CABBAGE FLEA BEETLE, *Phyllotreta* Spp (Coleoptera: Chrysomelidae) DISTRIBUTION, DAMAGE AND MANAGEMENT ON ETHIOPIAN MUSTARD, *Brassica Carinata* A. Braun, IN ARSI ZONE, OROMIA

M.Sc. Thesis

By

Getachew Eticha

July, 2012

Jimma University

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Submitted to the School of Graduate Studies Jimma University College of Agriculture and Veterinary Medicine

In Partial fulfillment of the Requirements for the degree of Master of Science in
Agricultural Entomology

By

Getachew Eticha

July, 2012
Jimma University

School of Graduate Studies

As thesis research advisor, I hereby certify that I have read and evaluated this thesis prepared, under my guidance by Getachew Eticha Bokore**,** entitled "**Cabbage Flea Beetles, P*hyllotreta* spp (Coleoptera: Chrysomelidae) Distribution, Damage and Management on Ethiopian Mustard, *Brassica carinata* A. Braun, in Arsi Zone, Oromia"**. I recommend that it be submitted as fulfilling thesis requirement.

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As member of the *Board of Examiners* of the *M.Sc. Thesis Open Defense Examination*, We certify that we have read, evaluated the thesis prepared by **…………………………... ……………………………………** and examined the candidate. We recommended that the thesis could be accepted as fulfilling the thesis requirement for the Degree of Master of Science in Agricultural Entomology.

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DEDICATION

I dedicated this thesis manuscript primarily to God Almighty and my family.

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First of all, I thank God Almighty for His grace and immeasurable love, for enabling me to join this M.Sc. study, for the strength and patience He supplied to me for doing this work. This all happened according to His perfect plan and good will. Praise YOU LORD JESUS!

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STATEMENT OF THE AUTHOR

Firstly, I declare that this thesis is my independent work and that all resources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for advanced Master of Science in Agricultural Entomology at Jimma University, College of Agriculture and Veterinary Medicine. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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Place: JUCAVM, Jimma University Date of Submission:___________________

BIOGRAPHICAL SKETCH

The author was borne from his father, Eticha Bokore and his mother, Dure Wolde on Augest 18, 1983 in Horo Woreda, Horo Guduru Wollega Zone of Oromia Regional State of Ethiopia. He attended his elementary and secondary school education at Shambu Elementary School and Shambu Secondary School, Shambu, respectively. Then he joined Bahir Dar University of Main Campus in 2002 and graduated in Biology major and chemistry minor in 2006.

After his graduation, he was employed by Ethiopian Ministry of Education as a teacher at Ghimbi Comprehensive High School, West Wellega of Oromia Regional State. In February 2010, he has joined Jimma University College of Agriculture and Veterinary Medicine to pursue his study for the degree of masters in Agricultural Entomology.

LIST OF ACRONYMS AND ABBREVIATIONS

Am	Anti meridian
ANOVA	Analysis of Variance
BC	Before Christ
CSA	Central Statistical Authority
D	Dust
EC	Emulsifiable Concentrate
EU	Europian Union
F	Flowable
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
IBC	Institute of Biodiversity Conservation
IENICA	Interactive European Network for Industrial Crops and Applications
IPM	Integrated Pest Management
N/P05	Nitrogen and phosphate
Pm	Post meridian
RCBD	Random Complete Block Design
Spp	Species
UK	United Kingdom
USA	United States of America
Vs	Versus

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Cabbage Flea Beetle, *Phyllotreta* spp (Coleoptera: Chrysomelidae) Distribution, Damage and Management on Ethiopian Mustard, *Brassica carinata* A. Braun, in Arsi Zone, Oromia

