EFFECT OF VARIETY AND INSECTICIDE ON POPULATION DENSITY AND DAMAGE BY BLACK BEAN APHID, *Aphis fabae* Scopoli (Aphididae: Homoptera) ON COMMON BEAN (*Phaseolus vulgaris* L.)

BY

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DEDICATION

This work is dedicated to my mother Mrs. Beatrice Wambui Mwangi.

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ABSTRACT

The black bean aphid (*Aphis fabae*) is a sporadic, but a serious pest of beans in Kenya during the second rain season. Studies were conducted during the short rain season of 2002 (October 2002-February 2003) both in the field and under greenhouse conditions at Egerton University, Njoro, Kenya, to determine the effect of variety, insecticide and their interaction on black bean aphid population, intrinsic rate of increase, damage and the yield of beans. Ten varieties of common bean and insecticide (dimethoate) were evaluated using a randomized complete block design in a factorial arrangement replicated three times. The experiment on the effect of varieties on the intrinsic rate of increase of *A. fabae* was conducted in randomized complete design replicated three times. Results obtained in the field experiment showed that mean number of aphids per plant did not significantly ($P> 0.05$) differ among the varieties. However, infestation incidence was significantly ($P< 0.05$) different among the varieties nine weeks after emergence. Plant height, pods per plant, seeds per pod and grain yield per hectare significantly varied with variety. Dimethoate applied at the rate of 1.5ml per liter of water significantly ($P< 0.05$) reduced aphid population, infestation incidence and increased plant height, pods per plant, seeds per pod and grain yield, but did not affect 100 seeds weight. Significant interaction between variety and insecticide was only observed in infestation incidence nine weeks after emergence and on plant height. Results of the greenhouse experiment showed that there were significant ($P< 0.05$) differences in mean number of aphids per plant eight weeks after emergence. The severity of damage, plant height, pods per plant, seeds per pod and grain yield was significantly different among the varieties. With few exceptions, the use of dimethoate resulted in significant increase on plant height, pods per plant and seeds per pod. Aphid infestation caused significant yield reduction ranging between 56.06% and 100% in all the varieties. Variety significantly ($P< 0.05$) affected fecundity, longevity and the intrinsic rate of increase of the aphid but did not significantly affect development time. In summary the study suggests that varieties Canadian wonder, Rosecoco small seeded and zebra are susceptible to *A. fabae* infestation while Mexican 142, Rosecoco large seeded and red haricot are resistant.

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CHAPTER ONE

INTRODUCTION

1.1 Black bean aphid (*Aphis fabae* Scopoli)

The black bean aphid (*Aphis fabae)* belong to the series Sterronyncha within the Order Homoptera and family Aphididae (Blackman and Eastop, 1989). It is a dull black aphid with black siphunculi and cauda (Plate 1). The third antennal segment bears 9-20 irregularly arranged sensoria. The femur bears many fine hairs on all surfaces and the cauda has 10-19 hairs (Eastop and Emden, 1989). The adult is 2mm long with white powdery secretion on abdominal segments (Plate 2).

The aphid is widespread in temperate regions of the Northern Hemisphere in the South America and in Africa, but not common in the hotter parts of the tropics and the Middle East (Blackman and Eastop, 1989). In Africa, it is wide spread, especially in the higher altitudes of Kenya, Sudan, Ethiopia, Uganda, Rwanda, Burundi, Tanzania, Democratic Republic of Congo, Malawi, Zimbabwe, Angola, Cameroon and Nigeria (Remaudierre *et al.*, 1985)

A. fabae is very polyphagous on its secondary host plants, which include many crops (Blackman Eastop, 1989). Though sporadic, Omunyin *et al.*, (1984) reported that *A. fabae* was a serious pest of common beans grown during the short rains season in Kenya. Yield losses of up to 90% have been realized due to the pest in Uganda and 37% in Tanzania (Karel and Autrique, 1989). Yield losses in Kenya have not been quantified (CIAT, 2001). CIAT (1998) recognized the aphid as a major production constraint in East Africa.

Several control methods have been identified and used by farmers to control the pest. Although insecticide control has been shown to be effective (Karel and Autrique,1989; Alexandra and Eric, 2001), there is always a danger of aggravating aphid problems by eradicating their parasites and predators (Ingram, 1969). In addition a major threat is the development of resistance to aphicides (Devonshire, 1989, as cited by Hawley, 2002). In some cases, aphicides are known to help the spread of non-persistently transmitted plant viruses by promoting brief probing and increased dispersal of virus bearing aphids (Gibson and Rice, 1989 as cited by Hawley, 2002). Timely planting, weeding and resistant varieties are also used to control the aphid. However, not all farmers practice



Plate 1. Wingless form of *A. fabae*



Plate 2. Winged form of *A. fabae*

timely planting and varietal resistance to bean aphid has not been explored in Africa (Singh, 1990) and especially in Kenya

1.2 Importance of common bean

The common beans (*Phaseolus vulgaris* L.) is the most important food legume for direct consumption in the world (CIAT, 2001). It is the most widely grown legume in Kenya, second to maize in importance as a staple food crop (Kiiya, 1997). Beans are a good source of protein, foric acid, dietary fiber and complex carbohydrates. When beans are part of the main diet, the nutritional value of maize and rice proteins increases since the amino acids are complementary. Beans are also one of the best non-meat sources of iron, providing 23-30% of daily recommended levels (Pachico, 1993).

Consumption of beans is high mostly because they are a relatively cheap food (Pachico, 1993). Common bean is grown for its green leaves, green pods, and immature and/or dry seeds. The dry seeds are the ultimate economic part of the bean plant (CIAT, 2001). Its dry leaves, threshed pods and stalks are fed to animals and used as fuel for cooking, especially in Africa and Asia (Sperling *et al.*, 1996).

In Africa, beans are mainly grown by small-scale farmers with less than five acres and mostly intercropped with maize (Mungai and Ndegwa, 1991). The beans are grown in a range of agro-ecological zones from upper highlands to middle highlands and parts of upper low lands (Jaetzold and Schmidt, 1983). The cropping season fall between April to July and October to January for the long and short rain season respectively (CIAT 1986). Abante and Ampofo (1996) reported that Kenya was the leading bean producer in Africa with 414,000 tons per annum.

1.3 Bean production constraints

In 1996 Abante and Ampofo reported that bean growers realize yields of about 300-700kg/ha, when the crop had a capacity of producing up to 3000kg/ha. He attributed the deficit to lack of improved varieties, poor agronomic practices, diseases and insect pests. *A. fabae* is one of the major constraints to bean production and ranks second after bean flies (CIAT, 1994). The aphid cause both direct and indirect damage to the plants. Infested leaves turn yellow due to the aphids sucking sap, younger plants become desiccated and may die while older ones may be stunted (Karel and Autrique, 1989 and

Bernhard *et al.*, 2001). An indirect and usually more harmful effect of aphid attack is the transmission and spread of bean common mosaic virus (BCMV). The disease severely reduces the seed yield of susceptible cultivars.

The deficit in the production of beans can be faced out to a greater extent by advising farmers to have a second season crop which they seldom grow. However, since the aphid is a major production constraint during the season there is need to come up with suitable recommendations for the control of aphid. Various control methods that include chemical, plant resistance, biological control and cultural have been used to control it. Though the use of plant host resistance is considered the most sustainable control method, Singh (1990) reported that aphid resistance by bean cultivars has not been explored in Africa. This leads to the lack of information on varietal resistance and tolerance of the common beans grown in Kenya.

There is therefore need to carry out exploratory studies on the resistance and tolerance of the common bean varieties mostly grown by the Kenyan farmers which can be recommended for production especially during the short rain seasons. Despite the fact that use of insecticide has been shown to be effective (Karel and Autrique, 1989 and Bernhard *et al.*, 2001) in the control of the aphid, farmers seldom use insecticides to control *A. fabae* in Kenya. The need to determine their effectiveness as an IPM component therefore arises. In addition research on the integration of these two control measures has not been undertaken. The integration of these two control components would form an IPM option, which would control not only the aphid but also, the bean common mosaic virus, which is transmitted by the aphid and hence realization of high yields during the second rain season.

1.4 Objectives

Broad objective

Increase bean yields, by developing an integrated pest management strategy for the control of black bean aphid (*A. fabae*).

Specific objectives

1 To determine the effect of varieties and insecticide and their interaction on black bean aphid population, damage and yield of beans under field conditions during the second rain season and under greenhouse conditions.

2 To identify bean varieties that are resistance/ tolerant to black bean aphid under greenhouse and field conditions.

3 To determine the effect of bean varieties on the development time, fecundity, longevity and the intrinsic rate of increase of black bean aphid under greenhouse conditions.

CHAPTER 2

LITERATURE REVIEW

2.1 Importance and distribution of black bean aphid.

The black bean aphid, *Aphis fabae* (Aphididae: Homoptera) is the main aphid pest of common beans in Africa. It is widely spread, especially in the higher altitudes of Sudan, Ethiopia, Kenya, Uganda, Rwanda, Burundi, Tanzania, Democratic republic of Congo, Malawi, Zimbabwe, Angola Cameroon and Nigeria (Remaudiere *et al.*, 1985). This aphid causes direct damage to the crop by sucking sap resulting in wilting and death of seedlings under severe infestation, while older plants are stunted (CIAT, 1994). An indirect and usually more harmful effect of aphid attack is the transmission and spread of bean common mosaic virus. The disease severely reduces the seed yield of susceptible cultivars (Karel, 1994).

2.2 Biology

The aphid reproduces parthenogenetically within a colony and wingless forms are produced when food is abundant and climatic conditions are optimal. However, when food is in short supply or the colony becomes over crowded, winged forms develop. Winged forms disperse to colonize new fields or plants and may invade bean fields soon after emergence (Karel and Autrique, 1989). Colonies of the aphid develop rapidly, especially in warm and humid weather. From birth, the aphid takes 11-13 days to mature and start larvipositing. On the average, an aphid larviposits 3-6 nymphs in a day and lives for 6-15 days (Karel and Autrique, 1989). Under temperate conditions, the life cycle of the aphid is different from that in the tropics. During winter, females lay eggs on the primary hosts namely, Euonymus, Viburnum, snowball bush and burning bush. In spring, there are two to three generations on the winter hosts, which are initially wingless asexual females, and later becomes winged asexual females. During summer, the asexual winged females fly and colonize the summer hosts, which include: beans, corn, sugarbeets, lambsquarter and pigweed. The aphid population at this stage is explosive due to short lifecycle giving rise to many generations in a short time. In fall, winged asexual females and winged sexual males returns to the winter hosts from the summer hosts. Sexual

females lay eggs on the winter hosts which include one generation only (University of Idaho, 2001).

2.3 Symptoms of damage

Winged aphids start colonies of wingless aphids on bean plants, which they infest. Colonies of aphids are found particularly around the stems, on growing points like leaf and flower buds, around flower clusters and on the underside of the leaves. Infestation is often severe during a dry spell or late in the season (Karel, 1994).

Infested leaves are destroyed by the aphids' feeding activities and turn yellow. Plants become desiccated and may eventually die (Karel and Autrique, 1989). Older plants may be stunted as a result of aphids attack. Sometimes the infestation continues during post flowering stage. However, the direct damage by bean aphids sometimes may be minimal. An indirect and usually more harmful effect of aphid attack is the transmission and spread of bean common mosaic virus. The disease severely reduces the seed yield of susceptible cultivars (Karel, 1994 and Bernhard *et al.*, 2001).

2.4 Control of *A. fabae*

2.4.1 Resistant cultivars

Bean cultivars resistant to aphids offer a good possibility for control. Rose *et al.*, (1978) identified sources of resistance to aphids. For aphids, the initial decision to insert the stylets depends on substrate colour and texture (Pelletier, 1990) but phytochemical stimuli detected at the plant surface are also important. Volatile phytochemicals may influence the initiation of stylet penetration (Storer *et al.*, 1996). Trichome exudates have been reported to disrupt settling behaviour (Rodriguez *et al.*, 1993; Musetti and Neal, 1997). Insects on the plant are also exposed to lipid components of the epicuticular wax layer, and these compound often play important roles as mediators of insect-plant interactions (Eigenbrode, 1996). There are some indications that plant waxes play a role in host selection by aphids although there may be no differences on aphid stylet insertion on bean plants without wax, an indication that no stimulating factors had been removed from the host plant surface (Glen *et al.*, 1999).

High mortality of bean aphids on resistant cultivars occurred because they were caught by the hooked trichomes on bean leaves. de Fluiter and Ankersmit (1948) reported that increased trichome density on bean leaves increased aphid capture. More aphids were trapped by plants grown under dry conditions than by those grown under ample moisture. Cichoka *et al.* (2002) while working on the response of *A. fabae* to different broad bean cultivars reported that the biology of the aphid was significantly affected by the cultivars. Varietal resistance to bean aphid has not been explored in Africa (Singh, 1990) and especially in Kenya.

2.4.2 Chemical control

Insecticidal control of aphids on common beans is effective (Karel, 1981; Oonyu, 1992). Certain insecticides have been identified and used for the control of aphids by farmers (CIAT, 1994). Alexandra and Eric (2001) reported that a registered insecticide ought to be applied when the aphids are first noticed. Such chemicals can be applied as spot sprays on infested areas or on entire field. Soil applied systemic insecticides can also be applied on seeds prior to planting. According to university of Idaho (2001), the following chemicals are effective and can be used; temik, diazinon, metasystox R, thimet, counter, pirimicarb, lennate, deciare and dibron. However, there is always a danger of aggravating aphid problems by eradicating their parasite and predators (Karel and Autrique, 1989). Insecticidal soap, horticultural oil, or neem oil can also be used (Alexandra and Eric, 2001). Though insecticides are effective farmers seldom use them in Kenya for the control of the aphid.

2.4.3 Biological control

Aphis fabae is affected by parasites and predators (Storey and Autrique (1985). Lady bird beetle, Green lacewing, Hover fly and parasitic wasps are recognized as common species that control bean aphid under natural conditions (University of Idaho, 2001). According to Storey and Autrique (1985) *Aphidius colemani* Viereck (Aphididae) naturally reduces the populations of *Aphis fabae* in Burundi. In humid weather, large aphid infestations can be wiped out by entomophagous fungi (Storey and Autrique, 1985). In the United States biological control involves mass rearing followed by mass

release of the predators and parasites from commercial insectaries (University of Idaho, 2001). There has been no such work in Kenya.

2.4.4 Cultural control

Timely planting has been identified to be effective cultural practice for control of bean aphid (CIAT, 1998). Since *A. fabae* is a polyphagous pest, it is important to check the surrounding weeds and other plants for aphids and destroy them to reduce aphid population. Removal of the crop residues immediately after harvest has been recommended (Alexandra and Eric, 2001). Scouting by visual counting of aphids per week is recommended, for correct application of other control measures to be applied (University of Idaho 1998). In Kenya weeding is practiced by farmers as an agronomic practice. On the other hand, timely planting is not practiced by all farmers.

2.4.5 Integrated pest management

The current management strategies rely on timely planting, and applying other remedies such as plant extract, ashes and insecticides (CIAT, 1998). Though resistance to the aphid can be a good IPM component, it has not been explored in Africa (Singh, 1990). However efforts are being made to identify resistant varieties, which can be used (CIAT, 1998) in aphid management. According to University of Idaho (2001), monitoring of bean plants and evaluating the aphid population and the extent of direct feeding have been used to determine the number of sprays per season. In addition, if natural enemies are active and aphid numbers are declining treatment with insecticides can be delayed for 3-5 days.

