as to obstruct insect movement. The pitfall traps were set weekly in replicates for a period of 24 hours. Insects were collected and counted separately from each plot. Trapping continued until 60% common bean senescence was attained. After 24 hours, the trapped insects were emptied into a small plastic bottle filled to half with 70% ethanol for preservation.


**Plate 3.2: Arrangement of pan and pitfall traps for assessment of beneficial insects on bean field**
Source: (Photos: M. Richard – Ndugutu Village, Nyandira Ward, and Mvomero –Morogoro).

### 3.4.3 Insect species identification

Taxonomic identification of specimens was conducted at Sokoine University of Agriculture Entomology Laboratory (Plate 3.3). Identification of beneficial was done using standard keys using morpholgical features (Buck *et al.*, 2009; Kirk-Spriggs and Sinclair, 2017; Packer *et al.*, 2007). Identified number of species were counted and recorded.

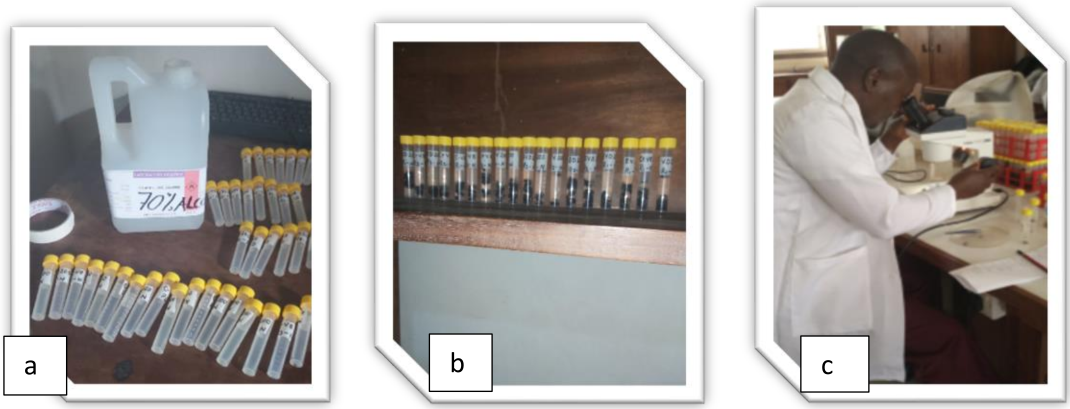

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**Plate 3.3: Alcohol diluted to 70% transferred in vials (a) Beneficial insects stored in vials (b) and Identification of beneficial insects in labolatory (c).**

Source: (Photos: M. Richard – Labolatory SUA-Morogoro).

### 3.4.4 Common bean yield

Yield of beans per plot was measured after threshing, this was done by randomly selecting six plants harvested from the three middle row per plot (Plate 3.4). Harvested beans were dried on screen house at SUA for three days. There after weight of beans in gram was calculated and then converted into yield in kg/ha. Samples of beans were weighed by using electronic weighing scale at 12.5% moisture content and measured by using Sparex Moisture Meter (Plate 3.5a, b and c).

Beans weight calculation formula; $$Y = \frac{[(100-K)]}{[(100-12.5)]} * J$$

Whereas Y is adjusted weight of sample, J is weight of measured sample (g), K is measured moisture of sample.

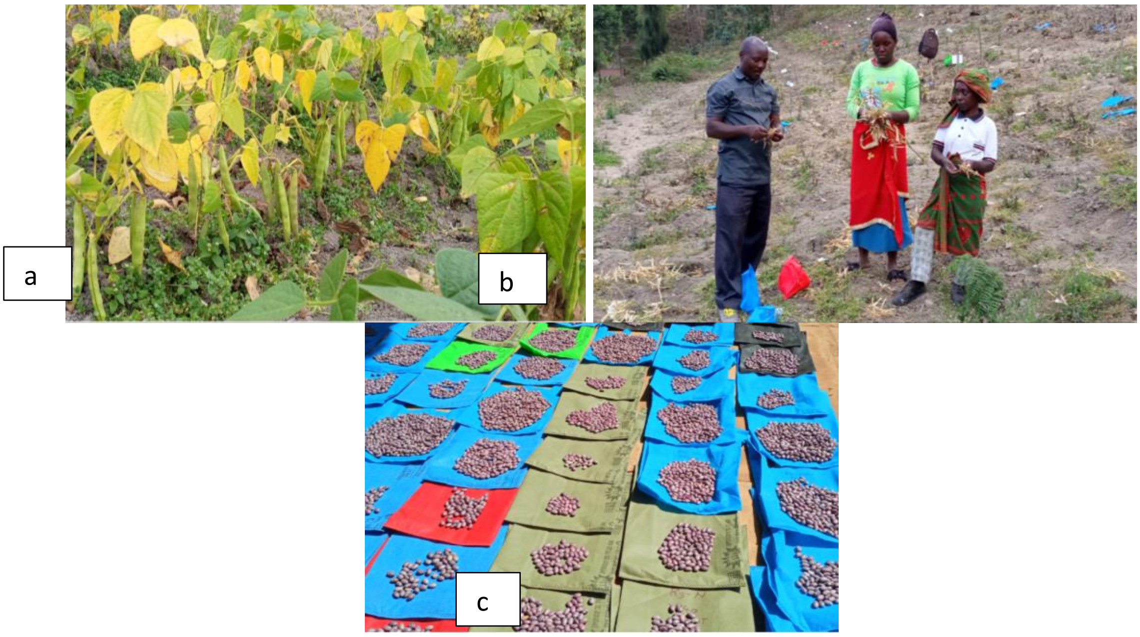


**Plate 3.4: Matured bean pods (a) Threshing harvested bean pods (b) and Drying threshed bean seeds (c).**

Source: (Photos: M. Richard – Ndugutu Village, Nyandira Ward – Mvomero –Morogoro.


**Plate 3.5: Electronic weighing scale and sparex moisture meter (a) Recording bean moisture content (b) Weighing bean seeds on electronic weighing scale (c).**

Source: (Photos: M. Richard – SUA, Morogoro).

### 3.5 Data Analysis

Data of abundance of beneficial insects, aphids, incidence and severity collected were subjected to Analysis of Variance (ANOVA) at 5% level of significance using XLSTAT 2015.01.41366 using the following model.

$Y_{ijk} = \mu + R_i + L_j + (RL)_{ij} + T_k + (LT)_{jk} + \mathcal{E}_{ijk}$

Where, $Y_{ijk}$ is the response variables; μ is the general mean effect, $R_i$ is the jth effect of replication, $L_j$ is the jth effect of level/concentration, $(RL)_{ij}$ is the ith and jth effect (main plot error), $T_k$ is the kth treatment effect, $(L_j)_{jk}$ is the jth and kth interaction effect and $\mathcal{E}_{ijk}$ is the experimental error. Significance different between the means of treatments were separated by Tukey's and Least Significance Difference ($LSD_{0.05}$).