ABSTRACT

Ethiopian mustard (*Brassica carinata* A. Braun) is an important plant to many small-scale farmers in Ethiopia as a vegetable, a source of income, to grease 'injera' and bread baking clay pan and oil. Its production, however, is constrained by several factors like very low in yield, its unacceptable level of naturally high levels of erucic acid and glucosinolates in its seed, lack of improved crop management, diseases and insect pests like flea beetle, diamondback moth etc. The objective of this study was to determine the distribution, damage and status of flea beetles, and their management using different seed rates and screening the chemicals with effective rate during 2011 cropping season. Survey of flea beetle was done in Lemu Bilbilo, Tiyo and Hetosa Woredas of Arsi Zone by taking purposive samples of mustard fields within a distance of about 5 km from each other. From each farm five one m^2 plots were used for sampling and the three first growth stages primordial, first true leaf and second true leaf stages were considered. Significant difference was found ($P<0.05$) among some farms in the mean number of flea beetles and the damage they cause at these considered stages. Variation was also recorded in mean number of productive plant stalks and plant population reduction. Monitoring of flea beetle damage, the effect of varying seed rate and screening effective insecticides were done in Kulumsa Agricultural research center by sowing Yellow Dodolla mustard. Two rows of 1m length were used for sampling flea beetles and their damage for the seed rate and screening and four rows of 1m length rows were used in monitoring. The number of flea beetles and the damage they sustained were higher during first true leaf and second true leaf stages and found decreasing from vegetative stage to matured stage. The six seed rates revealed no significant difference in mean number of flea beetles but the mean number of damaged plants was found to be decreased from plots sown with the lower seed rate to the higher seed rates for the all the stages. Productive plants and plant population reduction were maximum for plots of the highest seed rate (10.8g) and minimum for plots of the lowest (2.7g) seed rate. Maximum mean of yield (1917.8kg/ha) was obtained from plots sown with seed rate of 5.4g (10kg/ha). The higher rate of Carbaryl, Malathion and the two rates of Fenitrothion were found with reduced mean number of flea beetles and the damage ($P<0.05$) they caused to the plant. Productive plants and yield (kg/ha) were higher for plots treated with higher rate of Carbaryl, Malathion and lower rate of Fenitrothion. Significant positive correlation was found among flea beetles, their damage to the plant and plant population reduction. The correlation was significant and negative for yield (kg/ha) vs number of flea beetles, yield vs number of plant damage and number of plant damage vs productive plants. This study generally revealed that the recommended rate of seed rate and Fenitrothion at its recommended rate can be used in cabbage flea beetle management and the monitoring of the beetles should involve the seed pod setting stage.

Key Words: *Brassica, Carbaryl, Fenitrothion, Flea Beetles, Malathion, Monitoring*

1. INTRODUCTION

The genus *Brassica* is one of 51 genera in the tribe Brassiceae belonging to the crucifer family (Gomez-Campo, 1980) and includes a total of 41 species (Gladis and Hammer, 1990). Six of these are economically important species, namely, *Brassica rapa* (AA), *B. oleraceae* (CC), *B. nigra* (BB), *B. juncea* (AABB), *B. napus* (AACC) and *B. carinata* (BBCC) (Tsige *et al.*, 2005). *Brassica carinata* evolved as a natural cross between *B. nigra* (BB) (n=8) and *B. oleracea* (CC) (n=9), in the highlands of the Ethiopian plateau and the adjoining portion of East Africa and the Mediterranean coast and underwent further chromosomal doubling (2n=34) (Gomez-Campo and Prakash, 1999, IBC, 2007; Ma´rquez-Lema *et al.*, 2008). It is commonly referred to as gomenzer or Ethiopian mustard.

Brassica is the most economically important genus in the Brassicaceae family (syn. Cruciferae). The oilseed Brassicas are found within *Brassica juncea, Brassica carinata, Brassica rapa* (syn. *Brassica campestris*) and *Brassica napus* collectively, and commonly called oilseed rape (Cardoza and Stewart, 2004). Brassica oil production plays an important role in the world. The major producers of oilseeds are USA, China, Brazil, India, Malaysia, Indonesia, EU-15 Countries, Central Europe, Canada, and Argentina and the world oilseeds production is 449 million tons for 2010 (Hailegiorgis, 2011).