2.5 Rate of increase in aphids

Birch, (1948) describes the intrinsic rate of increase as a simple statistic that tells how fast a population multiplies and is often used to compare the population growth rate of organisms subjected to different growth rate of organisms subjected to different set of conditions. The rate of increase of aphid population depends on the speed of development, survival and fecundity. In many aphid species, reproduction rises rapidly in the early stages of adult life (Wyatt and White, 1977) and the reproductive time required

to contribute 95% to the natural intrinsic rate of increase (r_m) corresponds closely in value to the pre-reproductive period (Wyatt and White, 1977). The young ones produced in the first few days of reproduction contribute most to the value of r_m with the proportional contribution falling rapidly for later progeny. Using this information, a simplified equation for calculation of r_m and cohort generation time was formulated by Wyatt and White as follows

$r_m = 0.738(\log_e m_d)/d$

$T_c = 4d/3$

Where

r_m = intrinsic rate of increase

d = pre-reproductive time i.e the period (days) from birth to onset of reproduction

m_d = number of progeny (nymphs) produced within period equal to time d

T_c = cohort generation time

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experiment 1: Effect of variety and insecticide on population density of *A. fabae*, and its damage on the yields of beans under field conditions

3.1.1 Site description

The experiment was conducted in field 7, of Egerton University, Njoro. The site lies within 2238 M. a.s.l with a mean annual rainfall of 1012mm. The mean annual temperature is 14.9°C with a mean maximum and minimum temperature of 21.9° C and 7.9°C, respectively. The site is located 36° East and 0°20" South. The soils are vitric mollic andosols (Jaetzold and Schmidt, 1983). These are well-drained, deep dark reddish brown friable and silt clay to clay soils with humic topsoils.

3.1.2 Factors under study

1. Bean varieties namely; Rosecoco large seeded, Rosecoco small seeded, Canadian wonder, Red haricot, Mwitemania, Mwezi moja, Zebra, Mexican 142, Mwezi moja new variety and Yellow boston.
2. Insecticide (Dimethoate 40 EC, Danadim®) at two levels (zero and 1.5ml per litre of water).

3.1.3 Treatments combination

Treatment number	treatment description
1	Rosecoco large seeded without dimethoate
2	Rosecoco large seeded with dimethoate
3	Rosecoco small seeded without dimethoate
4	Rosecoco small seeded with dimethoate
5	Canadian wonder without dimethoate
6	Canadian wonder with dimethoate
7	Red haricot without dimethoate
8	Red haricot with dimethoate
9	Mwitemania (GLP 92) without dimethoate

10	Mwitemania (GLP 92) with dimethoate
11	Mwezi moja without dimethoate
12	Mwezi moja with dimethoate
13	Zebra without dimethoate
14	Zebra with dimethoate
15	Mexican 142 without dimethoate
16	Mexican 142 with dimethoate
17	Mwezi moja new variety without dimethoate
18	Mwezi moja new variety with dimethoate
19	Yellow boston without dimethoate
20	Yellow boston with dimethoate

3.1.4 Experimental design and field layout

The experiment was planted during the short rains season of 2002 (November – February 2003). The experimental design was a randomized complete block design in a complete factorial arrangement, replicated three times. With the use of random tables, treatments were randomly allocated to plots measuring 2 x 2.5 metres (Figure 1). Plots and replicates were separated from each other by a half-meter path and one meter alley, respectively. Planting was done at a spacing of 0.5 x 0.2 M (interrow and intrarow, respectively) with three seeds per hill and each plot having five rows (Plate 3). Seven days after emergence, one plant was thinned where it was necessary to leave two plants per hill. All the plots receiving insecticide treatment were sprayed thrice at an interval of three weeks starting three weeks after emergence. During spraying polythene paper was vertically placed on the half-metre path between plots to prevent the insecticide from drifting to other plots. Weeding was done manually using a hand hoe two weeks after emergence and one-month after the first one.

3.1.5 Variables measured

1. Plant stand count

Plant stand count on the three middle rows was taken 10 days after emergence (D.A.E) and at harvest.

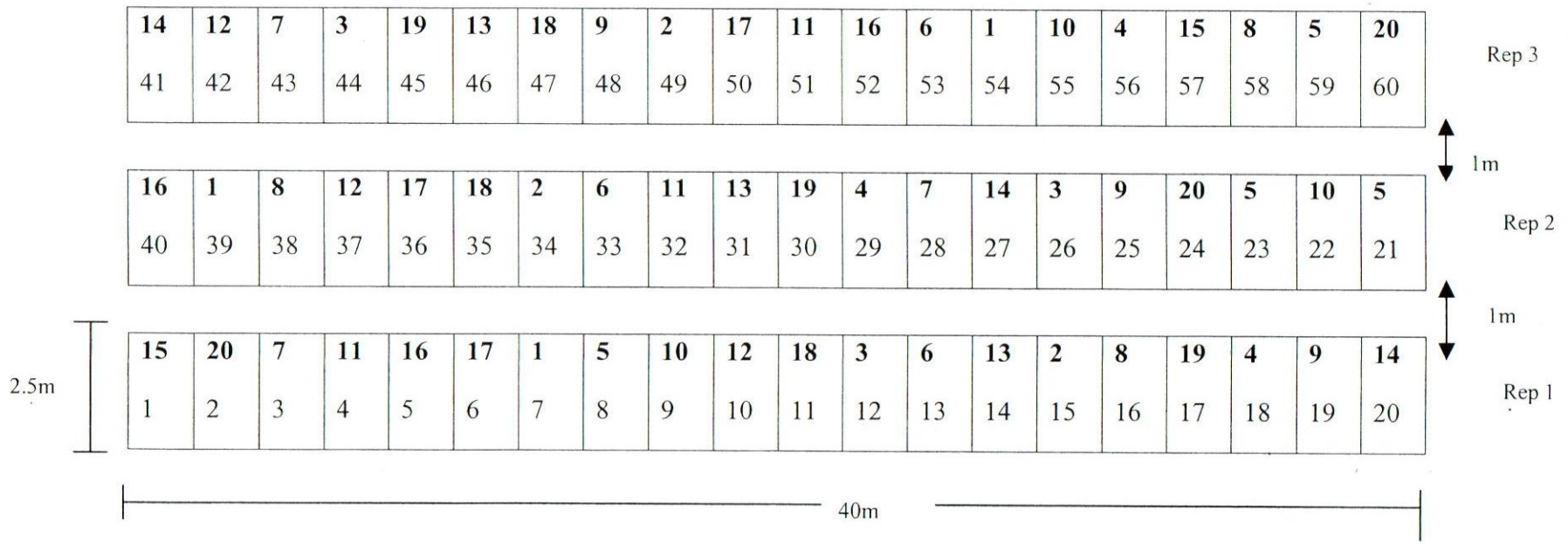


Figure1: Experimental field layout



Plate 3. Field experiment at field 7, Egerton University, Njoro

2. Mean number of aphids per plant

Three hills with two plants each were randomly selected from the three center rows examined for aphids, their numbers counted and recorded. This was done three times starting three weeks after emergence, with the second and third count done six and nine weeks after emergence.

3. Aphid incidence

After the counting of aphids, all the plants from the three center rows were examined and the plants infested by aphids were recorded and calculated as a percentage of the total number of plants in the three rows. After the counting and recording the incidence, the plots receiving insecticide were sprayed.

4. Severity of damage

Damage on plants by the aphids was rated at flowering stage on a scale of 1-5 as recommended by CIAT (1987) where:

1 = no damage

2 = leaves slightly cupped

3 = leaves moderately cupped with some slight yellowing

4 = severe distortion of leaves with considerable yellowing combined with honeydew production

5= very severe foliar distortion and yellowing combined with abundant honeydew production.

5. Plant height

Six plants were randomly selected from the three middle rows in each plot at physiological maturity. The height of each plant was measured and recorded.

6. Pods per plant

Six plants were randomly selected from the harvest area in each plot at physiological maturity and pods per plant were counted and recorded.

7. Seeds per pod

Ten pods were randomly picked from plants on the three middle rows in each plot. They were threshed and the average number of seeds per pod determined.

8. Total seed weight per hectare (Grain yield)

The three middle rows in each plot were harvested, threshed and the seeds were sun dried to a moisture level of 13% and weighed.

The total weight was then converted into tons per hectare using the formula;

$$\text{Yield (tons)} = \frac{\text{Field weight per plot (gm) X10, 000M}^2}{\text{Harvest area (4.05 M}^2\text{) X 100,000 gm}}$$

9. Hundred (100) seeds weight

Hundred (100) seeds were randomly selected from the harvested grains and their weight (grams) taken and recorded.

3.1.6 Data analysis

Data on mean number of aphids and infestation incidence three and six weeks after emergence were subjected to logarithmic (logx+1) and square root (x+1) transformation, respectively whereas data on infestation incidence nine weeks after emergence was subjected to arc-sine transformation according to Gomez and Gomez (1989) in order to homogenize the variance. The data collected was subjected to analysis of variance (ANOVA) using the MSTAT computer package (Michigan State University, 1985). The means were separated using Duncan's Multiple Range Test (DMRT). Total seed weight per hectare was then correlated with mean number of aphids per plant, incidence, damage and plant height using MSTAT computer package.

3.2 Experiment 2: Effect of variety on the population of *A. fabae* and its damage on beans under greenhouse conditions

3.2.1 Mass rearing of Aphids

Aphids to be used in experiment 2 and 3 were mass reared three weeks before setting the experiments. Rosecoco large seeded seedlings were planted in five polythene bags with a top diameter of 30 cm placed on one corner in the greenhouse. Seven days after emergence black bean aphids were collected from beans growing in field 7 of Egerton University. They were placed on the seedlings and left to multiply. The plants were then covered with netted screens to prevent the aphids from moving to the experimental plants.

3.2.2 Materials and methods

This experiment was conducted in a greenhouse located in field 3 (horticultural experimental plots) of Egerton University. The factor under study was all the bean varieties in experiment one. Two bean seeds were planted in polythene sleeves (top diameter 12 cm) and after emergence, thinning was done leaving one plant per sleeve. The experiment was arranged in randomized complete design replicated three times (Plate 4). Treatments were placed 20cm from each other and watering was done daily. Fourteen days after emergence three apterae aphids (in the fourth instar stage) were introduced on each plant. The population buildup and the varietal responses were then monitored. The protected plants (Plate 5), which were placed on the opposite side of the infested plants, were kept aphid free by spraying dimethoate at a two-week interval until physiological maturity.

3.2.3 Variables measured

1. Number of aphids per plant

The first aphid count was carried out two weeks after infestation and the number of aphids per plant were recorded. During the second aphid count two weeks after the first count, which coincided with six weeks after emergence, the number of aphids per plant, were very many and this made it impossible to carry out the counting precisely. The aphid count was therefore done on the stalk joining the third trifoliolate leaf to the stem in all the plants. The third count (eight weeks after emergence) was done on the stalk joining the fifth trifoliolate leaf to the stem in all the plants.

2. Severity of damage and honeydew production

Damage on plants by the aphids was rated at flowering stage on a scale of 1-5 as recommended by CIAT (1987) where:

1= no damage

2 = leaves slightly cupped

3 = leaves moderately cupped with some slight yellowing

4 = severe distortion of leaves with considerable yellowing combined with honeydew production



Plate 4. Infested bean plants in the green house



Plate 5. Protected bean plants in the green house

5 = very severe foliar distortion and yellowing combined with abundant honeydew productio

Honeydew production was scored on the same date as severity of damage on a scale of 1-5 where:

1= no honeydew and no sooty moulds

2= little honeydew and no sooty moulds

3= moderate honeydew and slight sooty moulds

4= high amounts of honeydew with moderate sooty moulds

5= a lot of honeydew with a lot of sooty moulds

3. Plant height

At physiological maturity the height of each plant was taken and recorded.

4. Pods per plant and seeds per pod

During harvesting, pods per plant were counted and recorded. Three pods from each plant were then threshed and the average number of seeds per pod was recorded.

5. Grain yield

Seeds per plant were sun dried to attain a moisture level of 13% for one week and their weight was recorded.

6. Yield loss

Percentage yield loss was computed using the formula

$$\% \text{ Yield loss} = \frac{\text{yield of protected plant- yield of infested X 100}}{\text{Yield of protected}}$$

3.2.4 Data analysis

Data on aphids per plant was subjected to logarithmic transformation (logX+1) according to Gomez and Gomez (1989) to homogenize the variance and subjected to analysis of variance (ANOVA) using the MSTAT computer package (Michigan State University, 1985). The means were separated using Duncan's Multiple Range Test (DMRT). Total seed weight per plant was then correlated with mean number of aphids per plant, damage and plant height using MSTAT computer package.

3.3 Experiment 3: Effect of variety on development time, fecundity, longevity and intrinsic rate of increase of *A. fabae* under greenhouse conditions.

3.3.1 Materials and methods

The experiment was carried out in the same greenhouse with experiment two .The 10 varieties used in experiment 1 and 2 were used in this experiment. Two seeds were planted on polythene sleeves (top diameter 12 cm) and placed 20cm from each other. The experimental design was a randomized complete design replicated three times. Seven days after emergence thinning was done to one plant. Fourteen days after emergence one apterae aphid at the fourth instar was placed on one leaf and the plant was caged using a veil net (Plate 6). After larvipositing the adult aphid and all the nymphs except one female were killed by piercing them with an insect pin. The remaining young female was used for study and observations were made daily.

3.3.2 Variables measured

1. **Development time**

This was done by noting the number of days from when the nymph was larviposited to the onset of larvipositing by the same nymph.

2. **Fecundity**

This entailed counting the number of nymphs per aphid on a 24 hours interval. After each counting all the nymphs were killed by piercing them using an insect pin.

3. **Longevity**

The longevity of the aphid was determined by noting the number of days from birth to death of the aphid.

4. **The intrinsic rate of natural increase** was computed following the formula (Wyatt and White, 1977);

$r_m=0.738(\log_e m_d/d$

$T_c=4d/3$

Where

r_m = intrinsic rate of increase

d = pre-reproductive time i.e the period (days) from birth to onset of reproduction

m_d = number of progeny (nymphs) produced within period equal to time d

T_c= cohort generation time

3.3.3 Data analysis

The data obtained was subjected to analysis of variance using MSTAT computer package (Michigan State University, 1985). DMRT was used to separate the means.

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Plate 6. Experimental layout to show the effect of variety on development time, fecundity, longevity and intrinsic rate of increase of *A. fabae* under greenhouse conditions.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Effect of variety and insecticide on population density of *A. fabae*, and its damage on the yields of beans under field conditions

4.1.1 Aphid population

Analysis of variance showed that variety did not significantly ($P>0.05$) affect the mean number of aphids per plant three, six and nine weeks after emergence (Table 1). However, three weeks after emergence the number of aphids per plant was very low with the highest (24.77) recorded on Red haricot and the lowest (4.33) on Mwezi moja new variety. Six weeks after emergence aphid population had risen with the highest number (158.65) recorded on variety Zebra and the lowest (15.56) on Mexican 142 followed by Rosecoco large seeded (16.00). Canadian wonder, Yellow boston, Rosecoco small seeded and Mwezi moja new variety had appreciably high number of aphids (Table 1).

Nine weeks after emergence, aphid population rose to over 100 aphids per plant in all varieties. Though the mean number of aphids per plant was not significantly different, the population appreciably varied with varieties. Canadian wonder supported the highest aphid numbers (375.56) followed by Zebra (352.00) and Rosecoco small seeded (345.09). Conversely, Mexican 142 had the lowest number of aphids followed by Rosecoco large seeded, Mwezi moja new variety and Red haricot (108.89, 140.78, 166.78 and 198.33, respectively) (Table1 and Figure 2). These results agree with those reported by Cichoka *et al.*, (2002) while working on the response of *A. fabae* to different broad bean cultivars. These varying numbers of aphids amongst the varieties can be attributed to the quality of plants, such as nutritional content, chemical and morphology which are important factors affecting the development, survival, longevity and reproduction of the aphids (Yue and Liu, 2000).

The population of aphids increased with time at different rates amongst the varieties (Figure 3). The greatest rate of increase in the population was observed nine weeks after emergence in all the varieties. However, it was highest in Canadian wonder, Rosecoco small seeded and Zebra and least in Mexican 142 followed by Rosecoco large seeded and Mwezi moja new variety, respectively. Yue and Liu (2000) reported similar findings while working on host selection, development, survival and reproduction of

turnip aphid on red and green cabbage varieties, and attributed the difference in population of aphids over time in varieties, to the aphid playing a key role during the first days of selecting the varieties to land on and determining the suitability of these varieties. After settling on their preferred plants they spend more time feeding and reproducing thus resulting to more aphids on their more preferred varieties than on the less preferred ones. These results suggest some degree of non-preference on the varieties that supported low aphid population. Even though the experiment did not establish the mechanism of resistance, Arthur *et al.* (1998) when working on resistance of common bean lines to the potato leafhopper suggested that lines with low nymphal populations may be expressing antixenosis as the predominant defence mechanism. Further work is thus required to establish whether this suggestion holds true in relation to this study.