### 3.6 Results

### 3.6.1 Abundance of black bean aphids

The total number of aphids collected in an area of $2184m^2$ at Ndugutu village during December, 2020 to August, 2021 of study period was 22018 (Table 3.3). Results showed that 8098 total aphids contributing to 36.78% were collected during wet season while 13920 with 63.22% being collected during dry season contributing to 100% of total Black Bean Aphids collected for each season

### 3.6.2 Abundance of Beneficial insects

A total of 2642 specimens belonging to four families and 25 species were collected during the entire study period. Results indicated that 70.67% of the total individuals were collected during wet season and the rest 29.33% were collected during dry season. *H. rubicundus* during wet and dry season were the most abundant pollinators recorded contributing to (15.91% and 31.87%) respectively. In addition, the second most abundant insect during wet and dry season was the *S. spilogaster* (8.94%) and *A. amphitrite* (24.77%). However, the least species found during wet season were the *S. carnaria* (0.54%), *L. sablense* (0.59%) and *L. Curtis* (0.59%) *and* all the three were not identified during dry season. Furthermore, the highest total percentage contribution of species during the entire study period were the *H. rubicundus* (20.59%) and *A. amphitrite* (10.86%) whereas the lowest were the *S. carnaria* (0.38%). However, it was observed that for most insect species, higher abundance was observed during wet season with few exceptions of *A. amphitrite, H. ligatus, H. farinosus* and *C. rufifacies* which the highest abundance was recorded during dry season.

**Table 3.3: Total numbers of beneficial insects and Aphids associated with common bean crop collected from Ndugutu Village in Mvomero District**

| A | Identified insect pest | Wet season Number/ (%) | Dry season Number/ (%) | Total Number/ (%) |
|---|---|---|---|---|
| 1 | *Aphis fabae* | 8098 (36.78) | 13920 (63.22) | 22018 (100) |
| **B** | **Beneficial insect** | | | |
| 1 | Orange legged furrow bees (*Halictus rubicundus*) | 297 (15.91) | 247 (31.87) | 544 (20.59) |
| 2 | Sweat bees (*Augochlora amphitrite*) | 95 (5.09) | 192 (24.77) | 287 (10.86) |
| 3 | Red tailed flesh fly *Sarcophaga spilogaster* | 167(8.94) | 35(4.52) | 202 (7.65) |
| 4 | Flesh fly (*Sarcophaga Africa*) | 165(8.84) | 16(2.06) | 181 (6.85) |
| 5 | Oriental latrine fly (*Chrysomya megacephala*) | 161(8.62) | 8(1.03) | 169 (6.40 ) |
| 6 | Blow fly (*Chrysomya putoria*) | 160(8.57) | 15(1.94) | 175 (6.62) |
| 7 | Green bottle fly (*Chrysomya albiceps*) | 139(7.45) | 20(2.58) | 159 ( 6.02) |
| 8 | Green bottle fly (*Chrysomya bezziana*) | 126(6.75) | 14(1.81) | 140 (5.30) |
| 9 | Ligated furrow bees(*Halictus ligatus)* | 28(1.50) | 72(9.29) | 100 (3.79) |
| 10 | Brown winged Furrow bees (*Halictus farinosus*) | 46(2.46) | 61(7.87) | 107 (4.05) |
| 11 | Green bottle fly (*Lucilia sericata*) | 120(6.43) | 1(0.13) | 121 (4.58 ) |
| 12 | True fly (*Blaesoxipha erythrura*) | 84(4.50) | 2(0.26) | 86 (3.26) |
| 13 | Blow flies (*Chrysomya phaonia*) | 50(2.68) | 10(1.29) | 60 ( 2.27) |
| 14 | Sheep blowfly (*Lucilia cuprina*) | 46(2.46) | 0(0.00) | 46 ( 1.74) |

| | | | | |
|---|---|---|---|---|
| 15 | Hairy maggot blowfly (*Chrysomya rufifacies*) | 16(0.86) | 24(3.10) | 40 ( 1.51) |
| 16 | Housefly (*Musca domestica*) | 16(0.86) | 15(1.94) | 31 (1.17) |
| 17 | Grey flesh fly (*Sarcophaga bullata)* | 33(1.77) | 18(2.32) | 51 (1.93) |
| 18 | Regal blowfly (*Chrysomya marginalis*) | 26(1.39) | 4(0.52) | 30 (1.14) |
| 19 | Marsh green bottle *(Lucilia silvarum)* | 20(1.07) | 2(0.26) | 22 (0.83) |
| 20 | House fly (*Muscina levida*) | 13(0.70) | 8(1.03) | 21 (0.79) |
| 21 | Sweat bee (*Augochlora iphigenia*) | 12(0.64) | 9(1.16) | 21 (0.79) |
| 22 | Green bottle flies (*Lucilia ampullaceal*) | 15(0.80) | 2(0.26) | 17 (0.64) |
| 23 | Furrow Bees (*Lasioglossum Curtis*) | 11(0.59) | 0(0.00) | 11 (0.42) |
| 24 | Sable island sweat bees (*Lasioglossum sablense*) | 11(0.59) | 0(0.00) | 11 (0.42) |
| 25 | Flesh fly (*Sarcophaga carnaria*) | 10(0.54) | 0(0.00) | 10 (0.38) |
| | **TOTAL** | **1867(100)** | **775(100)** | **2642 ( 100)** |
| | **Percentage species** | **70.67** | **29.33** | **100** |
| | **Total species** | **25** | **21** | **25** |

## 3.7Effects of Different botanical extracts on control of Black Bean Aphids and Beneficial Insects on beans

Pesticidal plants exhibited a significant effect on the abundance of Black Bean Aphids (BBAs) and Beneficial Insects across different treatments. Some insects were significantly affected by botanicals while others were not (Table 3.4 a, b and 3,5a, b). Results further, indicated that there is a significant effect of season, treatments (pesticides) and interaction of season and treatments on the abundance of beneficial insects and abundance, incidence, severity of BBAs on common bean.

### 3.7.1 Effects of Botanical extracts on abundance, incidence and severity of aphids

Botanicals displayed a significant difference (F = 6.93, df = 10, 374, p = 0.0001) on the abundance of BBAs, incidence (F= 9.21, df = 10, 374, p = 0.0001) and severity (F= 9.36, df = 10, 374, p = 0.0001). The highest abundance of aphids was observed on negative control whereas the lowest abundance was recorded on synthetic pesticide (Table3.4a). However, the effectiveness of *Derris trifoliata* with a concentration of 240 g/L and *Vernonia. amygdalina* with a concentration of (140 g/L, 240 g/L) individually were as similar as synthetic pesticide in the reduction of the abundance of aphids as compared to the rest of botanicals. Furthermore, *V. amygdalina* and *D. trifoliata* each with a concentration of 240 g/L was the most effective in reduction of incidence and severity of aphids compared with the rest of pesticidal plant extract which have revealed insignificant difference in their effectiveness (Table3.4a).