Ethiopia is one of the major centers of origin and diversity for several oil crops. Gomenzer (*Brassica carinata*), noug (*Guizotia abyssinica*), sesame (S*esamum indicum*) and linseed (*Lens culinaris*) are the major, indigenous oil crops having considerable diversity in the country (IBC, 2007). These crops are primarily used as sources of oil for local consumption and also contribute to the national economy through import substitution by helping save scarce foreign currency spent for importing cooking oil and nearly 0.8 million ha cultivated, accounting for 8% of the total cultivated area (IBC, 2007).

The culture and cultivation of Ethiopia mustard in Ethiopia is as old as cultivation of cereals, which is believed to date back to the 4th to 5th Millennia BC (Alemayehu and Becker, 2002; Mnzava and Schippers, 2007). There are two types of *Brassica spp.* Cultivated in Ethiopia namely Ethiopia mustard *(B. carinata* Braun*)* and the exotic rapeseed (*B. napus*) (Ethiopian Ministry of Agriculture, 2010; Fekadu, 2004*).*

Ethiopian mustard is mainly self-pollinating oilseed crop that has a considerable diversity for several vegetative traits. It is the third most important source of vegetable oil in the world (Kidd, 1993) and the third most important oil crop in the highlands of Ethiopia next to niger seed (*Guizotia abyssinica* Cass.) and linseed (*Linum usitatissimum* L) and the area as well as the production has increased between 1982 to 2003 by 575% and 1044%, respectively (CSA, 2003) and covers over 40,000 ha with a total production of over 35,000 tons in 2006 (IBC, 2007). According to (CSA, 2006/07), the national average yield of Ethiopian mustard is low, amounting to 950 kg per hectare. One study in Canada reported an average yield which ranged from 2000kg to 3000kg per hectare (IENICA, 2004). The Ethiopian mustard is grown by Ethiopian farmers as both an oilseed and a vegetable crop.

Brassica cultivation is under the threat of pest infestation throughout its cropping period and insect pests have close association with the phenology of crop from the seedling stage to head harvesting (Mayoori and Mikunrhan, 2009). Different insect pests are known to attack the roots, stems, leaves, flower buds, flowers, pods, and seeds of oilseed Brassica plants. Many of the important insect pests are as cosmopolitan as the crucifers themselves and the most serious pests of the oilseed Brassica crops are members of the order Coleoptera, particularly in Europe and North America (Lamb, 1989). Some of the insect pests in North America, such as flea beetles, root maggots, and diamondback moth are crucifer specialists and introduced from Europe or Asia and became pests of cruciferous vegetables before oilseed Brassica crops were introduced (Lamb, 1989). Thirteen insect pests were known to attack the crop in Ethiopia and the most serious pests are cabbage flea beetles, golden plusia, cabbage white, cabbage aphid and diamond-back moth (Kemale *et al.,* 1986; Anonymous, 1987). Although there is some level of resistance in Ethiopian mustard, all species need spray control (Hiruy, 1987).

Flea beetles, *Phyllotreta* spp (Coleoptera: Chrysomelidae), are the major insect pests of *Brassica* world wide. These beetles are tiny beetles, 2-3mm long, which jump like fleas when disturbed (Anonymous, 2009). Feeding injury caused by flea beetles results in seedling mortality, slower growth, delayed maturation, lower yield, and reduced seed quality (Putnam, 1977; Lamb, 1984). *Phyllotreta cruciferae* (Goeze) and *P. striolata* (Fabricius) are serious pests in the production of canola (*B. napus* L. and *B. rapa* L.), mustard (*B. juncea* (L.) Czern.) and several cole crops (principally *B. oleracea* L.) throughout North America (Tansey *et al.,* 2009). On Canadian canola crops, these beetles are considered responsible for economic losses estimated at more than 300 million Canadian dollars annually (Madder and Stemeroff, 1988). In North Dakota, flea beetles have been recorded attacking the growing point (meristem tissue), killing the plant (Tansey *et al.,* 2009). When heavy *P. cruciferae* infestations are associated with hot dry weather, whole crops are destroyed, requiring growers to reseed or leave the land fallow (Lamb, 1984). Flea beetle damage to canola has been estimated to cause an average annual yield loss of about 10% (Lamb and Turnock, 1982). *Phyllotreta mashonana* Jacob and *P. weisei* Jacob are major pests of the Ethiopia mustard and rapeseed, especially at the early seedling growth period (Tadesse and Bayeh, 2002; Bayeh and Biruk, 2008).