Dimethoate significantly ($P<0.05$) reduced the number of aphids per plant (Table 1 and Figure 4). The insecticide maintained the aphid population at low levels of 5.19 and 4.61, three and six weeks after spraying, respectively. However, in the unsprayed treatment the population increased drastically from 65.85 three weeks after spraying to 239.54, six weeks after spraying (Figure 4). Macharia *et al.* (1997) while working on the efficacy of insecticide on the control of Russian wheat aphid on wheat reported similar findings. Dimethoate killed the initial migrant aphids that are responsible of starting aphid colonies on plants. The subsequent sprays killed the aphids that were emigrating from the unsprayed plots as their population rose.

4.1.2 Incidence of aphid infestation

Overall aphid infestation was not significantly ($P<0.05$) affected by the varieties three and six weeks after emergence (Table 2). Three weeks after emergence infestation was very low, with the highest in Zebra and the lowest in Rosecoco small seeded and Mwitemania. Six weeks after emergence aphid incidence on variety Zebra rose from 9.62% being the highest at three weeks after emergence to 28.47 % in Canadian wonder. Zebra had a high incidence ranking second after Canadian wonder whereas Red haricot and Mwezi moja had the lowest percentage incidence (Table 2 and Figure 5).

Table 1. Effect of variety and insecticide on aphid population density

Factor	mean number of aphids/ plant		
	(3WAE)	(6 WAE)	(9 WAE)
Variety			
Rosecoco large seeded	0.84 (7.56)	1.20 (16.0)	2.06 (140.78)
Rosecoco small seeded	0.76 (7.64)	1.82 (67.56)	2.53 (345.09)
Canadian wonder	1.16 (14.56)	1.90 (91.44)	2.56 (375.56)
Red haricot	1.35 (24.77)	1.59 (58.45)	2.13 (198.33)
Mwitemania	1.07 (13.78)	1.57 (46.22)	2.34 (239.45)
Mwezi moja	1.05 (12.22)	1.68 (58.88)	2.29 (210.33)
Zebra	1.33 (21.66)	2.11 (158.65)	2.54 (352.00)
Mexican 142	0.85 (6.77)	1.19 (15.56)	2.02 (108.89)
Mwezi moja new variety	0.68 (4.33)	1.65 (65.77)	2.19 (166.78)
Yellow Boston	0.98 (13.63)	1.90 (79.99)	2.29 (258.22)
S.E	NS	NS	NS
Diamethoate			
0 ml/hectare	-	1.64 (65.85) [a]	2.29 (239.54) [a]
1.5 ml/liter of water	-	0.71 (5.19) [b]	0.52 (4.61) [b]
S.E	-	0.08	0.07
CV (%)	35.69	41.35	25.50

Figures in parenthesis are means of original values.

WAE = weeks after emergence

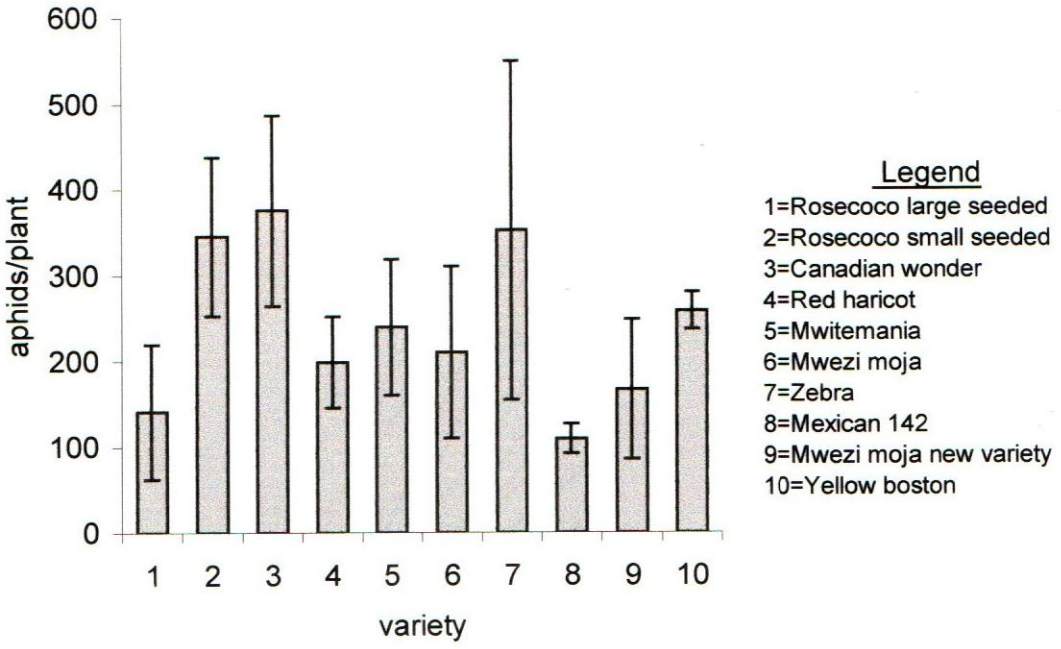


Figure 2. Effect of variety on population density of aphid 9 weeks after emergence.

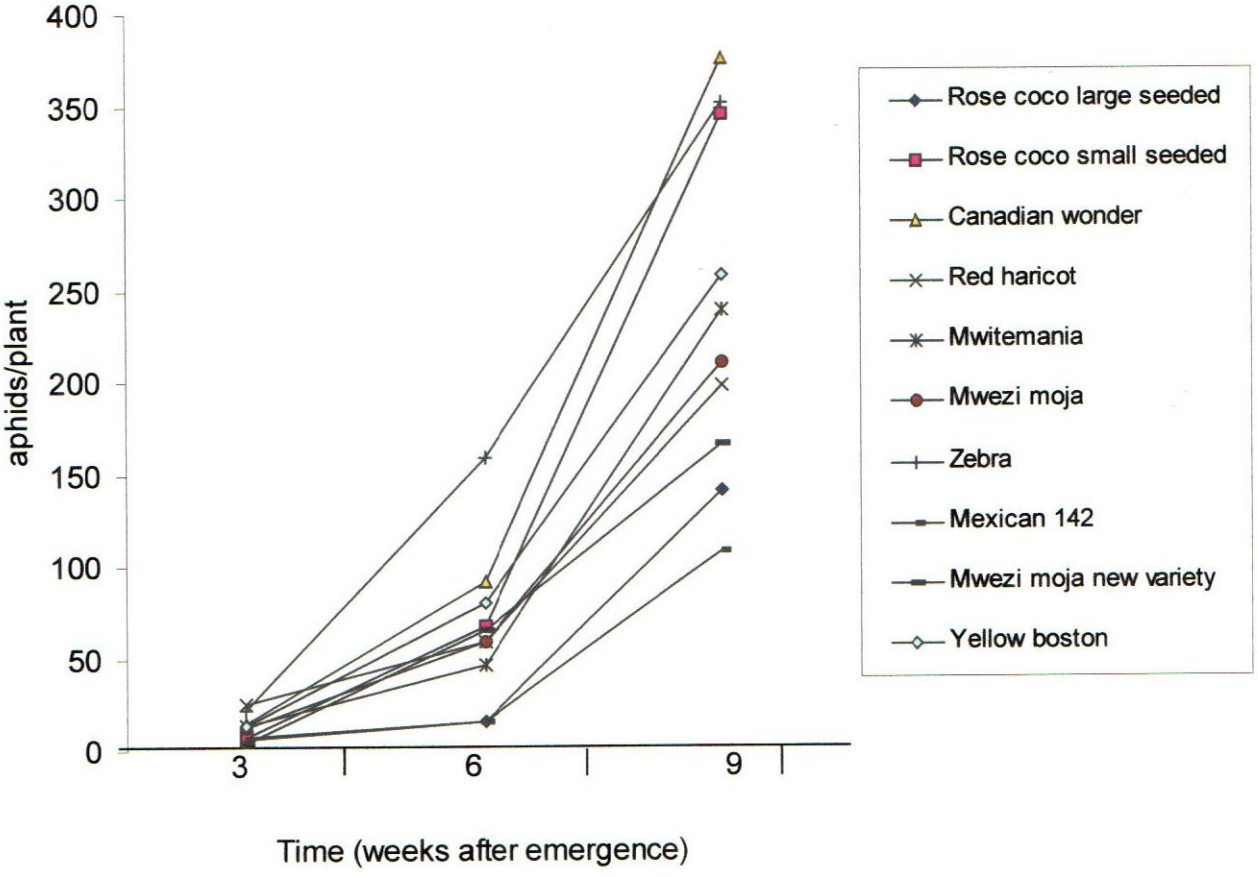


Figure 3. The effect of variety on *A. fabae* population build up three, six and nine weeks after plant emergence.

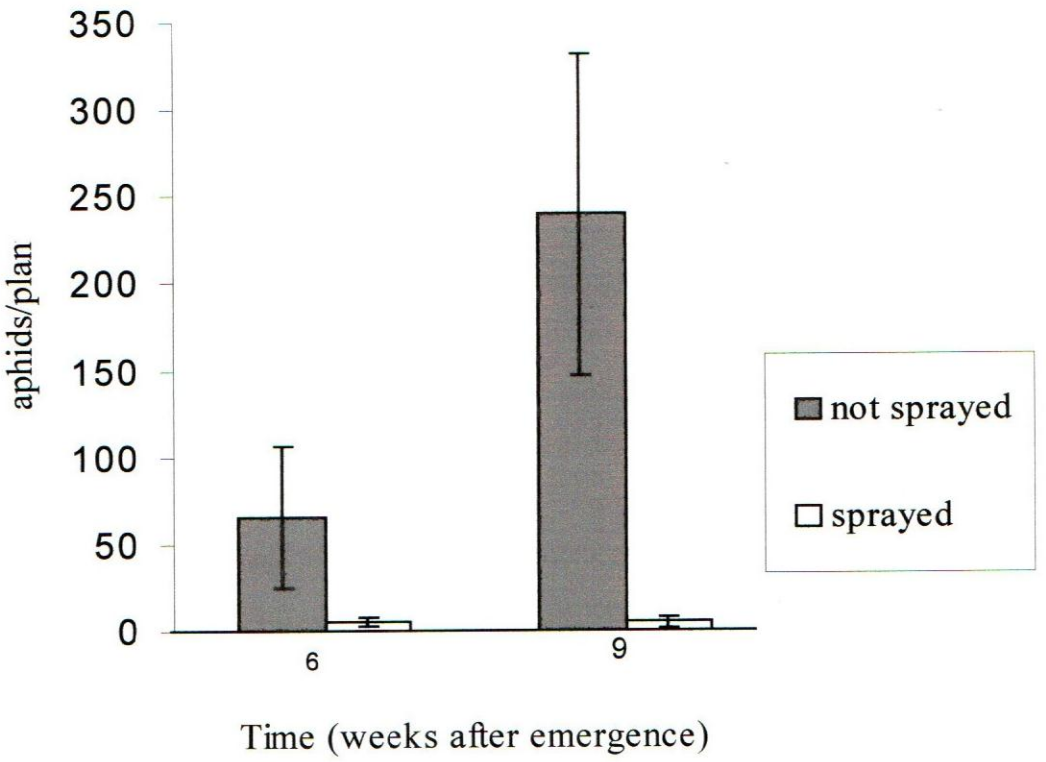


Figure 4. The effect of insecticide on aphid population density 6 and 9 weeks after emergence

However, aphid infestation incidence differed significantly ($P<0.05$) amongst bean varieties nine weeks after emergence. Canadian wonder had the highest infestation incidence, which was not significantly different from that in Mwitemania, Zebra, Rosecoco small seeded and Yellow boston. Rosecoco large seeded had the lowest infestation incidence which was not significantly different from Mwezi moja new variety, Mexican 142, Rosecoco small seeded, Mwezi moja, Yellow boston and Red haricot (Table 2, Figure 5 and 6). The high incidence in Canadian wonder can be attributed to the colour of its leaves, which are yellowish. Yellow colour attracts aphids (Hawley, 2002). As the population increased on the plants, alatae forms of *A. fabae* flew from those plants into the air in search of less populated plants. While in the air they might have been attracted more by the colour of the leaves of Canadian wonder resulting to high incidence than on any other plant. Growth habit too had some effect on the incidence. Rosecoco large seeded, Mwezi moja new variety and Mexican 142, which are determinate bush with strong and erect stem had the lowest incidence, Mwitemania an indeterminate bush type with tendrils with no ability to climb and Zebra an indeterminate with long tendrils coiling on the adjacent plants had significantly high incidence. This could have been due to the crawling of aphids from highly populated plants to the less populated neighbouring plants as they responded to their own population density using tendrils and leaves in the case of Mwitemania and tendrils in Zebra.

Spraying beans with dimethoate significantly ($P<0.05$) reduced the incidence of aphids (Table 2 and Figure 7). The pesticide reduced the incidence level from 16.12 to 6.91 six weeks after emergence and from 38.01 to 3.89 nine weeks after emergence whereas the unsprayed treatments registered an increase in infestation incidence from 16.12 to 38.01 six and nine weeks after emergence, respectively (Figure 7). This was due to the insecticide killing the aphids settling on the plants and probably repelling others.

There was significant ($P<0.05$) interaction between variety and insecticide on aphid incidence nine weeks after emergence (Table 3). This interaction was due to the differences in the rate at which dimethoate reduced the aphid incidence on the varieties (Figure 8). Dimethoate achieved the highest incidence reduction in variety Canadian wonder followed by Zebra, Mwitemania, Mwezi moja, Rosecoco large seeded and Yellow boston, and the least in variety Rosecoco large seeded and Mexican 142 (Figure

8). These results can be attributed to the different ability by the varieties to support varying infestation incidence levels, while dimethoate almost achieved a uniform reduction of incidence in all the varieties. However, though at varying degrees, the insecticide significantly reduced the incidence in all the varieties (Table 3). This means that the varieties that had significantly high infestation incidence could combine well with the insecticide compared to those varieties with a low aphid infestation incidence. These findings means that a combination of both variety and insecticide can be used to achieve a much lower aphid incidence on some varieties which when left unsprayed suffer a high incidence.

4.1.3 Severity of damage caused by *A. fabae* on bean varieties

There were no significant ($P>0.05$) differences on severity of damage amongst the varieties (Table 4). However, the highest average damage score of 3.17 was recorded on Canadian wonder and mwezi moja new variety and the least score (2.17) was recorded on Mexican 142 and zebra. The leaves were slightly to moderately curled with very little amounts of honeydew in all the varieties. The little amount of honeydew observed was probably due to ants that followed the aphids and fed on honeydew before flowering. This led to restricted growth of saprophytic moulds and clogging of stomata by the honeydew both of which leads to yellowing and pre-mature senescence of leaves (Rabbinge and Mantel 1981). During flowering and podding stage, there were no ants observed but there were heavy rains (Appendix 1). The rains washed off the honeydew that was deposited on the upper surface of the leaves thus reducing its accumulation and consequently growth of saprophytic moulds.

4.1.4 The effect of variety and insecticide on plant height, pods per plant, seeds per pod, 100 seed weight and total grain yield of common bean varieties naturally infested with *A fabae*.

The results on the effect of variety and insecticide on plant height, pods per plant and seeds per pod, and 100 seed weight and total grain yield per hectare of common beans under natural field infestation with *A. fabae* are depicted in Tables 5, 6 and 7, respectively and reported and discussed under section 4.1.4.1-4.1.4.4.