### 3.7.2 Effects of Botanical extracts on abundance of beneficial insects

Pesticidal plant extracts exhibited a significant difference *H. rubicundus* (F= 3.02, df = 10, 374, p = 0.001), *H. farinosus* (F= 2.24, df= 10, 374, p = 0.015), *C. megacephala* (F= 2.50, df = 10, 374, p = 0.006), *C. bezziana* (F= 2.65, df = 10, 374, p = 0.004), *C. rufifacies* (F = 2.58, df = 10, 374, p = 0.005), *S. spilogaster* (F= 5.43, df = 10, 374, p = 0.0001), *L. cuprina* (F = 2.84, df = 10. 374, p = 0.002), *L. sericata* (F= 2.52, df = 10, 374, p = 0.006) and Others –*A. iphigenia, L. sablense, M. domestica, M. levida, S. carnaria, C. marginalis, L. ampullaceal* and *B. erythrura* (F= 3.98, df = 10, 374, p = 0.0001).

However, there was no significant effect of botanicals on *H. ligatus* (F= 0.91, df = 10, 374, p = 0.519), *C. putoria* (F= 0.65, df = 10, 374, p = 0.769), *C. albiceps* (F= 0.879, df = 10, 374, p = 0.553), *S. africa* (F= 0.93, df = 10, 374, p = 0.506), *S. carnaria* (F= 0.54, df = 10, 374, p = 0.858) and *L. silvarum* (F= 0.410, df = 10, 374, p = 0.942).

The highest abundance of beneficial insects was observed on negative control (Table 3.4a, b). However, the rest of pesticidal plant extract exhibited no significant difference with synthetic pesticides in the abundance of beneficial insects observed. Relatively, *Halictus rubicundus* among other beneficial insects, the highest abundance was recorded on both negative control and synthetic pesticide while the lowest number was recorded on the rest of pesticidal plants (Table 3.4a and b).

### 3.7.3 Effects of season on abundance, incidence and severity of aphids

Results revealed that season has a significant effect (F=52.93, df=10,374, p=0.0001) on BBAs, incidence (F=177.85, df= 10, 374, p= 0.0001) and severity (F= 28.94, df = 10, 374, p = 0.001)

Population of aphids, incidence and severity was higher during dry season as compared with wet season (Table 3.4a).

### 3.7.4 Effects of season on abundance of beneficial insects

Results shown that season has a significant effect *H. ligatus* (F = 13.28, df = 10, 374, p =0.000), *C. putoria* (F = 30.82, df= 10, 374, p = 0.0001), *C. albiceps* (F = 28.83, df = 10, 374, p = 0.0001), *C. megacephala* (F= 40.83, df = 10, 374, p = 0.0001), *C. bezziana* (F = 1950, df = 10,374, p = 0.0001), *S. africa* (F = 19.45, df = 10, 374, p = 0.0001), *S. spilogaster* (F = 63. 58, df= 10, 374, p = 0.0001), *S. carnaria* (F= 5.56, df = 10, 374, p = 0.019), *L. cuprina* (F = 12.92, df = 10, 374, p = 0.000), *L. sericata* (F = 28.51, df = 10, 374, p = 0.0001), *L. silvarum (*F = 6.04, df = 10, 374, p = 0.014), p = 0.012) and Others- *A. iphigenia, L. sablense*, M. *domestica, M. levida, C. marginalis, L. ampullaceal and B. erythrura* (F= 28.04, df = 10, 374, p = 0.0001). However, there was no significant effect of season on *H. rubicundus* (F= 0.76, df = 10, 374, p = 0.380), *H. farinosus* (F= 0.92, df = 10.374, p = 0.337) and *C. rufifacies* (F= 0.56, df = 10,374, p = 0.456).

However, abundance of beneficial insects was higher during wet season as compared with dry season (Table 3.4a and b). In addition, among other beneficial insects *C. megacephala* and others were the most abundant beneficial recorded during wet season. Nevertheless, season demonstrated insignificant effect on *H. rubicundus C. rufifacies,* and *H. farinosus* during two seasons.

**Table 3.4a: Effect of botanicals and season on Abundance, incidence and severity of black bean aphids and abundance of beneficial insects**

| Season | Aphids Abundance | Aphids Incidence | Aphids Severity | *H.rubicundus* | *C. megacephala* | *C.bezziana* | *S.spilogaster* | *L.cuprina* | *L.sericata* | *C.rufifacies* | Others |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Wet | 3.36 | 14.44 | 0.67 | 1.10 | 0.61 | 0.53 | 0.52 | 0.22 | 0.59 | 0.29 | 0.90 |
| Dry | 11.09 | 39.70 | 0.96 | 0.96 | 0.04 | 0.07 | 0.03 | 0.00 | 0.01 | 0.01 | 0.24 |
| SE | 0.75 | 1.34 | 0.04 | 0.12 | 0.06 | 0.07 | 0.04 | 0.04 | 0.08 | 0.04 | 0.09 |
| $LSD_{0.05}$ | 2.09 | 3.723 | 0.103 | 1.096 | 0.582 | 0.671 | 0.405 | 0.396 | 0.716 | 0.353 | 0.815 |
| P.value | 0.0001 | 0.0001 | 0.0001 | 0.384 | 0.001 | 0.001 | 0.001 | 0.000 | 0.001 | 0.073 | 0.001 |
| **Treatments** | | | | | | | | | | | |
| NC | 19.48$^{a}$ | 43.89$^{a}$ | 1.47$^{a}$ | 2.17$^{a}$ | 0.92$^{a}$ | 1.06$^{a}$ | 0.97$^{a}$ | 0.58$^{a}$ | 1.00$^{a}$ | 0.50$^{a}$ | 1.72$^{a}$ |
| DT1 | 8.78$^{b}$ | 33.89$^{b}$ | 0.97$^{b}$ | 0.92$^{bcd}$ | 0.17$^{b}$ | 0.33$^{b}$ | 0.19$^{b}$ | 0.08$^{b}$ | 0.14$^{b}$ | 0.03$^{b}$ | 0.39$^{b}$ |
| DT2 | 8.78$^{b}$ | 32.22$^{b}$ | 0.86$^{bc}$ | 1.06$^{bcd}$ | 0.17$^{b}$ | 0.28$^{b}$ | 0.17$^{b}$ | 0.03$^{b}$ | 0.06$^{b}$ | 0.08$^{b}$ | 0.53$^{b}$ |
| DA2 | 7.22$^{b}$ | 32.22$^{b}$ | 0.81$^{bc}$ | 0.47$^{d}$ | 0.14$^{b}$ | 0.25$^{b}$ | 0.11$^{b}$ | 0.03$^{b}$ | 0.08$^{b}$ | 0.00$^{b}$ | 0.33$^{b}$ |
| VA2 | 7.06$^{b}$ | 28.33$^{bc}$ | 0.81$^{bc}$ | 0.97bcd | 0.14$^{b}$ | 0.14$^{b}$ | 0.19$^{b}$ | 0.08$^{b}$ | 0.06$^{b}$ | 0.00$^{b}$ | 0.56$^{b}$ |
| DA1 | 6.89$^{b}$ | 27.78$^{bc}$ | 0.78$^{bc}$ | 1.30$^{bc}$ | 0.31$^{b}$ | 0.22$^{b}$ | 0.19$^{b}$ | 0.03$^{b}$ | 0.06$^{b}$ | 0.08$^{b}$ | 0.25$^{b}$ |
| DA3 | 6.24$^{b}$ | 27.22$^{bc}$ | 0.78$^{bc}$ | 0.86$^{bcd}$ | 0.17$^{b}$ | 0.11$^{b}$ | 0.28$^{b}$ | 0.00$^{b}$ | 0.25$^{b}$ | 0.00$^{b}$ | 0.31$^{b}$ |
| VA1 | 4.99$^{bc}$ | 26.67$^{bc}$ | 0.75$^{bc}$ | 0.86$^{bcd}$ | 0.25$^{b}$ | 0.08$^{b}$ | 0.22$^{b}$ | 0.03$^{b}$ | 0.42$^{b}$ | 0.06$^{b}$ | 0.31$^{b}$ |
| DT3 | 4.76$^{bc}$ | 20.56$^{cd}$ | 0.72$^{c}$ | 0.58$^{cd}$ | 0.42$^{b}$ | 0.33$^{b}$ | 0.19$^{b}$ | 0.00$^{b}$ | 0.53$^{ab}$ | 0.11$^{b}$ | 0.75$^{b}$ |
| VA3 | 4.41$^{bc}$ | 17.78$_{d}$ | 0.64$^{c}$ | 0.61$^{cd}$ | 0.47$^{b}$ | 0.17$^{b}$ | 0.14$^{b}$ | 0.00$^{b}$ | 0.25$^{b}$ | 0.06$^{b}$ | 0.50$^{b}$ |
| PC | 0.89$^{c}$ | 7.22$^{e}$ | 0.36$^{d}$ | 1.50$^{ab}$ | 0.42$^{b}$ | 0.50$^{b}$ | 0.33b | 0.19$^{b}$ | 0.44$^{b}$ | 0.19$^{b}$ | 0.67$^{b}$ |
| SE | 1.76 | 3.14 | 0.09 | 0.28 | 0.15 | 0.17 | 0.10 | 0.10 | 0.18 | 0.09 | 0.21 |
| P.value | 0.001 | 0.001 | 0.001 | 0.001 | 0.006 | 0.004 | 0.001 | 0.002 | 0.006 | 0.005 | 0.001 |

Different letters within the same column indicate significant difference at P = 0.05 as determined by Tukey's Test;
PC = Synthetic pesticide, NC = Negative control (without treatment application), SE = Standard error, D1, DA2 and DA3 =*Dysphania ambrosioides* with concentrations of 140,200 and 240 g/L, DT1, DT2 and DT3 =*Derris trifoliata* with concentrations of 140,200 and 240 g/L, and VA1, VA2 and VA3 =*Vernonia amygdalina* with concentrations of 140,200 and 240 g/L

**Table 3.4b: Effect of botanicals and season on the abundance of beneficial insects**

| Season | *H.farinosus* | *H.ligatus* | *C. putoria* | *C.albiceps* | *S.africa* | *S.carnaria* | *L.silvarum* |
|---|---|---|---|---|---|---|---|
| Wet | 0.20 | 0.36 | 0.67 | 0.60 | 0.45 | 0.05 | 0.10 |
| Dry | 0.13 | 0.11 | 0.04 | 0.08 | 0.06 | 0.00 | 0.01 |
| SE | 0.05 | 0.05 | 0.08 | 0.07 | 0.06 | 0.02 | 0.14 |
| $LSD_{0.05}$ | 0.445 | 0.452 | 0.742 | 0.638 | 0.583 | 0.140 | 0.241 |
| P.value | 0.337 | 0.000 | 0.0001 | 0.0001 | 0.0001 | 0.019 | 0.014 |
| **Treatments** | | | | | | | |
| NC | 0.64[a] | 0.44 | 0.64 | 0.67 | 0.50 | 0.06 | 0.14 |
| DT1 | 0.22[b] | 0.33 | 0.53 | 0.50 | 0.42 | 0.06 | 0.08 |
| DT2 | 0.19[b] | 0.31 | 0.50 | 0.39 | 0.39 | 0.06 | 0.08 |
| DA2 | 0.17[b] | 0.31 | 0.42 | 0.36 | 0.31 | 0.06 | 0.08 |
| VA2 | 0.14[b] | 0.28 | 0.33 | 0.36 | 0.28 | 0.03 | 0.06 |
| DA1 | 0.14[b] | 0.19 | 0.31 | 0.33 | 0.25 | 0.03 | 0.06 |
| DA3 | 0.11[b] | 0.19 | 0.28 | 0.33 | 0.25 | 0.00 | 0.03 |
| VA1 | 0.06[b] | 0.17 | 0.28 | 0.28 | 0.19 | 0.00 | 0.03 |
| DT3 | 0.06[b] | 0.14 | 0.25 | 0.19 | 0.14 | 0.00 | 0.03 |
| VA3 | 0.06[b] | 0.11 | 0.17 | 0.17 | 0.06 | 0.00 | 0.03 |
| PC | 0.03[b] | 0.08 | 0.17 | 0.16 | 0.06 | 0.00 | 0.00 |
| SE | 0.11 | 0.12 | 0.19 | 0.05 | 0.15 | 0.04 | 0.06 |
| P.value | 0.015 | 0.519 | 0.679 | 0.553 | 0.506 | 0.86 | 0.942 |

Different letters within the same column indicate significant difference at P = 0.05 as determined by Tukey’s Test;
PC = Synthetic pesticide, NC = Negative control (without treatment application), SE = Standard error, D1, DA2 and DA3 =*Dysphania ambrosioides* with concentrations of 140,200 and 240 g/L, DT1, DT2 and DT3 =*Derris trifoliata* with concentrations of 140,200 and 240 g/L, and VA1, VA2 and VA3 =*Vernonia amygdalina* with concentrations of 140,200 and 240 g/L

### 3.7.5 Effects of botanicals and season interaction on abundance, incidence and severity of aphids

Interaction demonstrated significant difference (F= 3.35, df= 10, 374, p = 0.000) on the abundance of Black Bean Aphids, incidence (F= 4.18, df = 10, 374, p = 0.0001). Contrariwise, interaction showed insignificant different on Aphids severity (F= 0.84, df = 10,374 p = 0.589).