4.1.4.1 Plant height

There were significant differences on plant height amongst all the ten varieties (Table 5). Zebra had the greatest average height (49.89 cm), which was significantly ($P<0.05$) different from all the varieties. This was followed by Red haricot and Canadian wonder, which were not significantly different from each other, but different from all the other varieties. In contrast, Yellow boston, Mwezi moja, Rosecoco small seeded and Rosecoco large seeded, were significantly shorter than the other varieties but were not significantly different from each other. Rabbige *et al.*, (1980) attributed stunted growth of plants infested by aphids to the sucking and removal of nutrients from the plant.

Diamethoate significantly ($P<0.05$) affected the plant height with unprotected ones registering reduced height compared to the protected (Table 5). Katwijukiye and Kyamanywa (1997) and Cichoka *et al* (2002) reported similar results and found significant differences in heights of protected and unprotected plants.

Variety by insecticide interaction on plant height was significant ($P<0.05$). Use of dimethoate resulted to significantly increased plant height on varieties Canadian wonder, Red haricot, Mwitemania, Zebra and Mexican 142 (Table 6). However, the rate at which the insecticide affected the plant height was not the same on these varieties. Variety Zebra experienced the greatest height increase with the spray of dimethoate which was significantly ($P<0.05$) different from the others and was followed by Mexican 142, Mwitemania, Canadian wonder, Red haricot and Yellow boston in that order (Figure 9). These results show that some varieties are more tolerant to the aphid than others. Varieties Rosecoco large seeded, Rosecoco small seeded, Mwezi moja and Mwezi moja new variety are tolerant while Zebra, Mexican 142, Mwitemania, Canadian wonder, Red haricot and Yellow boston are not or are less tolerant. However, of all these varieties Rose coco large seeded can be said to be the most tolerant whereas Zebra is the least tolerant.

4.1.4.2 Number of pods per plant

The number of pods per plant were significantly ($P<0.05$) higher in Mexican 142(13.22), though not significantly different from Red haricot. However, the number of pods per plant in Red haricot was not significantly different from Rosecoco large seeded

Table 2. Effect of variety and insecticide on mean infestation incidence of *A. fabae*

Factor	mean infestation incidence of aphids		
	(3 WAE)	(6 WAE)	(9 WAE)
Variety			
Rose coco large seeded	2.48 (6.16)	3.61 (12.41)	23.19 (15.56) [d]
Rose coco small seeded	2.02 (4.10)	3.75 (13.32)	39.03 (39.93) [abcd]
Canadian wonder	2.28 (5.21)	5.33 (28.47)	52.51 (62.50) [a]
Red haricot	2.52 (6.36)	3.31 (10.26)	35.45 (34.33) [bcd]
Mwitemania	2.02 (4.10)	4.42 (19.96)	46.13 (52.00) [ab]
Mwezi moja	2.29 (5.15)	3.59 (12.25)	38.11 (38.28) [abcd]
Zebra	3.02 (9.62)	4.55 (20.33)	44.59 (49.27) [abc]
Mexican 142	2.70 (7.29)	3.85 (13.92)	31.75 (29.32) [bcd]
Mwezi moja new variety	2.91 (8.47)	3.80 (13.71)	29.10 (23.88) [cd]
Yellow Boston	2.27 (5.18)	4.12 (16.54)	35.08 (35.06) [abcd]
S.E	NS	NS	3.40
Diamethoate			
0 ml/hectare	-	4.03 (16.12) [a]	37.50 (38.01) [a]
1.5ml/ liter of water	-	2.52 (6.91) [b]	8.01 (3.89) [b]
S.E	-	0.20	1.52
CV (%)	23.52	34.11	36.69

Figures in parenthesis are means of original values.

Means within a column followed by the same letter are not significantly different at $P<0.05$, Duncan multiple range test

WAE = weeks after emergence

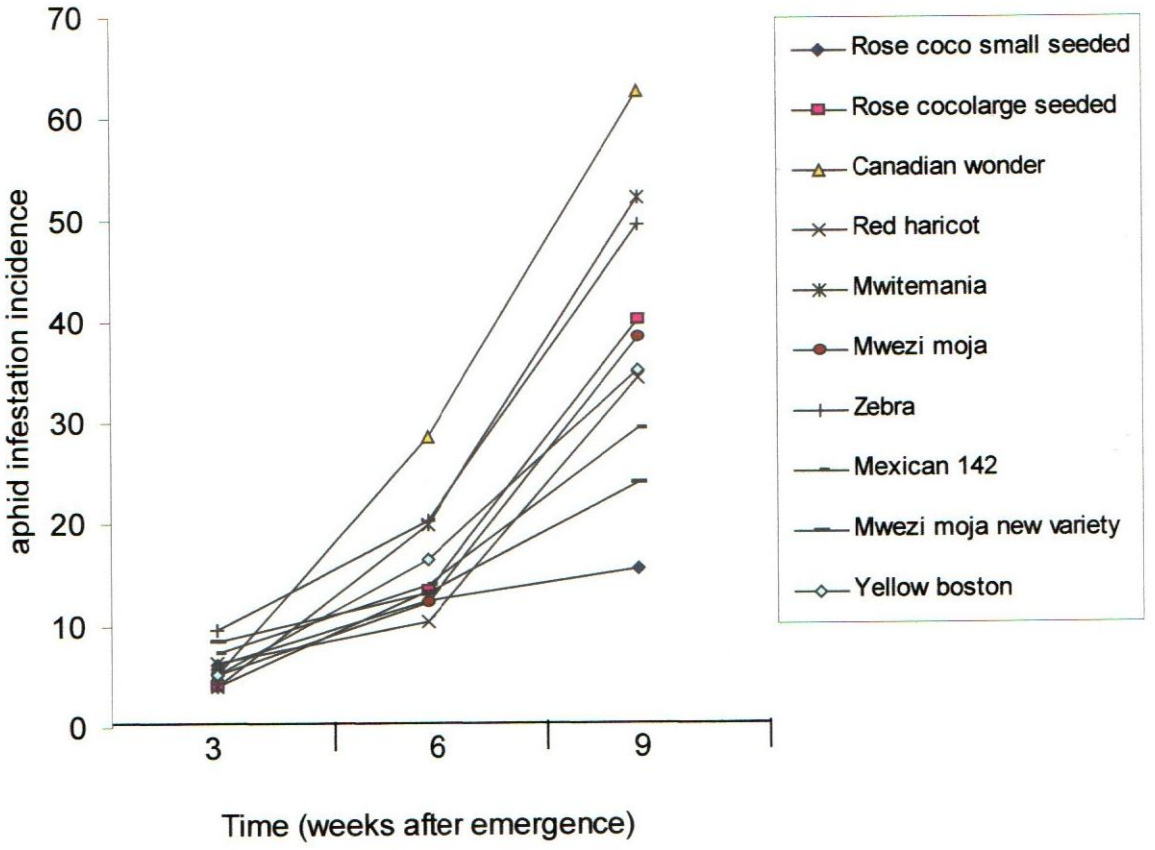


Figure 5. Aphid infestation incidence build up over time.

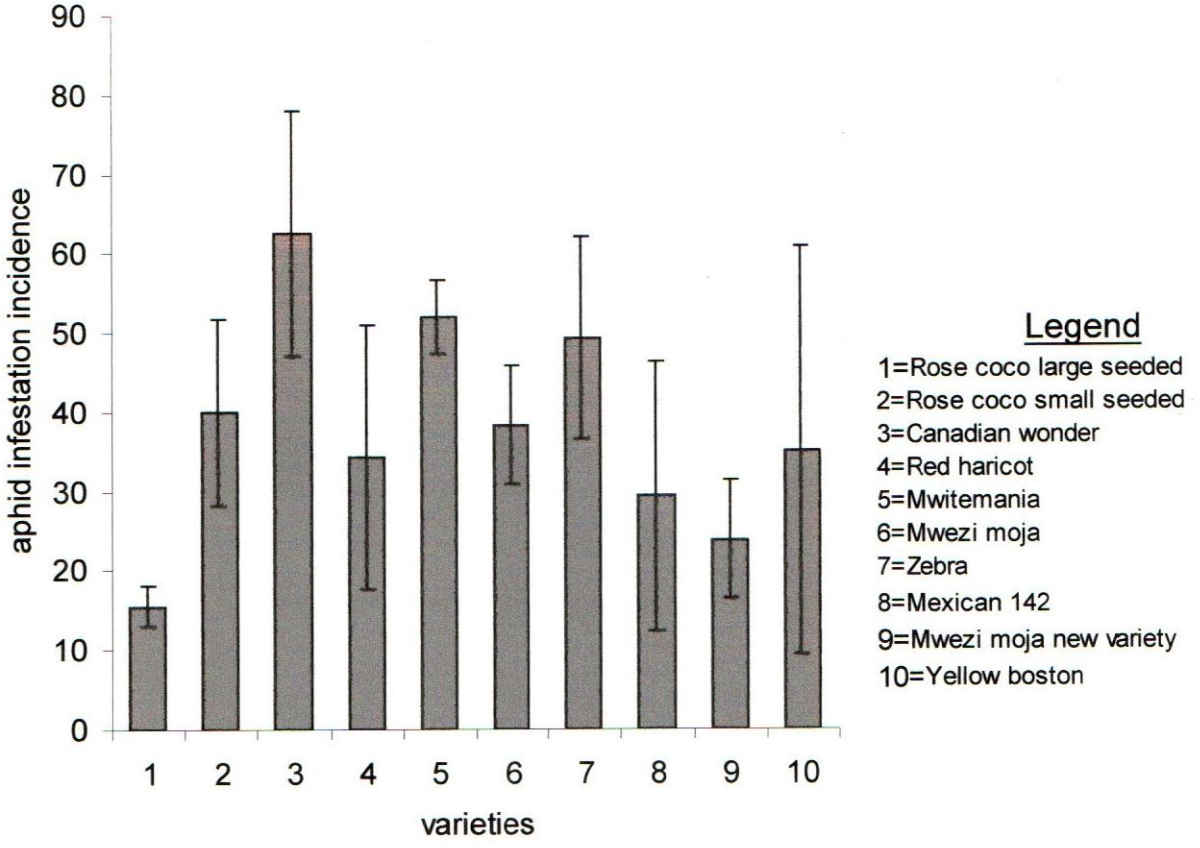


Figure 6. Effect of variety on aphid infestation incidence nine weeks after emergence

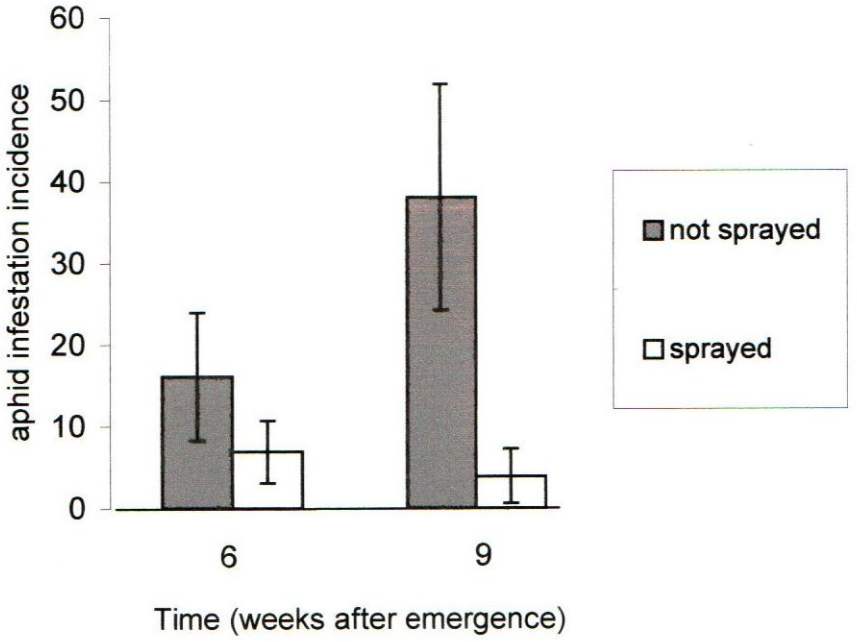


Figure 7. Effect of insecticide on aphid infestation six and nine weeks after emergence.

Table 3. Effect of interaction between varieties and insecticide on percentage incidence of *A. fabae* nine weeks after emergence on beans grown under field conditions.

	Aphid infestation incidence	
Variety	not sprayed	sprayed
Rose coco large seeded	23.19 (15.56) [a]	12.98 (7.47) [b]
Rose coco small seeded	39.03 (39.93) [a]	7.14 (2.29) [b]
Canadian wonder	52.51 (62.50) [a]	8.51 (3.37) [b]
Red haricot	35.45 (34.33) [a]	5.85 (3.03) [b]
Mwitemania	46.13 (52.00) [a]	15.82 (8.14) [b]
Mwezi moja	38.11 (38.28) [a]	0.00 (0.00) [b]
Zebra	44.59 (49.27) [a]	0.00 (0.00) [b]
Mexican 142	31.75 (29.32) [a]	17.18 (9.48) [b]
Mwezi moja new variety	29.10 (23.88) [a]	5.85 (3.03) [b]
Yellow Boston	35.08 (35.06) [a]	6.61 (2.05) [b]
S.E	3.40	
C.V	36.69	

Figures in parenthesis are means of original figures.

Means in the same row followed by the same letter are not significantly different at $P<0.05$ using LSD.

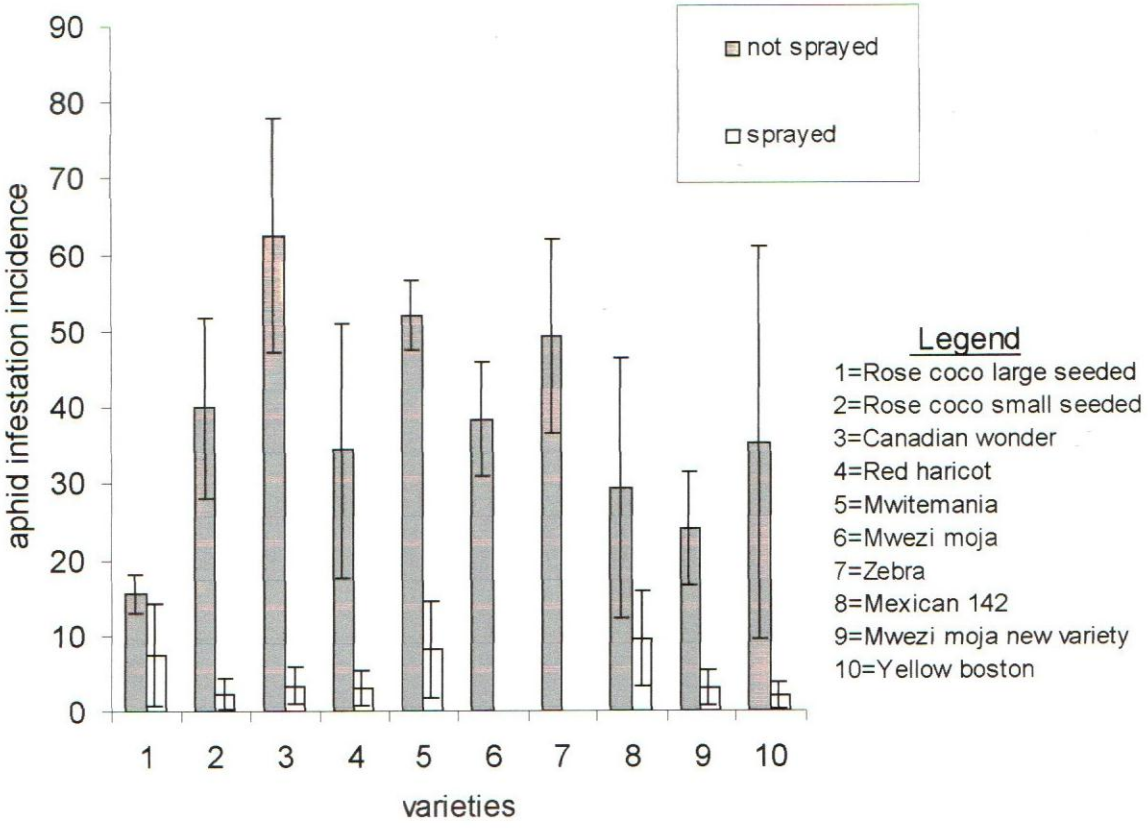


Figure 8. Effect of interaction between varieties and insecticide on aphid infestaion incidence 9 weeks after emergence.

Table 4. Effect of severity of damage by *A. fabae* on bean varieties

Variety	mean score on a scale of 1-5
Rose coco large seeded	2.33
Rose coco small seeded	2.00
Canadian wonder	3.17
Red haricot	3.00
Mwitemania	2.67
Mwezi moja	2.67
Zebra	2.17
Mexican 142	2.17
Mwezi moja new variety	3.17
Yellow Boston	2.50
S.E	NS
CV (%)	26.05

Mwitemania, Canadian wonder and Mwezi moja new variety. Zebra had the least pods per plant (Figure 11) and was not significantly different from Yellow boston, Rosecoco small seeded, Mwezi moja, Mwezi moja new variety, Mwitemania and Canadian wonder (Table 5). Similar findings have been reported elsewhere by Cichoka *et al.* (2002) on broad beans cultivars.

Dimethoate lowered number of aphids resulting to more pods development per plant (Table 5). These results are consistent with those reported by Cichoka *et al* (2002) and Katwijukye and Kyamanywa (1997) who reported high number of pods per plant in protected plants and attributed the differences to the presence of aphids on unprotected plants.

4.1.4.3 Number of seeds per pod

There were significant ($P<0.05$) differences on seeds per pod amongst the varieties (Table 5). Red haricot had significantly higher number of seeds per pod, which was not significantly different from Mwezi moja and Mwezi moja new variety, which on the other hand were not significantly different from Mexican 142. Seeds per pod in Mexican 142 were not significantly different from Yellow boston, Mwitemania, Rosecoco small seeded and Canadian wonder, whereas seeds per pod in Rosecoco large seeded were not different from Yellow boston, Mwitemania, Rose coco small seeded and Canadian wonder. Zebra had the least number of seeds per pod, which were not significantly different from rosecoco large seeded (Table 5). These results could have been due to Variation in aphid infestation levels and the genetic make up of the varieties. Katwijukye and Kyamanywa (1997) reported that varying number of aphids per plant significantly affected seeds per pod. This agrees with these results where it was observed that the varieties with a high aphid population had significantly lower seeds per pod. However, Cichoka *et al.* (2002) showed that aphid infestation led to reduction in seeds per pod in some varieties and not in others. This agrees with these results where, despite Rosecoco large seeded having a considerably low aphid population had a significantly low number of seeds per pod. This means that the significantly low number of seeds per pod in Rosecoco large seeded could be due to its genetic make up.

Dimethoate significantly (P=0.05) increased the number of seeds per pod in every variety.

4.1.4.4 Hundred (100) Seeds weight

The weight of 100 seeds was significantly (P<0.05) different among the varieties. Zebra had significantly higher 100 seeds weight, which was not significantly different from Mwezi moja new variety, Rosecoco large seeded, Mwezi moja, and Rosecoco small seeded, whose 100 seeds weight was not different from that of Yellow boston and Canadian wonder. Mexican 142 had the least 100 seed weight, which was not significantly different from that of Red haricot (Table 7). These differences are most probably due to the genetic variation among the varieties as the large seeded varieties (Zebra, Rosecoco large seeded, and Mwezi moja varieties) were found to have a significantly higher 100 seeds weight than the small seeded varieties Mexican 142 and Red haricot. This is further supported by the findings by Katwijukye and Kyamanywa (1997) who found that varying number of aphids per plant did not significantly affect the weight of 100 seeds. Likewise, Cichoka *et al.* (2002) found that *A. fabae* did not significantly affect 100 seed weight of protected and unprotected broad bean cultivars. These findings are further supported by this work, where dimethoate had no significant (P<0.05) effect on 100 seed weight (Table 7).

4.1.4.5 Grain yield

Grain yields significantly (P<0.05) differed with varieties (Table 7) with the yields ranging between 3.02 and 1.55 tons per hectare. Red haricot recorded the highest yield, which was not significantly different from Mwezi moja variety, Rosecoco large seeded and Mwezi moja. The grain yield of (2.70) in Rosecoco large seeded was not significantly different from that of Mwezi moja variety and Mexican 142, both of which were not significantly different from Canadian wonder and Mwitemania. Rosecoco small seeded had the least yield, which was not significantly different from Zebra, Canadian wonder, Yellow boston, Mwitemania and Mexican 142 (Table 7). These differences in yields are attributed to the varying number of aphids per plant. Katwijukye and Kyamanywa (1997) found that varying number of aphids per plant led to significant

differences in yields and that a difference of up to four aphids caused significant yield reduction. The aphids caused the grain yield reduction by reducing both the number of pods per plant and the seeds per pod and this was consistent with the findings by Cichoka *et al* (2002). Those varieties that supported a high population of aphids gave significantly low grain yield. These varieties included Rosecoco small seeded, Zebra and Canadian wonder. It is also observed that incidence too had an impact on the yield. For instance, Canadian wonder, Zebra and Mwitemania which had a significantly higher incidence had low yields. Though Canadian wonder recorded the highest population of aphids its yield was not significantly different from that of Mexican 142, Yellow boston, Mwitemania and Mwezi moja which had fairly low aphid population. This could mean that this variety is more tolerant to the aphid attack.

Use of dimethoate resulted to significantly ($P<0.05$) higher grain yields. This was consistent with the findings by Macharia *et al* (1997) who reported significantly higher yields on wheat crop sprayed with insecticide, while working on the efficacy of seed dress insecticide in the management of Russian wheat aphid in Kenya.

4.1.5 The correlation between yield of bean varieties with the mean number of aphids per plant, aphid infestation, severity of damage and plant height

The correlation between mean number of aphids per plant and aphid incidence was significant and negatively correlated with the yields (Table 8). This agrees with what was observed in the field in this study where plots that were heavily populated and with a high infestation gave low yields. This agrees with findings by Katwijukye and Kyamanywa (1997) who reported a negative relationship between aphid population and yields. However, the correlation between severity of damage and plant height to yield of beans were not significant ($P<0.05$). These results are possibly due to the fact that severity of damage was not significantly different amongst the varieties, while plant height reduction between the sprayed and unsprayed plants was not significantly different in some varieties namely, Rosecoco large seeded, Rosecoco small seeded, Mwezi moja and Mwezi moja new variety.

Table 5. Effect of bean variety and controlling *A. fabae* on plant height, pods/plant and seeds/pod

Factor	mean plant Height (cm)	mean number of pods/plant	mean number of seeds/pod
Variety			
Rose coco large seeded	27.00 ^{def}	8.33 ^{bc}	2.97 ^{de}
Rose coco small seeded	26.44 ^{ef}	5.50 ^{cd}	3.50 ^{cd}
Canadian wonder	31.44 ^{b}	7.00 ^{bcd}	3.53 ^{cd}
Red haricot	41.67 ^{b}	10.28 ^{ab}	4.57 ^{a}
Mwitemania	28.45 ^{cde}	7.33 ^{bcd}	3.30 ^{cd}
Mwezi moja	26.22 ^{f}	5.07 ^{cd}	4.43 ^{ab}
Zebra	49.89 ^{a}	4.11 ^{d}	2.40 ^{e}
Mexican 142	29.20 ^{c}	13.22 ^{a}	3.80 ^{bc}
Mwezi moja new variety	25.00 ^{f}	6.78 ^{bcd}	3.87 ^{abc}
Yellow Boston	25.67 ^{f}	4.72 ^{cd}	3.33 ^{cd}
S.E	2.88	0.77	0.17
Dimethoate			
0 ml/hectare	32.00 ^{b}	7.23 ^{b}	3.57 ^{b}
1.5 ml/liter of water	47.02 ^{a}	9.44 ^{a}	3.91 ^{a}
S.E	2.87	0.35	0.07
CV (%)	18.04	25.39	10.89

Means within a column followed by the same letter are not significantly different at $P<0.05$, DMRT

Table 6. Effect of interaction between varieties and insecticide on the plant height of bean varieties in the field trial.

Variety	Plant height	
	not sprayed	sprayed
Rose coco large seeded	27.00 [a]	36.33 [a]
Rose coco small seeded	26.44 [a]	33.89 [a]
Canadian wonder	31.44 [b]	49.44 [a]
Red haricot	41.67 [b]	59.55 [a]
Mwitemania	28.45 [b]	48.89 [a]
Mwezi moja	26.22 [a]	31.11 [a]
Zebra	49.89 [b]	89.44 [a]
Mexican 142	29.20 [b]	54.88 [a]
Mwezi moja new variety	25.00 [a]	28.45 [a]
Yellow Boston	25.67 [b]	38.22 [a]
S.E	4.06	
C.V	18.04	

Means in the same row followed by the same letter are not significantly different at $P<0.05$ using LSD.

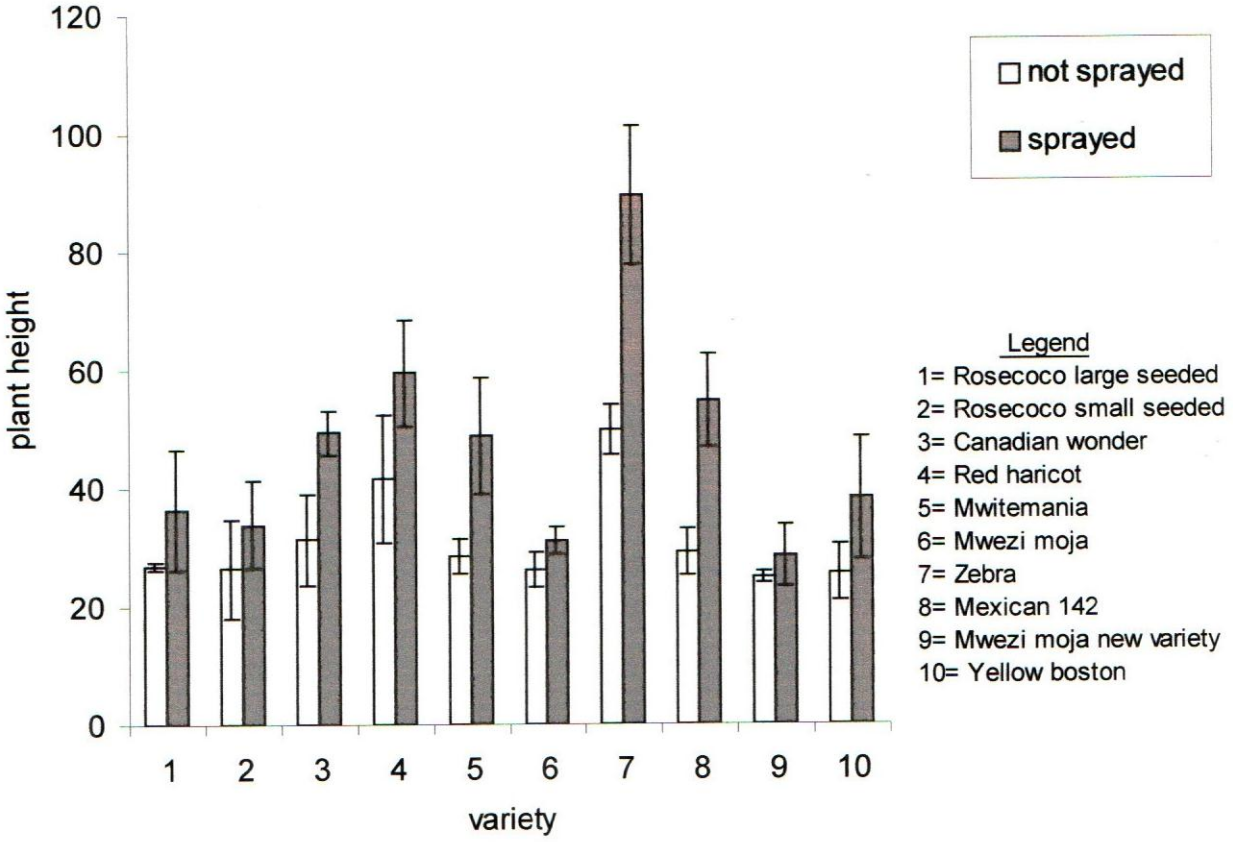


Figure 9. Effect of interaction between varieties and insecticde on the plant height

Table 7. Effect of variety and insecticide on hundred (100) seed weight and grain yield of beans

Factor	100 seed weight (Grams)	Yield (tons/hectare)
Variety		
Rose coco large seeded	53.46 ^{ab}	2.70 ^{ab}
Rose coco small seeded	52.93 ^{ab}	1.55 ^{d}
Canadian wonder	47.88 ^{bc}	1.78 ^{cd}
Red haricot	38.02 ^{d}	3.02 ^{a}
Mwitemania	45.73 ^{c}	1.95 ^{cd}
Mwezi moja	53.20 ^{ab}	2.40 ^{abc}
Zebra	59.69 ^{a}	1.57 ^{d}
Mexican 142	31.98 ^{d}	2.03 ^{bcd}
Mwezi moja new variety	53.67 ^{ab}	2.77 ^{a}
Yellow Boston	50.42 ^{bc}	1.84 ^{cd}
S.E	1.50	0.17
Diamethoate		
0 ml/hectare	48.70 ^{a}	2.16 ^{b}
1.5 ml/liter of water	50.00 ^{a}	2.61 ^{a}
S.E	0.67	0.08
CV (%)	7.46	17.31

Means within a column followed by the same letter are not significantly different at $P<0.05$, DMRT.

Table 8. The correlation between yields of bean varieties with the mean number of aphids per plant, incidence of aphid infestation, severity of damage and plant height as affected by *A. fabae*

Parameter	correlation	intercept	slope	covariance	probability	SE
Aphid number	-0.38	3.66	-0.55	-0.09	0.038	0.26
Incidence	-0.52	3.37	-0.20	-0.47	0.04	0.06
Damage	0.09	1.96	0.08	0.04	0.64	0.17
Plant height	-0.01	2.17	0.00	-0.03	0.98	0.01

4.2 Effect of variety on the population of *A. fabae* and its damage on beans under greenhouse conditions

4.2.1 Effect of bean variety on mean number of *A. fabae* per plant

There were no significant ($P<0.05$) differences in number of aphids per plant four weeks after emergence (Table 9). Aphid numbers ranged between 29.33 aphids in Red haricot and 52 aphids in Mwezi moja with the rest in between these values. Two weeks later the aphid number had risen so much, such that it was impossible to count the aphids on the whole plant. The aphids were therefore counted from the stalk joining the third trifoliate leaf to the stem. Number of aphids per stalk was not significantly different among the varieties. Six weeks after emergence the mean aphid number was however appreciably higher in varieties Canadian wonder (94.33), Mwezi moja (83.67), Rosecoco small seeded (76.00) and Zebra (74.33). Yellow boston and Mexican 142 (43.33 and 47.00, respectively) had the lowest number of aphids (Table 9). Eight weeks after emergence, aphid count was done on the stalk of the fifth trifoliate leaf. The number of aphids were significantly high in varieties Zebra, Mwezi moja new variety, Mwezi moja, Rosecoco small seeded, Canadian wonder and Yellow boston. The number of aphids per stalk in Yellow boston was however not significantly different from Rosecoco large seeded, Red haricot and Mwitemania. Mexican 142 had the least number of aphids, which was not significantly different from Red haricot, Mwitemania and Rosecoco large seeded (Table 9). This trend was similar to that found in the field experiment. Despite some slight differences with both mwezi moja varieties having significantly higher population than in the field. This was possibly due to the aphids being exposed to rainfall in the field, which have been shown by Cichoka *et al* (2002) to dislodge the aphids off the plants since the two varieties have open canopies. Eight weeks after emergence the number of aphids on Mexican 142 was extremely low. This was as a result of the plant growing even taller than the protected counter part, thus giving the aphid more space for distribution. The number of aphids per plant in this experiment increased very fast over time compared to the field experiment. This can be attributed first, to the high temperatures which have been shown to have a positive relationship with aphid population build up (Nyaanga, 2002) and secondly to absence of rainfall and winds which

dislodge aphids from the plant (Cichoka *et al.*, 2002), and thirdly to the absence of natural enemies which reduces the population of the aphids under natural conditions.