The highest abundance of Black Bean Aphids was recorded on negative control during dry season. Additionally, among other pesticidal plants, *V. amygdalina* with concentration of 140, 200 and 240) g/L and *D. trifoliata* 240 g/L were the most effective against abundance of aphids and incidence during dry season (Table 3.5a). Alternatively, during wet season there was no significant difference in the abundance of aphids recorded on all treatments. Therefore, in effectiveness all pesticidal plant extracts were relatively at par with synthetic pesticide. The highest and lowest mean incidence of aphids during both dry and wet season was observed on negative control and synthetic pesticide respectively. Comparatively, *V. amygdalina* with a concentration of 140 g/L and 240 g/L were the most effective in reduction of incidence of BBAs while *D. trifoliata*140 g/L was less effective during dry season.

### 3.7.6 Effects of botanicals and season interaction on abundance of beneficial insects

Interaction revealed significant difference on *C. megacephala* (F= 2.69, df = 10, 374, p = 0.003), *C. bezziana* (F= 2.31, df = 10, 374, p = 0.012), *S. spilogaster* (F= 4.96, df = 10, 374 p = 0.0001), *L. cuprina* (F= 2.84, df = 10, 374, p = 0.002), *L. sericata* (F = 0.54, df = 10, 374, p = 0.005) and Others (F= 2.08, df = 10, 374, p =0.026).

Conversely, interaction showed insignificant on *H. rubicundus* (F= 0.41, df = 10,374, p = 0.94), *H. farinosus* (F= 0.61, df = 10,374, p = 0.804), *H. ligatus* (F= 0.88, df = 10,374, p = 0.551), *C. putoria* (F= 0.758, df = 10,374, p = 0.679), *C. albiceps* (F= 1.13, df = 10,374, p = 0.340), *S. africa* (F= 0.71, df= 10,374, p = 0.719), *S. carnaria* (F= 0.54, df = 10,374, p = 0.858) and *L. silvarum* (F= 0.54, df = 10,374, p = 0.858).

The highest numbers of beneficial insects were recorded on negative control during wet season. (Table 3.5a). However, among other treatments, negative control sustained same number of *L. cuprina* as sustained on synthetic pesticide during wet season. Generally, there was a slight difference on the abundance of beneficial insects observed on synthetic pesticide with the rest of pesticidal plants during wet season. Nevertheless, among other pesticidal plants, *L. sericata* was observed to have the highest number of beneficial insects on *Derri trifoliata* with a concentration of 240g/L during wet season. In addition, the effect of the rest treatments revealed no significant difference in the abundance of beneficial insects recorded during dry season (Table 3.5a).

**Table 3.5a: Effect of interaction of botanicals with season on abundance, incidence and severity of aphids and abundance of beneficial insects**

| Season*Treatments | Aphids abundance | Aphids Incidence | Aphids Severity | *C.megacephala* | *C.bezziana* | *S.spilogaster* | *L.cuprina* | *L.sericata* | Others |
|---|---|---|---|---|---|---|---|---|---|
| Dry*NC | 30.97a | 65.56a | 1.72 | 0.00$^{e}$ | 0.11$^{c}$ | 0.06$^{cd}$ | 0.00$^{b}$ | 0.00$^{e}$ | 0.56$^{bcd}$ |
| Dry*DT1 | 15.01b | 53.33ab | 1.22 | 0.11$^{e}$ | 0.11$^{c}$ | 0.06$^{cd}$ | 0.00$^{b}$ | 0.00$^{e}$ | 0.11$^{d}$ |
| Dry*DA3 | 13.96bc | 50.00bc | 1.22 | 0.00$^{e}$ | 0.00$^{c}$ | 0.06$^{cd}$ | 0.00$^{b}$ | 0.00$^{e}$ | 0.17$^{d}$ |
| Dry*DA1 | 11.89bcd | 46.67bc | 1.00 | 0.06$^{e}$ | 0.06$^{c}$ | 0.00$^{d}$ | 0.00$^{b}$ | 0.00$^{e}$ | 0.06$^{d}$ |
| Dry*DA2 | 11.22bcd | 44.44bc | 0.94 | 0.00$^{e}$ | 0.39$^{bc}$ | 0.00$^{d}$ | 0.00$^{b}$ | 0.06$^{e}$ | 0.17$^{d}$ |
| Dry*DT2 | 11.44bcd | 41.11bc | 0.94 | 0.06$^{e}$ | 0.00$^{c}$ | 0.00$^{d}$ | 0.00$^{b}$ | 0.00$^{e}$ | 0.06$^{d}$ |
| Dry *DT3 | 7.89cde | 38.89cd | 0.94 | 0.11$^{e}$ | 0.06$^{c}$ | 0.06$^{cd}$ | 0.00$^{b}$ | 0.00$^{e}$ | 0.50$^{bcd}$ |
| Dry*VA2 | 7.22cde | 38.89cd | 0.94 | 0.00$^{e}$ | 0.06$^{c}$ | 0.06$^{cd}$ | 0.00$^{b}$ | 0.00$^{e}$ | 0.28$^{bcd}$ |
| Dry*VA1 | 7.12cdef | 26.67de | 0.83 | 0.00$^{e}$ | 0.06$^{c}$ | 0.00$^{d}$ | 0.00$^{b}$ | 0.00$^{e}$ | 0.22$^{cd}$ |
| Dry*VA3 | 7.01def | 23.33ef | 0.78 | 0.06$^{e}$ | 0.00$^{c}$ | 0.00$^{d}$ | 0.00$^{b}$ | 0.00$^{e}$ | 0.28$^{bcd}$ |
| Wet*NC | 5.87def | 22.22ef | 0.78 | 1.83$^{a}$ | 2.00$^{a}$ | 1.89$^{a}$ | 0.00$^{b}$ | 2.00$^{a}$ | 2.89$^{a}$ |
| Wet*DA1 | 5.06def | 17.78efg | 0.78 | 0.11e | 0.39$^{bc}$ | 0.39$^{bcd}$ | 0.06$^{b}$ | 0.00$^{e}$ | 0.44$^{bcd}$ |
| Wet*VA2 | 3.60ef | 16.67efg | 0.72 | 0.28cde | 0.22$^{bc}$ | 0.33$^{bcd}$ | 0.17$^{b}$ | 0.11$^{e}$ | 0.83$^{bcd}$ |
| Wet*DT3 | 3.22ef | 14.44efg | 0.72 | 0.56$^{bcde}$ | 0.61$^{bc}$ | 0.33$^{bcd}$ | 0.00$^{b}$ | 1.06$^{b}$ | 1.00$^{bc}$ |
| Wet*VA1 | 2.97ef | 14.44efg | 0.67 | 0.50$^{bcde}$ | 0.11$^{c}$ | 0.44$^{bc}$ | 0.06$^{b}$ | 0.83$^{bcd}$ | 0.39$^{bcd}$ |
| Wet*DA3 | 2.97ef | 14.44efg | 0.67 | 0.33$^{bcde}$ | 0.22$^{c}$ | 0.56$^{b}$ | 0.28$^{b}$ | 0.50$^{bcd}$ | 0.44$^{bcd}$ |
| Wet*DT1 | 2.64ef | 14.44efg | 0.61 | 0.17$^{de}$ | 0.17$^{bc}$ | 0.33$^{bcd}$ | 0.17$^{b}$ | 0.28$^{cde}$ | 0.67$^{bcd}$ |
| Wet*DT2 | 2.56ef | 13.33efg | 0.56 | 0.28$^{cde}$ | 0.56$^{bc}$ | 0.33$^{bcd}$ | 0.06$^{b}$ | 0.11$^{e}$ | 1.00$^{bc}$ |
| Wet*VA3 | 2.40ef | 12.22fg | 0.56 | 0.89$^{b}$ | 0.33$^{bc}$ | 0.28$^{bcd}$ | 0.00$^{b}$ | 0.50$^{bcd}$ | 0.72$^{bcd}$ |
| Wet*DA2 | 2.23ef | 12.22fg | 0.56 | 0.28$^{cde}$ | 0.33$^{bc}$ | 0.22$^{bcd}$ | 0.06$^{b}$ | 0.06$^{e}$ | 0.50$^{bcd}$ |
| Wet*PC | 1.36ef | 7.78fg | 0.44 | 0.00e | 0.17$^{bc}$ | 0.61$^{b}$ | 1.17$^{a}$ | 0.17$^{de}$ | 1.06$^{b}$ |
| Dry*PC | 0.42ef | 6.67g | 0.28 | 0.83$^{b}$ | 0.83$^{b}$ | 0.06$^{cd}$ | 0.39$^{b}$ | 0.89$^{bc}$ | 0.28$^{bcd}$ |
| SE | 2.49 | 4.44 | 0.12 | 0.21 | 0.24 | 0.15 | 0.14 | 0.25 | 0.29 |
| P.value | 0.0001 | 0.000 | 0.59 | 0.003 | 0.012 | 0.0001 | 0.002 | 0.005 | 0.026 |