4.2.2 Effect of variety on severity of damage and honeydew production by *A. fabae.*

The severity of damage by *A. fabae* on the bean varieties was significantly different ($P<0.05$). Damage score was significantly high in Mwezi moja new variety, though it was not significantly different from that of Canadian wonder, Red haricot, Mwezi moja, Zebra and Yellow boston. Rosecoco large seeded, Mexican 142 and Mwitemania had the least damage score which was not significantly different from that of Zebra and Yellow boston (Table 10). The differences in damage were probably due to varying aphid number per plant. It was observed that the varieties that had higher aphids per trifoliate stalk had a higher damage score. Though Red haricot had a fairly low number of aphids it had significantly high damage score. This could be due to small leaf sizes possessed by this variety, which means that although it had low number of aphids the leaf was still more densely populated thus more leaf cupping and yellowing.

Variety did not significantly affect honeydew production by *A. fabae* (Table 10). The highest honeydew score was in mwitemania (3.80) and the least in rosecoco large seeded (2.50). These results could have been probably due to varying number of ants feeding on the honeydew. Even though the scores were not significantly different, the varying scores could be due to varying levels of proteins content and type in the plants. According to Rabasse and Wyatt (1985), aphids feed on phloem sap which is low in amino acids but rich in sugars, and thus the aphids must take in large quantities of sap to meet their amino acid requirements, and pass out the remaining sugary liquid or honeydew. This implies therefore, that if a plant has more amino acids the aphid will feed less and eject less honeydew.

Table 9. Effect of variety on mean number of *A. fabae* per plant and leaf stalk on bean varieties

Variety	mean number of aphids		
	Per plant (4 WAE)	per stalk of the third trifoliolate Leaf (6 WAE)	per stalk of the fifth trifoliolate leaf (8 WAE)
Rose coco large seeded	1.67(46.67)	1.74(56.00)	1.64(44.00) ^{bc}
Rose coco small seeded	1.72(53.33)	1.83(76.00)	2.06(115.33) ^{a}
Canadian wonder	1.64(44.67)	1.93(94.33)	2.04(114.33) ^{a}
Red haricot	1.41(29.33)	1.59(39.67)	1.61(41.33) ^{bc}
Mwitemania	1.54(34.67)	1.77(60.00)	1.55(40.67) ^{bc}
Mwezi moja	1.71(52.00)	1.89(83.67)	2.07(118.33) ^{a}
Zebra	1.59(39.33)	1.86(74.33)	2.13(134.67) ^{a}
Mexican 142	1.57(40.00)	1.62(47.00)	1.23(17.33) ^{c}
Mwezi moja new variety	1.67(48.33)	1.76(57.00)	2.09(127.00) ^{a}
Yellow Boston	1.57(40.00)	1.58(43.33)	1.89(78.33) ^{ab}
S.E	NS	NS	0.09
CV (%)	7.89	12.86	8.43

Figures in parenthesis are means of the original values.

Means within a column followed by the same letter are not significantly different $P<0.05$, DMRT

WAE = weeks after emergence

Table 10. Effect of variety on severity of damage and honeydew production by *A. fabae*

Variety	severity of damage (score 1-5)	honeydew production (score 1-5)
Rose coco large seeded	2.50 ^{c}	2.5
Rose coco small seeded	3.00 ^{bc}	3.2
Canadian wonder	4.00 ^{ab}	2.7
Red haricot	4.00 ^{ab}	3.2
Mwitemania	2.7 ^{c}	3.8
Mwezi moja	4.0 ^{ab}	3.0
Zebra	3.67 ^{abc}	3.3
Mexican 142	2.67 ^{c}	2.7
Mwezi moja new variety	4.33 ^{a}	2.7
Yellow Boston	3.67 ^{abc}	2.8
S.E	0.4	NS
CV (%) 20.25		29.26

Means within a column followed by the same letter are not significantly different $P<0.05$,(DMRT)

4.2.3 Effect of *A. fabae* on plant height, number of pods per plant, number of seeds per pod grain yield and percent yield loss of common bean varieties.

4.2.3.1 Plant height

Variety significantly ($P<0.05$) affected bean plant height (Table 11). The greatest height (33.00 cm) was recorded in variety Mexican 142 and was not significantly different from that of Zebra, Mwitemania and Rosecoco large seeded. Mwezi moja new variety and Canadian wonder had the least height of 16.67 and 17.00 cm, respectively. The latter height was not significantly ($P<0.05$) different from that of varieties Red haricot, Rosecoco large seeded, Rosecoco small seeded, Mwezi moja new variety and Yellow boston (Table 11). These findings are consistent with those observed in the field experiment though with some slight differences. Zebra, which had the greatest height in the field, was second to Mexican 142 which was even taller than its protected counterpart, whereas Canadian wonder which was second from the top in the field was second to the least. These results could mean that Zebra and Canadian wonder were affected by the temperature differences experienced by the plants under the two conditions and the limited area of the sleeves as well.

The results observed on protected bean varieties showed that A. *fabae* infestation significantly ($P<0.05$) reduced the height of plant in all the varieties except in Mexican 142, Zebra and Mwitemania (Figure 10). The lack of significant height reduction in the three varieties may be an indication that they were able to tolerate the damage by the aphids. However, amongst the three varieties that recorded insignificant height reduction, Zebra can be said to be more tolerant since it supported the highest population of aphids than any other variety. It was observed that rather than having a reduction, Mexican 142 recorded an increase in height though it was less vigorous than the protected counterpart.

4.2.3.2 Pods per plant

There were significant ($P<0.05$) differences on the number of pods per plant amongst the varieties. Mexican 142 had the highest number of pods, which were significantly different from all the other varieties, followed by Red haricot, which was not, significantly different from Rosecoco large seeded, Mwitemania and Zebra. On the other hand, Canadian wonder and Mwezi moja new variety had the least pods per plant

which were not significantly different from Rosecoco small seeded, Mwezi moja and Yellow boston (Table 11). These results were consistent with the results recorded in the field experiment where Mexican 142 and Red haricot had the highest seeds per pod and Canadian wonder, Yellow boston had the least with the rest falling in between. Similarly, the large seeded varieties had the least number of pods per plant and vice versa a trend that was observed in the field experiment.

However, all the tested varieties reacted to the aphid infestation by significantly ($P<0.05$) reducing pods per plant with an exception in Zebra (Figure 11). This agrees with what Cichoka *et al.* (2002) reported while working on the response of *A. fabae* to different broad bean cultivars.

4.2.3.3 Seeds per pod

There were significant ($P<0.05$) differences on the number of seeds per pod among the varieties. Red haricot (3.80) and Mexican 142 (3.62) had significantly higher seeds per pod compared with all the other varieties, followed by Mwitemania, Canadian wonder and Rosecoco large seeded. In contrast, Zebra and Mwezi moja on the other hand, had seedless pods though not significantly different from Rosecoco small seeded and Mwezi moja new variety (Table 11). These results disagree slightly with those found in the field experiment of this study. Mexican 142 and Canadian wonder had significantly more seeds per pod than both Mwezi moja varieties under greenhouse conditions, which was not the case in the field conditions. Also both the Mwezi moja varieties had significantly low seeds per pod than was the case in the field. This variation could have resulted from the high aphid population on the two varieties in the greenhouse, which was not the case in the field experiment.

Protecting common bean varieties by spraying dimethoate significantly ($P<0.05$) affected the seeds per pod amongst the varieties except in varieties Red haricot and Mwitemania (Figure 12) These findings are consistent with those reported by Cichoka *et al* (2002) who found that *A. fabae* significantly reduced the number of seeds per pod in some varieties and not in others

4.2.3.4 Grain yield

Variety significantly ($P<0.05$) affected the grain yield (Table 11). The highest grain yield was recorded in Mexican 142 which was significantly different from all the other varieties studied, and was followed by Mwitemania and Red haricot, which had yields that were significantly different from those of the other varieties. Zebra, Mwezi moja, Rosecoco small seeded, Canadian wonder and Mwezi moja new variety, respectively recorded the least yields that were significantly different from those of the other varieties (Table 11). These results were different from those found in the field experiment in this study. These differences were due to the appreciably high aphid population on plants in the green house compared to the population in the field and probably due to differences in the climatic conditions namely, temperatures which were a bit higher in the greenhouse than was in the field and the limited space exhibited by the sleeve.

All the varieties had a significant ($P<0.05$) yield reduction due to the aphid infestation (Figure 13). Cichoka *et al.* (2002) reported such findings and attributed them to the reduction in pods per plant and seeds per pod by the aphid. However, based on the findings in this work, the reduction in yield in some varieties could have resulted from the combination of the reduction in plant height, pods per plant and seeds per pod. In variety Zebra, plant height and pods per plant reduction was not significant and therefore, grain yield reduction was due to a reduction in seeds per pod. On the other hand, in variety Mwitemania, both plant height and seeds per pod were not significantly reduced by the aphid but the insect significantly reduced pods per plant and thus the reduction in grain yield was probably due to significant reduction in pods per plant. In both varieties Rosecoco large seeded and Mexican 142, plant height was not significantly reduced by the aphid infestation but pods per plant and seeds per pod were, hence the grain yield reduction was due to reduction of pods per plant and seeds per pod.

4.2.3.5 Percent yield loss

The percent yield loss due to *A. fabae* was significantly ($P<0.05$) different amongst the varieties that were tested. Varieties Rosecoco small seeded, Mwezi moja and Zebra had significantly high yield loss of 100 % which was not significantly different

from Mwezi moja new variety (99.45) and Canadian wonder (96.82) (Table 11). The yield loss in Red haricot and Yellow boston were not significantly different from each other but were different from the losses incurred by Rosecoco large seeded. Mexican 142 had significantly the least yield loss (56.06 %) (Table 12). These differences were probably due to the varying number of aphids per plant. Plants that had significantly higher aphid population had the highest yield losses. These varieties include Canadian wonder, Zebra, Rosecoco small seeded and both Mwezi moja varieties. When compared to both Rosecoco large seeded and Red haricot, all of which had aphid population with no significant differences, Mwitemania can be said to be most tolerant than the two since it recorded less and significantly different yield loss.

4.2.4 Correlation between yield and yield losses with plant height, mean number of aphids, severity of damage and honeydew production by *A. fabae*

The analysis of the relationship between yields of the common bean varieties and number of aphids per plant showed that they were negatively and significantly ($P<0.05$) correlated (Table 12). This means that the higher the population the lower the yield and vice versa. This agrees with the results found in both the field and greenhouse experiments where the highly populated varieties recorded considerably low yields. The correlation between the yields and plant height was significant ($P<0.05$) and positive. This means that ones the height is reduced the yield are reduced and this holds true to what was observed in the experiment. Damage had a significant ($P<0.05$) negative correlation with the yield. This means the higher the damage the lower the yield (Table 12). This was consistent with the results obtained in the experiment under greenhouse conditions where the highly damaged varieties namely Canadian wonder, Mwezi moja, Zebra and Mwezi moja new variety recorded the lowest yields. There was no correlation between honeydew and the yield. This was possibly due to lack of significant differences in the amount of honeydew produced by the aphids amongst the varieties.

Table 11. Effect of variety on plant height, pods per plant, seeds per pod, yield per plant and percent yield loss due to *A. fabae*

Variety	plant Height (cm)	Pods per plant	seeds/pods	Yield/plant (grams)	percent yield loss
Rose coco large seeded	24.50 ^{abc}	3.33 ^{bc}	1.89 ^{b}	1.13 ^{c}	73.25 ^{c}
Rose coco small seeded	22.00 ^{bc}	2.67 ^{cd}	0.50 ^{cd}	0.00 ^{d}	100.00 ^{a}
Canadian wonder	17.00 ^{c}	2.00 ^{d}	2.00 ^{b}	0.25 ^{d}	96.82 ^{a}
Red haricot	22.00 ^{bc}	4.33 ^{b}	3.80 ^{a}	1.78 ^{b}	84.05 ^{b}
Mwitemania	26.67 ^{ab}	3.33 ^{bc}	2.16 ^{b}	2.03 ^{b}	65.10 ^{d}
Mwezi moja	22.67 ^{bc}	2.33 ^{cd}	0.00 ^{d}	0.00 ^{d}	100.00 ^{a}
Zebra	27.67 ^{ab}	3.33 ^{bc}	0.00 ^{d}	0.00 ^{d}	100.00 ^{a}
Mexican 142	33.00 ^{a}	6.00 ^{a}	3.62 ^{a}	2.54 ^{a}	56.06 ^{e}
Mwezi moja new variety	16.67 ^{c}	1.67 ^{d}	0.33 ^{cd}	0.03 ^{d}	99.45 ^{a}
Yellow Boston	21.33 ^{bc}	2.33 ^{cd}	1.00 ^{c}	0.88 ^{c}	81.38 ^{b}
S.E	2.41	0.34	0.27	0.13	2.54
CV (%)	18.33	14.57	20.15	26.56	5.14

Means within a column followed by the same letter are not significantly different $P<0.05$ using DMRT

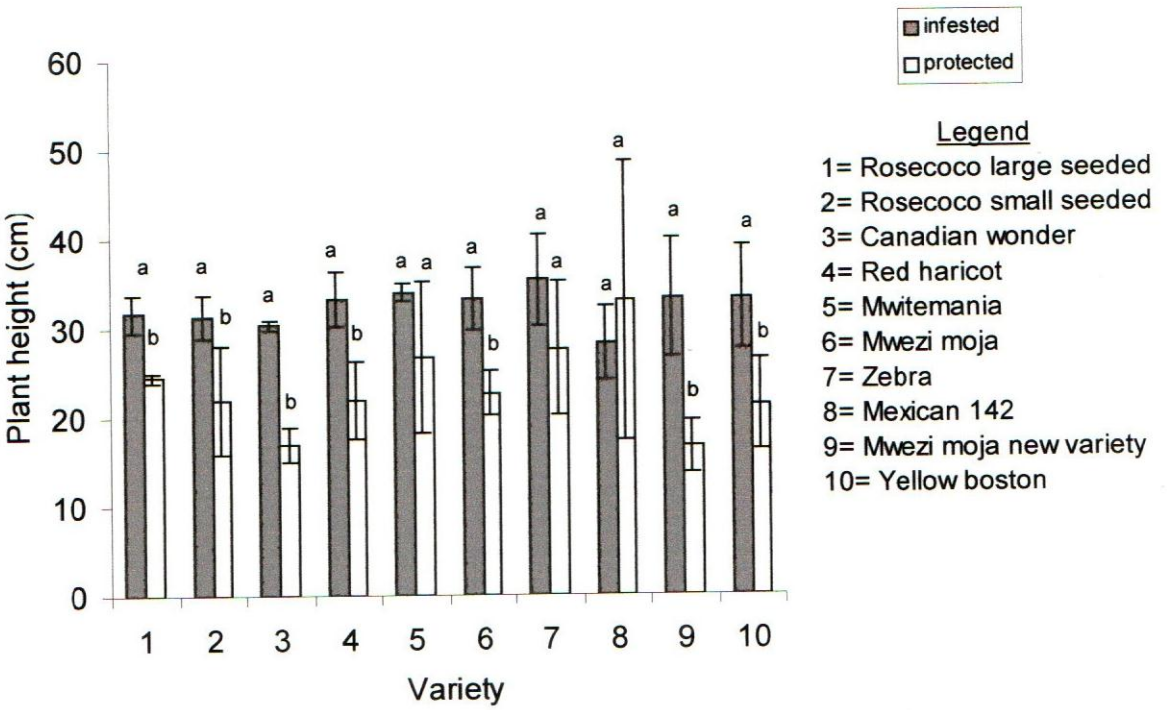


Figure 10. Effect of controlling *A. fabae* on plant height of common beans variety.

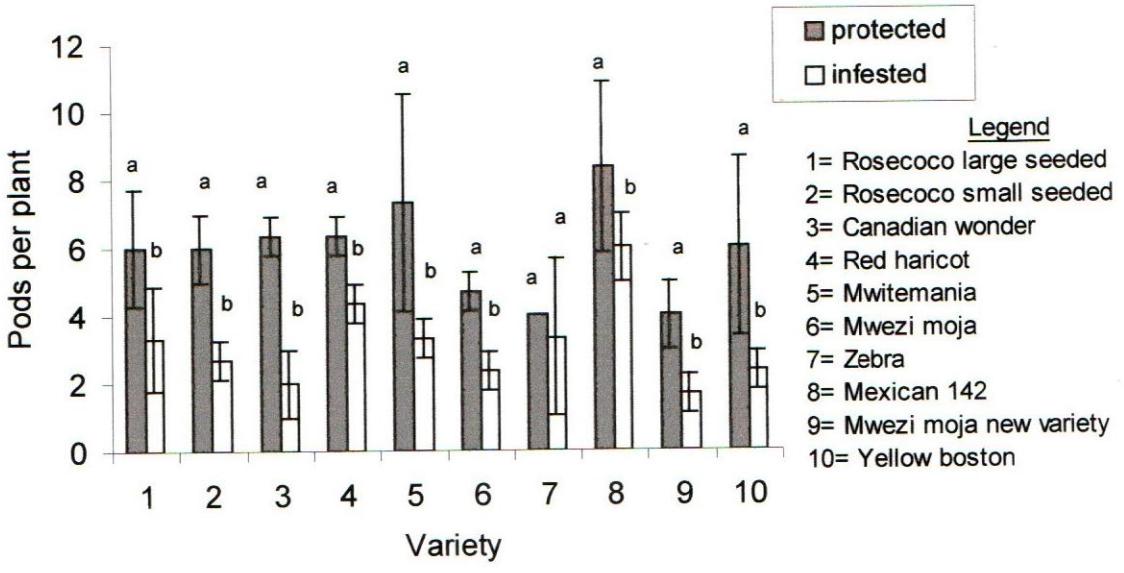


Figure 11. Effect of controlling *A.fabae* on pods per plant on common bean varieties

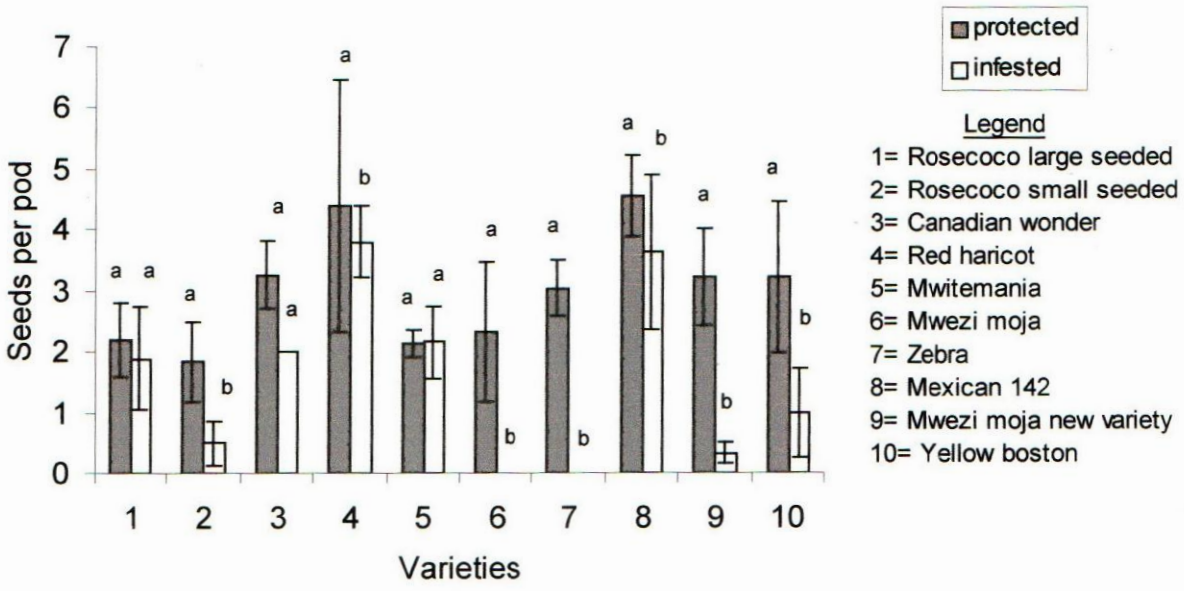


Figure 12. Effect of controlling *A.fabae* on seeds per pod on common bean varieties

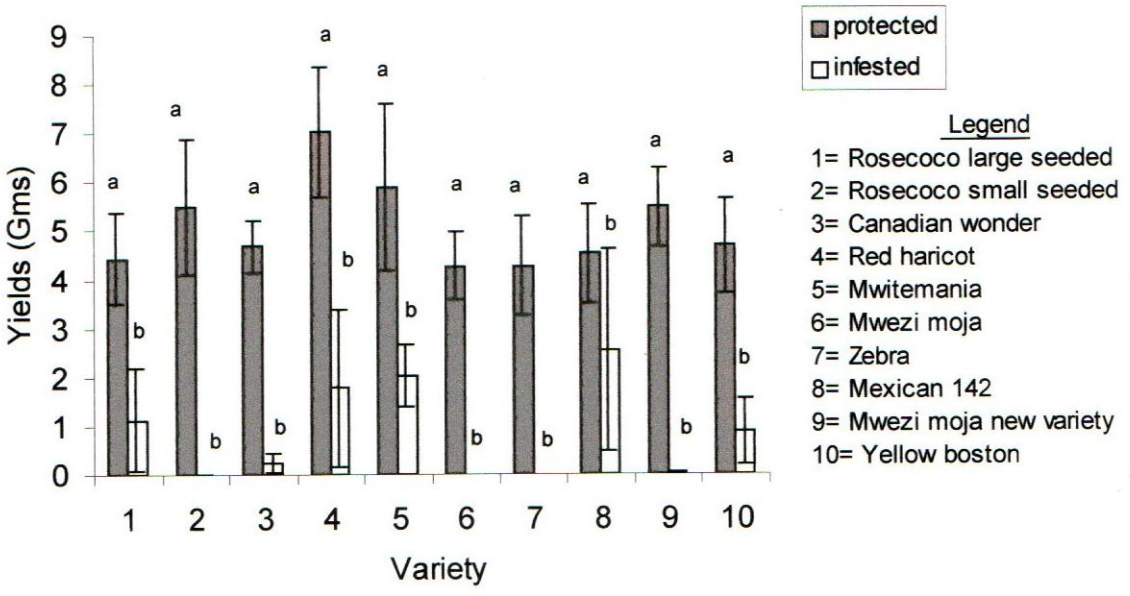


Figure 13. Effect of controlling *A.fabae* on yields of common bean varieties

Table 12. The correlation between yields of bean varieties with the mean number of aphids per plant, incidence of aphids, severity of damage and plant height as affected by *A. fabae*

Parameter	correlation	intercept	slope	covariance	probability	SE
Aphid number	-0.92	5.91	-2.77	-0.28	0.00	0.23
Plant height	0.36	13.65	3.25	2.21	0.05	1.59
Damage	-0.37	2.03	-0.34	-0.36	0.05	0.16
Honeydew	0.36	0.79	0.03	0.02	0.91	0.23

4.3 Effect of variety on development time, fecundity, longevity and intrinsic rate of increase of *A. fabae* under greenhouse conditions.

4.3.1 Developmental time

Developmental time of *A. fabae* from newborn nymphs to adult emergence reared on 10 varieties of common beans were not significantly different (Table 13). The period ranged from 8.7 days in variety Mwezi moja to as long as 10.7 days in varieties Rosecoco large seeded and Red haricot. Though the differences in nymph development period were not significant the period varied considerably, with the highest difference being two days (between Rosecoco large seeded and Mwezi moja). Inspite of the development time not being significantly different amongst the varieties the difference especially of the two days observed between mwezi moja and rosecoco large seeded could have a great impact. Karel and Autrique (1989) reported that on average an aphid can larviposit 3-6 aphids in a day. This translates to a difference of 6-12 aphids for the two varieties, which after passing through the developmental time would start reproducing. This implies that given some time say like 24 days when there will be three generations in variety Mwezi moja and just two in Rosecoco large seeded the former will be having a very high population compared to the latter. Despite nutritional and other chemical differences in the varieties having been shown to affect the developmental time (Yue and Liu, 2000) morphological differences in the varieties may have led to the lack of significant differences in the development time. The ten varieties exhibited different growth habits, which may have changed the microclimate within the plant. It was expected that bush type varieties would have low temperatures within the canopy than on semi climber type. However, according to work done by Nyaanga (2002) temperature was found to be negatively correlated to developmental time. This therefore, means that the effect of the nutritional content and chemistry of the plant would have interacted with the differences in the temperatures within the canopy and thus led to lack of significant differences in the development time of *A. fabae* amongst the varieties. These possible factors affecting development period were not investigated during this study. Future research work would be useful to verify their roles.

4.3.2 Fecundity

The fecundity of *A.fabae* differed significantly ($P<0.05$) among the 10 varieties. Variety Rosecoco large seeded and Zebra had significantly higher number of progenies than all the other varieties. Mwitemania had the least number of progenies, which were not significantly different from Canadian wonder, Mexican 142, Mwezi moja new variety, and Rosecoco small seeded (Table 13). Similar findings have been reported by Cichoka *et al.* (2002) while working on the response of *A. fabae* to various broad bean cultivars. He found that the varieties that had significantly higher progenies were characterised by much higher content of essential and non-essential free amino acids than those that had significantly lower progenies. Doorsher (1988) also found similar results while working on *Aphis craccivora* on different pea cultivars and attributed the difference to differences in the concentration of free Amino acids. In a similar work, Soroka and Mackay (1991) attributed the differences to the morphology of the varieties. Differences in the feeding location of the aphid on the plant could possibly have caused these differences too. Larso and Whitman (1991) reported that feeding location can influence herbivore fecundity by altering nutrients access.

4.3.3 Longevity

Longevity of *A. fabae* was significantly ($P<0.05$) affected by bean varieties. The aphids lived significantly longer on varieties Rosecoco large seeded (24.3 days), which was not significantly different from Mexican 142 (22.3 days), and Canadian wonder (22.00 days). However, the longevity of *A. fabae* on these varieties (Mexican 142 and Canadian wonder) was not significantly different from that of Rose coco small seeded, Zebra and Red haricot. In contrast, Yellow boston recorded the least longevity which was not significantly different from that of Mwitemania and Mwezi moja (Table 13). Legrand and Barbasa (2000) while working on pea aphid fecundity, rate of increase, and within-plant distribution unaffected by plant morphology, reported similar findings and attributed them to different leaf shapes, while Campbell and Mackauer (1977) in a similar work attributed them to differences in temperatures. Nyaanga. (2002) when working on some factors that affect cereal aphids colonization on wheat reported that temperatures were positively correlated to number of progenies per adult aphid. Leaf shapes changes

the microclimate within the plant while high temperatures reduces the survivorship of aphids (Campbell and Mackauer, 1977). The aphids lived long in Rosecoco large seeded and Canadian wonder, which have broad leaves and in Mexican 142 a bush type. These characteristics may have changed the microclimate below and within the canopy by causing a shading effect and thus a decrease in temperatures within the canopy. On the other hand, the aphid longevity was low in Yellow boston and Mwitemania which have tendrils and open canopies. This may have allowed direct sunrays to reach the aphids and consequently increasing the temperatures within the canopy thus reducing the survivorship of the aphid.

4.3.4 Intrinsic rate of increase

Varieties significantly ($P<0.05$) affected the intrinsic rate of increase of *A. fabae* (Table 13). This agrees with findings by Soroka and Mackay (1991) who worked on the antibiosis and antixenosis of pea aphid in pea cultivars in the field. The rate of increase was significantly higher in varieties Zebra (0.43) which was not significantly different from that of Rosecoco large seeded (0.41), Mwezi moja (0.41), Yellow boston (0.37), Red haricot (0.34) and Mwezi moja new variety (0.31). The intrinsic rate of increase of *A. fabae* was least in variety Canadian wonder and Mwitemania each with 0.24, and this was not significantly different from that in Red haricot, Mwezi moja new variety, Mexican 142 and Rose coco small seeded. (Table 13). Nyaanga (2002) found similar results and attributed them to the differences in the developmental time of the aphid. Wyatt and White (1977) attributed similar findings to two factors of the aphid life history, the developmental time and the number of female young ones.

Table 13. Effect of variety on mean development time, fecundity, longevity and intrinsic rate of natural increase of *A. fabae*

Variety	development Time (days)	fecundity (Nymphs/ Aphid)	longevity (days)	intrinsic rate of increase
Rose coco large seeded	10.67	38.00 [a]	24.33 [a]	0.41 [ab]
Rose coco small seeded	9.33	24.00 [c]	21.67 [bc]	0.30 [bc]
Canadian wonder	10.33	22.00 [c]	22.00 [ab]	0.24 [c]
Red haricot	10.67	31.00 [b]	20.00 [bcd]	0.34 [abc]
Mwitemania	10.00	21.00 [c]	16.33 [e]	0.24 [c]
Mwezi moja	8.67	31.67 [b]	18.33 [de]	0.41 [ab]
Zebra	9.67	36.33 [a]	21.33 [bc]	0.43 [a]
Mexican 142	9.00	23.00 [c]	22.33 [ab]	0.30 [bc]
Mwezi moja new variety	9.00	24.00 [c]	19.33 [cd]	0.31 [abc]
Yellow Boston	9.67	31.00 [b]	16.00 [e]	0.37 [ab]
S.E	NS	1.19	0.77	0.04
CV (%)	7.24	7.32	6.65	19.53

Means within a column followed by the same letter are not significantly different $P<0.05$, Duncan multiple range test.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

From the field and greenhouse experiments, it was evident that some varieties supported large aphid population and infestation incidence than others. Varieties Canadian wonder, Zebra and Rosecoco small seeded supported the largest population of aphids while Mexican 142, Rosecoco large seeded and Red haricot had the least. On the other hand, Canadian wonder, Mwitemania, Zebra and Rosecoco small seeded had the highest infestation incidence while Rosecoco large seeded had the least. These results implies that Canadian wonder, Zebra, Mwitemania and Rosecoco small seeded are susceptible since they are more preferred by the aphid than Mexican 142, Rosecoco large seeded and Red haricot which can be termed resistant. Yield losses correlated positively with aphid population and infestation incidence. The highly populated varieties, with a high infestation incidence gave low yields and the converse is true. These results can be used as basis for selection of varieties to be grown by farmers where the pest is prevalent.

Dimethoate on the other hand, effected significant population and infestation incidence control and yield increase in all the tested varieties, both in the field and green house. Thus it can be recommended to farmers with certainty as an effective IPM component under those conditions.

Results of the third experiment, which was aimed at determining the effect of common bean varieties on the development time, fecundity, longevity and the intrinsic rate of increase, showed that varieties affected all these parameters. The development time of aphid varied with varieties with the largest range being two days between Mwezi moja and Rosecoco large seeded. Despite the fact that there were no significant differences between the development time the implication of the difference of two days are discussed in chapter four of this report. Fecundity, longevity and intrinsic rate of increase varied significantly with the variety. Rosecoco large seeded and Mwezi moja were high in these parameters whereas Canadian wonder and Mwitemania were the least.

In conclusion the use of resistant bean varieties identified in this study may reduce yield loss due to the black bean aphid, and the economic and environmental costs associated with the use of aphicides.

5.2 Recommendations

The following recommendations are made based on the findings in this work:

1. Farmers should be advised to grow varieties that support low population and in which the population growth rate is not very fast when high temperatures and erratic rainfall are anticipated. However, varietial selection for planting during the short rains season should consider other farmer's desired traits, such as the market, seed colour, time to maturity and yield potential just to mention few.
2. Since variety alone (susceptible or resistant) did not achieve control of the aphid to a level below the significant injury, it would be advisable to use insecticide alongside the even resistant varieties. In this case, Visual scouting and spot spraying should be carried out at the right time to save labour and the amount of chemical used.
3. Insecticides of the same group and with similar mode of action as dimethoate should be used to control the aphid during the short rain season.
4. There is need to sensitise bean farmers on the importance of suitable selection of varieties and use of insecticide on the crop to be grown during the short rain season when *A. fabae* is a major pest.