Different letters within the same column indicate significant difference at P = 0.05 as determined by Tukey's Test;
Wet and Dry season*(PC = Synthetic pesticide, NC = Negative control (without treatment application), D1, DA2 and DA3 =*Dysphania ambrosioides* with concentrations of 140,200 and 240 g/L, DT1, DT2 and DT3 =*Derris trifoliata* with concentrations of 140,200 and 240 g/L) and (VA1, VA2 and VA3 =*Vernonia amygdalina* with concentrations of 140,200 and 240 g/L) and SE = Standard error.

**Table 3.5b: Effect of interaction of botanicals with season on abundance of beneficial insects**

| Season*Treatments | *H.farinosus* | *H.rubicundus* | *H.ligatus* | *C.putoria* | *C.albiceps* | *C.rufifaciens* | *S.africa* | *S.carnaria* | *L.silvarum* |
|---|---|---|---|---|---|---|---|---|---|
| Dry*NC | 0.78 | 2.28 | 0.67 | 1.22 | 1.33 | 0.50 | 0.89 | 0.11 | 0.28 |
| Dry*DT1 | 0.50 | 2.06 | 0.67 | 1.06 | 0.78 | 0.50 | 0.67 | 0.11 | 0.17 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Dry*DA3 | 0.33 | 1.61 | 0.56 | 1.00 | 0.67 | 0.39 | 0.67 | 0.11 | 0.17 |
| Dry*DA1 | 0.28 | 1.61 | 0.44 | 0.83 | 0.67 | 0.17 | 0.61 | 0.11 | 0.17 |
| Dry*DA2 | 0.28 | 1.39 | 0.44 | 0.61 | 0.61 | 0.11 | 0.50 | 0.06 | 0.06 |
| Dry*DT2 | 0.28 | 1.28 | 0.28 | 0.56 | 0.61 | 0.11 | 0.50 | 0.06 | 0.06 |
| Dry *DT3 | 0.22 | 1.28 | 0.28 | 0.50 | 0.61 | 0.11 | 0.50 | 0.00 | 0.06 |
| Dry*VA2 | 0.17 | 1.11 | 0.22 | 0.50 | 0.56 | 0.06 | 0.33 | 0.00 | 0.06 |
| Dry*VA1 | 0.17 | 1.00 | 0.22 | 0.44 | 0.39 | 0.06 | 0.17 | 0.00 | 0.06 |
| Dry*VA3 | 0.11 | 0.94 | 0.17 | 0.33 | 0.33 | 0.06 | 0.17 | 0.00 | 0.06 |
| Wet*NC | 0.11 | 0.89 | 0.17 | 0.28 | 0.22 | 0.06 | 0.11 | 0.00 | 0.06 |
| Wet*DA1 | 0.06 | 0.89 | 0.17 | 0.11 | 0.17 | 0.06 | 0.11 | 0.00 | 0.06 |
| Wet*VA2 | 0.06 | 0.83 | 0.11 | 0.06 | 0.11 | 0.06 | 0.11 | 0.00 | 0.00 |
| Wet*DT3 | 0.06 | 0.83 | 0.11 | 0.06 | 0.11 | 0.00 | 0.11 | 0.00 | 0.00 |
| Wet*VA1 | 0.06 | 0.83 | 0.11 | 0.06 | 0.11 | 0.00 | 0.06 | 0.00 | 0.00 |
| Wet*DA3 | 0.06 | 0.67 | 0.11 | 0.06 | 0.11 | 0.00 | 0.06 | 0.00 | 0.00 |
| Wet*DT1 | 0.06 | 0.61 | 0.11 | 0.06 | 0.06 | 0.00 | 0.06 | 0.00 | 0.00 |
| Wet*DT2 | 0.06 | 0.61 | 0.11 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 |
| Wet*VA3 | 0.00 | 0.56 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Wet*DA2 | 0.00 | 0.50 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Wet*PC | 0.00 | 0.44 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Dry*PC | 0.00 | 0.39 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| SE | 0.16 | 0.39 | 0.16 | 0.27 | 0.07 | 0.26 | 0.21 | 0.05 | 0.09 |
| P.value | 0.804 | 0.094 | 0.553 | 0.679 | 0.340 | 0.880 | 0.719 | 0.858 | 0.858 |

Different letters within the same column indicate significant difference at P = 0.05 as determined by Tukey's Test

Wet and Dry season*(PC = Synthetic pesticide, NC = Negative control (without treatment application), D1, DA2 and DA3 =*Dysphania ambrosioides* with concentrations of 140,200 and 240 g/L, DT1, DT2 and DT3 =*Derris trifoliata* with concentrations of 140,200 and 240 g/L) and (VA1, VA2 and VA3 =*Vernonia amygdalina* with concentrations of 140,200 and 240 g/L) and SE = Standard error.

### 3.7.7 Common bean yield

Significant effect (F = 8.731, df = 10, 44, p = 0.0001) was observed when comparing yields of common bean in plots treated with different treatments. Further, interaction of botanicals with season had significant effect on yield (F = 2.743, df = 10, 44, p = 0.010). However, there was no significant difference of season on bean yield Table (3.6). The highest bean yield was recorded in plot sprayed with synthetic pesticide while the lowest was recorded on negative control. The highest bean yield among pesticidal plants was recorded in bean plots treated *D. trifoliata* 240 g/L while the rest of pesticidal plant displayed no statistical difference in yield performance (Table 3.6).

**Table 3.6: Common bean yield**

| **Season** | **Yield(kg/Ha)** |
|---|---|
| Wet | 752.01 |
| Dry | 750.70 |
| SE | 38.29 |
| $LSD_{0.05}$ | 109.121 |
| P.value | 0.981 |
| | |
| **Treatments** | |
| PC | $1400.79^{a}$ |
| DT3 | $1003.56^{b}$ |
| DA3 | $807.06^{bc}$ |
| VA1 | $790.30^{bc}$ |
| DA1 | $746.75^{c}$ |
| VA3 | $651.73^{c}$ |
| VA2 | $649.66^{c}$ |
| DT1 | $649.04^{c}$ |
| DA2 | $593.82^{cd}$ |
| DT2 | $579.95^{cd}$ |
| NC | $392.27^{d}$ |
| SE | 101.23 |
| P.value | 0.0001 |

Different letters within the same column indicate significant difference at P = 0.05 as determined by Tukey's Test;
PC = Synthetic pesticide, NC = Negative control (without treatment application), SE = Standard error, D1, DA2 and DA3 =*Dysphania ambrosioides* with concentrations of 140,200 and 240 g/L, DT1, DT2 and DT3 =*Derris trifoliata* with concentrations of 140,200 and 240 g/L, and VA1, VA2 and VA3 =*Vernonia amygdalina* with concentrations of 140, 200 and 240 g/L

### 3.7.8 Effect of interaction of botanicals with season on yield of common bean

The highest bean yields recorded on *D. ambrosioides* and *D. trifoliata* each with a concentration of 240 g/L, *D. ambrosioides* and *V. amygdalina* each with a concentration of 140 g/L during wet season was similar with synthetic pesticide while during dry season the highest yield was recorded on synthetic pesticide and the second highest being recorded on *D. trifoliata* 240 g/L (Table 3.7). However, the lowest yield among botanicals during both wet and dry season was recorded on (*D.* ambrosioides and *D. trifoliata*) with concentration of 200 g/L. Moreover, the lowest yield among treatments was observed on negative control during the two seasons.

***Table 3.7: Yield interaction of botanicals and season***

| Interaction | Means(kg/ha) | Groups | | | | | |
|---|---|---|---|---|---|---|---|
| Dry*PC | 1755.49 | a | | | | | |
| Dry*DT3 | 1165.70 | b | | | | | |
| Wet*PC | 1046.08 | b | c | | | | |
| Wet*DA3 | 993.49 | b | c | d | | | |
| Wet*DT3 | 841.42 | b | c | d | e | | |
| Wet*DA1 | 810.58 | b | c | d | e | f | |
| Wet*VA1 | 804.00 | b | c | d | e | f | |
| Dry*VA1 | 776.60 | | c | d | e | f | |
| Wet*VA3 | 748.67 | | c | d | e | f | |
| Wet*VA2 | 727.17 | | c | d | e | f | |
| Dry*DA1 | 682.92 | | | d | e | f | g |
| Dry*DT1 | 674.24 | | | d | e | f | g |
| Wet*DT2 | 665.25 | | | d | e | f | g |
| Dry*DA2 | 637.47 | | | d | e | f | g |
| Wet*DT1 | 623.83 | | | | e | f | g |
| Dry*DA3 | 620.63 | | | | e | f | g |
| Dry*VA2 | 572.15 | | | | e | f | g |
| Dry*VA3 | 554.79 | | | | e | f | g |
| Wet*DA2 | 550.17 | | | | e | f | g |
| Dry*DT2 | 494.65 | | | | e | f | g |
| Wet*NC | 461.44 | | | | | f | g |
| Dry*NC | 323.09 | | | | | | g |
| SE | 126.98 | | | | | | |
| P.value | 0.010 | | | | | | |

Different letters within the same column are significant difference at P = 0.05 as determined by Tukey's Test; Wet and dry season*(PC = Synthetic pesticide, NC = Negative control (without treatment application), Dry season*(D1, DA2 and DA3 =*Dysphania ambrosioides* with concentrations of 140,200 and 240 g/L, Dry season*(DT1, DT2 and DT3 =*Derris trifoliata* with concentrations of 140,200 and 240 g/L) and Dry season*(VA1, VA2 and VA3 =*Vernonia amygdalina* with concentrations of 140,200 and 240 g/L) and SE = Standard error.

## 3.8 Discussion

### 3.8.1Pesticidal plants

Results from this study has demonstrated that pesticidal plants namely *D. trifoliata*,*D. ambrosioides* and *V. amygdalina* contain some pesticidal activity against Black Bean Aphids (BBAs). The possible effect of pesticidal plants against BBAs agrees with earlier findings of Roy *et al*. (2016); Stevenson *et al.* (2017); Isman (2016); *Roy et al.* (2016); Green *et al.* (2017); Pavela *et al.* (2017) who reported that pesticidal plant species contain chemical compounds against crop insect pests. There was insignificant difference in effectiveness in all treatments during wet season against BBAs whereas *V. amygdalina* with all concentration of all levels tested and *D. trifoliata* 240 g/L were the most effective against incidence and Black Bean Aphids during dry season. Low abundance and incidence of BBAs could be contributed by the effectiveness of these pesticidal plants secondary metabolites which protect plants against aphids as reported by Matsuura *et al.* (2016). The extracts from leaves of *V. amygdalina* has also demonstrated to have active ingredient of saponins and alkaloids, terpenes, flavonoids and phenolic, vernodalin, vernodalol, epivernodalol and sesquiterpene lactones which have repellent, feeding and deterring chemicals which also discourage the insects from feeding the crop (Green *et al.,* 2017; Tembo *et al.*, 2018; Mpumi *et al.*, 2016). Moreover, leaf extract from *D. ambrosioides* has demonstrated to contain pesticidal activities as documented by Pavela *et al.* (2017) who reported that *D. ambrosioides* contain phytochemical compounds such as (flavonoids, saponins, terpenes, sterols, and alkaloids) used to repel and disappoint field insect pests from feeding crops. In addition, *D. trifoliata* leaf extract also has demonstrated to have pesticidal activity against insect pest El –Wakeil (2013) reported that *D. trifoliata* is one of the broad spectrum pesticidal plant which contains active ingredient known as rotenone that acts as a contact and stomach poison, kills various insect pests on crops. Synthetic pesticide was the most effective in reducing abundance of BBAs in this study by exhibiting least incidence to the bean crop. The higher effectiveness of synthetic pesticide was due to persistent which can take more than two weeks and quick acting against insect pests due to its active ingredient (Biondi *et al.*, 2012).