5.3 Suggestions for future studies

Owing to the limitation of time and resources, there are some important aspects that this study did not investigate. Also the results obtained in this study provides some insight into what can be investigated in future. Therefore further work is needed to:

1. Determine the mechanism and the sources of resistance in the resistant varieties
2. Determine the frequency of insecticide spraying per season depending on the prevailing weather conditions.

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APPENDICES

Appendix 1.Mean temperatures and rainfall In Field 7 of Egerton university for the period August 2002 to march 2003

Month	Year	Mean temperatures (°C)	Total rainfall (mm)
August	2002	16.25	80.1
September	2002	16.55	17.3
October	2002	17.05	42.6
November	2002	16.54	38.7
December	2002	16.53	203.2
January	2003	16.35	59.00
February	2003	18.05	8.6
March	2003	18.25	81.2

Appendix 2. Mean temperatures per day in the green house for experiment three

Day	mean temperature (°C)
1	26
2	27.5
3	27
4	27.5
5	28.5
6	26.75
7	27.5
8	27
9	24.5
10	25
11	24.75
12	27.5
13	21.5
14	21
15	19.5
16	24
17	22
18	19.75
19	22.5
20	22.5
21	22.5
22	25
23	27
24	24
25	23
26	21.5
27	21.75

Appendix 3.Mean temperatures per day in the green house for experiment two

Month	mean minimum temp day time	mean maximum temp day time (°C)
November (2002)	19.27	26.65
December (2002)	17.45	25.80
January (2003)	20.75	32. 50
February (2003)	20.50	32.75

Appendix 4. ANOVA table for the effect of variety on mean number of aphids per plant 3 weeks after emergence

Source	degrees of Freedom	sum of squares	mean square	F value	probability
Replicate	2	0.08	0.042	0.33	ns
Variety	9	1.43	0.159	1.23	ns
Error	18	2.33	0.129		
Total	29	3.85			

S.E= 0.21

Appendix 5. ANOVA table for the effect of variety and insecticide on the mean number of aphids per plant six weeks after emergence

K Value	Source	degrees of freedom	sum of squares	mean squares	F value	probability
1	replication	2	0.339	0.200	1.101	ns
2	variety (A)	9	1.296	0.144	0.731	ns
4	insecticide (B)	1	18.973	18.973	96.369	0.000
6	AB	9	1.891	0.210	1.067	ns
7	error	38	7.481	0.197		
	total	59	30.041			

s_ for means group 1: 0.099 Number of Observations: 20
y

s_ for means group 2: 0.181 Number of Observations: 6
y

s_ for means group 4: 0.081 Number of Observations: 30
y

s_ for means group 6: 0.256 Number of Observations: 3
y

Appendix 6. ANOVA table for the effect of variety and insecticide on the mean number of aphids per plant 9 weeks after emergence

K Value	Source	degrees of freedom	sum of squares	mean squares	F value	probability
1	replication	2	0.395	0.197	1.534	ns
2	variety (A)	9	1.563	0.174	1.349	ns
4	insecticide (B)	1	46.817	46.817	363.73	0.000
6	AB	9	2.392	0.266	2.065	ns
7	error	38	4.891	0.129		
	total	59	56.058			

s_y for means group 1: 0.0.80 Number of Observations: 20

s_y for means group 2: 0.147 Number of Observations: 6

s_y for means group 4: 0.066 Number of Observations: 30

s_y for means group 6: 0.207 Number of Observations: 3

Appendix 7. ANOVA table for the effect of variety on aphid incidence 3 weeks after emergence

Source	degrees of Freedom	sum of squares	mean square	F value	probability
Replicate	2	4.23	2.115	5.89	ns
Variety	9	5.16	0.573	1.600	ns
Error	18	6.47	0.359		
Total	29	15.86			

S.E= 0.35

Appendix 8. ANOVA table for the effect of variety and insecticide on the incidence of aphids 6 weeks after emergence

K Value	Source	degrees of freedom	sum of squares	mean squares	F value	probability
1	replication	2	0.983	0.492	10.393	ns
2	variety (A)	9	16.595	1.844	1.475	ns
4	insecticide (B)	1	34.036	34.036	27.228	0.000
6	AB	9	6.961	0.773	0.619	ns
7	error	38	47.501	0.250		
	Total	59	106.076			

s_y for means group 1: 0.250 Number of Observations: 20

s_y for means group 2: 0.456 Number of Observations: 6

s_y for means group 4: 0.204 Number of Observations: 30

s_y for means group 6: 0.646 Number of Observations: 3

Appendix 9. ANOVA table for the effect of variety and insecticide on the incidence of aphids 9 weeks after emergence

K Value	Source	degrees of freedom	sum of squares	mean squares	F value	probability
1	replication	2	0.546	0.273	0.218	ns
2	variety (A)	9	20.063	2.229	1.776	ns
4	insecticide (B)	1	243.493	243.493	194.02	0.000
6	AB	9	31.914	3.546	2.826	0.012
7	error	38	47.688	1.255		
	Total	59	343.704			

s_y for means group 1: 0.251 Number of Observations: 20

s_y for means group 2: 0.457 Number of Observations: 6

s_y for means group 4: 0.204 Number of Observations: 30

s_y for means group 6: 0.647 Number of Observations: 3

Appendix 10. ANOVA table for the effect of variety on severity of damage by *A.fabae*

Source	degrees of Freedom	sum of squares	mean square	F value	probability
Replicate	2	0.52	0.258	0.570	ns
Variety	9	4.87	0.542	1.200	ns
Error	18	8.15	0.453		
Total	29	13.54			

S.E= 0.39

Appendix 11. ANOVA table for the effect of variety and insecticide on plant height

K Value	Source	degrees of freedom	sum of squares	mean squares	F value	probability
1	replication	2	129.793	64.897	1.307	ns
2	variety (A)	9	9153.826	1017.092	20.483	0.000
4	insecticide (B)	1	3803.447	3803.447	76.596	0.000
6	AB	9	1629.443	181.049	3.646	0.023
7	error	38	47.688	1.255		
	Total	59	16603.434			

s_y for means group 1: 1.576 Number of Observations: 20

s_y for means group 2: 2.877 Number of Observations: 6

s_y for means group 4: 2865 Number of Observations: 30

s_y for means group 6: 4.068 Number of Observations: 3

Appendix 12. ANOVA table for the effect of variety and insecticide on the number of pods per plant

K Value	Source	degrees of freedom	sum of squares	mean squares	F value	probability
1	replication	2	1.198	0.599	0.167	ns
2	variety (A)	9	528.381	58.709	16.323	0.000
4	insecticide (B)	1	96.317	93.317	26.779	0.000
6	AB	9	58.917	6.546	1.820	ns
7	error	38	136.674	3.597		
	Total	59	821.487			

s_ for means group 1: 0424 Number of Observations: 20
y

s_ for means group 2: 0.774 Number of Observations: 6
y

s_ for means group 4: 0.346 Number of Observations: 30
y

s_ for means group 6: 1.095 Number of Observations: 3
y

Appendix 13. ANOVA table for the effect of variety and insecticide on seeds per pod

K Value	Source	degrees of freedom	sum of squares	mean squares	F value	probability
1	replication	2	1.108	0.554	3.336	ns
2	variety (A)	9	20.447	2.272	13.679	0.000
4	insecticide (B)	1	1.768	1.768	10.645	0.002
6	AB	9	1.870	0.208	1.251	0.295
7	error	38	6.312	0.166		
	Total	59	31.506			

s_y for means group 1: 0.091 Number of Observations: 20

s_y for means group 2: 0.166 Number of Observations: 6

s_y for means group 4: 0.074 Number of Observations: 30

s_y for means group 6: 0.235 Number of Observations: 3

Appendix 14. ANOVA table for the effect of variety and insecticide on 100 seed weight

K Value	Source	degrees of freedom	sum of squares	mean squares	F value	probability
1	replication	2	14.082	7.041	0.520	ns
2	variety (A)	9	3870.568	430.066	31.756	0.000
4	insecticide (B)	1	24.384	24.384	1.801	ns
6	AB	9	89.784	9.976	0.737	ns
7	error	38	514.632	13.543		
	Total	59	4513.479			

s_ for means group 1: 0.823 Number of Observations: 20
y

s_ for means group 2: 1.502 Number of Observations: 6
y

s_ for means group 4: 0.672 Number of Observations: 30
y

s_ for means group 6: 2.125 Number of Observations: 3
y

Appendix 15. ANOVA table for the effect of variety and insecticide on total yield (tons) per hectare

K Value	Source	degrees of freedom	sum of squares	mean squares	F value	probability
1	replication	2	0.153	0.076	0.447	ns
2	variety (A)	9	12.958	1.440	8.438	0.000
4	insecticide (B)	1	3.033	3.033	17.779	0.000
6	AB	9	1.538	0.171	1.002	ns
7	error	38	6.483	0.171		
	Total	59	24.165			

s_ for means group 1: 0.092 Number of Observations: 20
y

s_ for means group 2: 0.168 Number of Observations: 6
y

s_ for means group 4: 0.075 Number of Observations: 30
y

s_ for means group 6: 0.239 Number of Observations: 3
y

Appendix 16. ANOVA table for the effect of variety on mean number of aphid per plant 4 weeks after emergence

Source	degrees of Freedom	sum of squares	mean square	F value	probability
Replicate	2	0.08	0.042	2.62	ns
Variety	9	0.24	0.026	1.62	ns
Error	18	0.29	0.016		
Total	29	0.610			

S.E= 0.07

Appendix 17. ANOVA table for the effect of variety on mean number of aphid per stalk 6 weeks after emergence

Source	degrees of Freedom	sum of squares	mean square	F value	probability
Replicate	2	0.270	0.133	2.64	ns
Variety	9	0.430	0.047		ns
Error	18	0.900	0.050		
Total	29	1.600			

S.E= 0.13

Appendix 18. ANOVA table for the effect of variety on mean number of aphid per stalk 8 weeks after emergence

Source	degrees of Freedom	sum of squares	mean square	F value	probability
Replicate	2	0.030	0.015	0.620	ns
Variety	9	2.430	0.270	11.410	0.000
Error	18	0.430	0.025		
Total	29	2.890			

S.E= 0.09

Appendix 19. ANOVA table for the effect of variety on severity of damage due to *A.fabae*

Source	degrees of Freedom	sum of squares	mean square	F value	probability
Replicate	2	10.050	5.025	10.300	ns
Variety	9	12.34	1.371	2.81	0.029
Error	18	8.780	0.488		
Total	29	31.180			

S.E= 0.04

Appendix 20. ANOVA table for the effect of variety on honeydew production by *A. fabae*

Source	degrees of Freedom	sum of squares	mean square	F value	probability
Replicate	2	1.620	0.808	1.060	ns
Variety	9	4.410	0.490	0.640	ns
Error	18	13.720	0.762		
Total	29	19.740			

S.E= 0.5

Appendix 21: ANOVA table for the effect of infestation and protection of *A. fabae* on plant height of common bean varieties

K Value	Source	degrees of freedom	sum of squares	mean squares	F value	probability
1	replication	2	119.858	59.292	1.6719	ns
2	variety (A)	9	928.837	36.537	3.0195	0.047
-3	Error	18	645.225	35.846		
4	insecticide (B)	1	1237.604	1237.604	47.349	0.000
6	AB	9	434.271	48.252	1.8461	ns
-7	error	20	522.750	26.138		
	Total	59	4188.546			

s_ for means group 1: 1.3388 Number of Observations: 20
y

s_ for means group 2: 2.4442 Number of Observations: 6
y

s_ for means group 4: 0.9334 Number of Observations: 30
y

s_ for means group 6: 2.9517 Number of Observations: 3
y

Appendix 22. ANOVA table for the effect of infestation and protection of *A. fabae* on pods per plant of common bean varieties

K Value	Source	degrees of freedom	sum of squares	mean squares	F value	probability
1	replication	2	1.633	0.817	1.0232	ns
2	variety (A)	9	79.483	8.831	11.065	0.000
-3	Error	18	14.367	0.789		
4	insecticide (B)	1	114.817	114.817	264.961	0.000
6	AB	9	16.017	1.780	4.1068	0.004
-7	error	20	8.667	0.433		
	Total	59	234.983			

s_ for means group 1: 0.1998 Number of Observations: 20
y

s_ for means group 2: 0.3647 Number of Observations: 6
y

s_ for means group 4: 0.1202 Number of Observations: 30
y

s_ for means group 6: 0.3801 Number of Observations: 3
y

Appendix 23. ANOVA table for the effect of infestation and protection of *A. fabae* on seeds per pod of common bean varieties

K Value	Source	degrees of freedom	sum of squares	mean squares	F value	probability
1	replication	2	0.086	0.043	0.2335	ns
2	variety (A)	9	60.445	6.716	36.289	0.000
-3	Error	18	3.331	0.185		
4	insecticide (B)	1	36.364	36.364	168.049	0.000
6	AB	9	13.745	1.527	7.057	0.001
-7	error	20	4.328	0.216		
	Total	59	118.299			

s_ for means group 1: 0.0962 Number of Observations: 20
y

s_ for means group 2: 0.1756 Number of Observations: 6
y

s_ for means group 4: 0.0849 Number of Observations: 30
y

s_ for means group 6: 0.2686 Number of Observations: 3
y

Appendix 24. ANOVA table for the effect of infestation and protection of *A. fabae* on yields of common bean varieties

K Value	Source	degrees of freedom	sum of squares	mean squares	F value	probability
1	replication	2	1.249	0.624	0.8561	ns
2	variety (A)	9	34.207	3.801	5.2106	0.004
-3	Error	18	13.130	0.729		
4	insecticide (B)	1	281.320	281.320	585.330	0.000
6	AB	9	10.378	1.153	2.399	0.050
-7	error	20	4.328	0.216		
	Total	59	349.896			

s_ for means group 1: 0.1910 Number of Observations: 20
y

s_ for means group 2: 0.3487 Number of Observations: 6
y

s_ for means group 4: 0.1266 Number of Observations: 30
y

s_ for means group 6: 0.4003 Number of Observations: 3
y

Appendix 25. ANOVA table for the effect of variety on percentage yield loss percentage yield loss due to *A. fabae*

Source	degrees of Freedom	sum of squares	mean square	F value	probability
Replicate	2	31.900	15.949	0.820	ns
Variety	9	7215.56	801.729	41.350	0.000
Error	18	349.02	19.390		
Total	29	7596.480			

S.E= 2.54

Appendix 26. ANOVA table for the effect of variety on mean developmental period of *A. fabae*

Source	degrees of Freedom	sum of squares	mean square	F value	probability
Replicate	2	3.80	1.900	2.660	ns
Variety	9	13.63	1.515	2.120	ns
Error	18	12.870	0.715		
Total	29	30.300			

S.E= 0.49

Appendix 27. ANOVA table for the effect of variety on number of progenies per *A. fabae*

Source	degrees of Freedom	sum of squares	mean square	F value	probability
Replicate	2	8.600	4.300	1.010	ns
Variety	9	1027.47	114.163	26.78	0.000
Error	18	76.730	4.263		
Total	29	1112.80			

S.E= 1.19

Appendix 28. ANOVA table for the effect of variety on mean longevity of *A. fabae*

Source	degrees of Freedom	sum of squares	mean square	F value	probability
Replicate	2	16.270	8.133	4.520	0.026
Variety	9	195.500	21.722	12.070	0.000
Error	18	32.400	1.800		
Total	29	244.17			

S.E= 0.77

Appendix 29. ANOVA table for the effect of variety on intrinsic rate of increase of *A. fabae*

Source	degrees of Freedom	sum of squares	mean square	F value	probability
Replicate	2	0.010	0.007	1.660	ns
Variety	9	0.130	0.014	3.33	0.014
Error	18	0.080	0.004		
Total	29	0.220			

S.E= 0.04

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