### 3.8.2 Beneficial insects

The findings from this study demonstrated that the highest abundance of beneficial insects were recorded during wet season as compared with dry season. This abundance could be attributed by weather changes which might have affected population dynamics. Intachat (2001) stated that rainfall impact the survivor of beneficial insects by influencing vegetation sprout as a lava food resource and early life cycle stages. However, in this investigation, it was observed that some beneficial insects such as *H. rubicundus* was not affected by weather condition similar to the findings by Orr and Haeuser (1996); Finheiro *et al.* (2002) who reported that there was no significant different in number of butterfly recorded during wet and dry season.

However, it was observed that for most insect species, higher abundance was observed during wet season with few exceptions of *A. amphitrite, H. ligatus, H. farinosus* and *C. rufifacies* which the highest abundance was recorded during dry season.

This align with findings by Richards (2004) who reported that eusocial bees (*A. amphitrite, H. ligatus, H. farinosus*) reproduce more and extend colony cycles during dry season at lower altitudes. This result of *C. rufifacies* highest being recorded during dry is similar to the findings revealed by Ngoen-Klan (2011) who potraid that *C. megacephala* the highest abundance was observed in dry season and declined during rainy season.

Findings from this study revealed also that all treatments sustained different abundance of beneficial insects. The sustenance provided by each individual treatment to these beneficial differed as some beneficial were highly sustained than others.

Generally, negative control sustained higher number of beneficial insects as compared with other treatment throughout common bean growth period. Possibly this was contributed by absence of detrimental effect which could interfere their survivor. Alternatively, some of the abundance of beneficial recorded on synthetic pesticide and pesticidal plants were observed to be at par. This reveals that effect posed by these pesticides had similar consequences or they are less harmful to the beneficial insects that could affect their sustenance as reported by Mkindi *et al*. (2017; Mtei and Ndakidemi (2016); Aziz *et al.* (2013).

In addition, Fermades *et al.* (2016); Milglani and Bisht, 2019) found that some modern synthetic pesticides such as Neonicotinoids and Chlorantraniliprole are less harmful to some non-target insects compared with older synthetic pesticides. However, apart from impact which can be resulted from the use of pesticidal plants for the control of crop pests on non-target insects their importance in supporting beneficial insects has been reported by other several researchers Mkindi *et al*. (2015); Sola *et al*. (2014); Grzywacz *et al*. (2014).

### 3.8.3 Season

The results of this study indicated that there was a significant variation in the abundance of Black Bean Aphids recorded during dry season as compared with wet season. The highest abundance of aphids was observed during dry season and less on wet season. The variation of abundance of these aphids during two seasons probably could be attributed by weather condition differences on aphid population dynamics. This is similar to the results as reported by (Namni *et al.* (2017); Mandal *et al.* (2018); Mohammad *et al.* (2019). This finding also is in agreement with the report of Simon *et al.* (2014); Wanjama (1979) who reported that dry season favour aphid's high fecundity up to ten offspring's a day ensuing into three to four generations per month.

Heavy rainfall observed during wet season possibly contributed to reduced abundance of aphids by confiscating them from the crop plants. This study is in line with the findings by Backetia and Sindhu (1983) who reported that rainfall dropped aphid population from the crops. Nevertheless, during dry season due to absence of rainfall most of aphids are prevalent as reported by Leather *et al.* (2017); Feng *et al.* (1992); Honek and Martinkova, (2004).

### 3.8.4 Yield

Common bean yield in this study was found to be influenced by treatments during the two seasons. The higher beans yield observed in synthetic pesticide plots was the indication of low infestation caused by BBAs compared with pesticidal plants. Similar results were reported by Mkenda *et al.* (2015). Likewise, during dry season *D. trifoliata* with a concentration of 240 g/L demonstrated the highest yield among other pesticidal plants. This yield could be attributed by a broad spectrum secondary metabolite known as rotenone found in *D. trifoliata* which is contact and stomach toxic pesticide against different crop insect pests El –Wakeil (2013). This study results also agree with observation by Stevenson and Belmain (2017) that a toxic (rotenoid) substance found on *T. vogelli* present also on *D. trifoliata* might have reduced effect of aphid population and hence increase yield. Nevertheless, during wet season the highest yield compared with other pesticidal plants was recorded on *D. ambrosioides* with a concentration of 240 g/L. This could be attributed by chemical compound which have discouraging and repellence effect on ben crop as reported by Pavela *et al.* (2017).

During study period different plant flower visitors were recorded and these could probably contribute to the yield performance. Potts *et al.* (2016) and Bishop *et al.* (2016) reported that pollinators contribute about 75% of crop production, crop quality and yield even in self-pollinated crops. When pollinating insects move between crop flowers, they maximize pollen flow and fertilization of crops, which increases crop quality and yield (Douka *et al.,* 2018; Mainkete *et al.,* 2019). Therefore, yields observed on various treatments during wet season could be contributed by more number of plant flower visitors captured there by enhancing bean yield through seed weight, number of seeds per pod, and number of pods per plant (Douka *et al.*, 2018).

### 3.8.5 Conclusion and Recommendations

Findings from this current study research show that pesticidal extract from *D. Trifoliata*, *D. ambrosioides* and *V. amygdalina* have the ability to control of BBAs and reduce levels of incidence. Furthermore, it shows that *V. amygdaina* with all three different concentrations (140, 200 and 240) g/L and *D. trifoliata* 240 g/L were the most effective on reduction of abundance of aphids and incidence. Additionally, pesticidal plants with high concentration 240g/L demonstrated highest yield during the study period. It is, therefore, suggested that *V. amygdalina, D. ambrosioides* and *D. trifoliata* can be incorporated in pest management options by smallholder farmers in Tanzania.

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