Currently, the most effective control measure is the use of insecticides for managing the overwintered generation of flea beetles that emerge early in the spring (Lamb and Turnock, 1982, Weiss *et al.,* 1991 and Trdan *et al.,* 2005). Beetles can be killed by coming in contact with the spray or with treated leaves, or by feeding on treated leaves (Hazzard *et al.*, 2002). Insecticidal control measures are recommended when 25% or more of the seedling cotyledon or leaf surface is destroyed and flea beetles are present (Saskatchewan Agriculture and Food, 2008). The strategy used most commonly in western North America to protect seedlings of canola (*B. rapa* L. and *B. napus* L.) from attack by adults of the flea beetles *P. cruciferae* (Goeze) and *P. striolata* (Fabricius) involves planting seed coated with insecticide for systemic activity (Tansey *et al*., 2009). Predators and parasites provide limited regulation of flea beetle populations (Wylie, 1984).

In Ethiopian condition oilseed crops are very important both in terms of their contribution to human diet as edible oil source and as one of the major crops of cash income for the farmers and as national foreign exchange earning crops (Bayeh and Bayou, 2009). The demand for edible oils for local consumption has been increasing from time to time and currently it has reached at climax, but the present level of production could not meet such high demand. Thus, the price of edible oils is soaring high and even now it is difficult to get on the market. The value of imported edible oil is 40 to 50% of the export earnings of oilseeds and increasing domestic edible oil production can substitute these imports and improve the trade balance (Wijnands *et al*., 2009). The yield per unit of land of oil crops in general is very low and it appears that lack of break through in breeding, lack of improved crop management and perhaps diseases and insect pests are contributing to such low yield (Bayeh and Bayou, 2009). *B. carinata* had been backyard crop for along past years due to no attention was given for its production. Currently, it is becoming more of an open field crop and playing an important role in an increase of farmers' income and also can contribute a lot in satisfaction of the demand of national edible oil. For example, in Bale zone farmers use it as a break crop for the management of grass weeds in fields of wheat (BADE, 2003) and in Arsi Zone the acreage and yield was 2,416 ha and 3,878.7 tonnes in 2007 and increased to 7,405 ha and 12,820 tonnes in 2012 (Agricultural Bureau of Arsi Zone, 2012, Personal Communication).

Since the cabbage flea beetle is a confirmed major insect pest of Brassica crops and crop acreage in Ethiopia is on the increase (Bayeh and Biruk, 2008) and since predators and parasites (Wylie, 1984) as well as cultural and biological control has low efficiency, at present insecticides are the only viable option for controlling the crucifer flea beetles (Hiiesaar *et al.*, 2003). Therefore, it is timely that work on this insect pest be carried out. Population monitoring and accurate identification of flea beetle species are also essential for making control strategy decisions (Tansey *et al*., 2009). Managing insect pest attack is very important to increase the yield of these crops and satisfy our national demand of food oil. So this research work is proposed with the following objectives:

OBJECTIVES

General Objectives

To contribute to the development of appropriate control measures for flea beetles management on gomenzer (*Brassica carinata* A. Braun) in Arsi Zone.

Specific Objectives

- ☞ To determine the distribution over places of flea beetles on open field grown Ethiopian mustard *(Brassica carinata* A. Braun) in Arsi Zone.
- ☞ To monitor the population of flea beetles on Ethiopian mustard (gomezer) at different growth stages of the crop.
- ☞ To identify appropriate seed rate and effective insecticides for the management of flea beetle on *Brassica carinata*.

2. LITERATUE REVIEW

2.1. The taxonomy and origins of the oilseed Brassica crops

The *Brassica* genus contains many agronomically important crop species with a range of adaptation for cultivation under varied agroclimatic conditions. The genomes of Brassica cultivated have been denoted as the A, B and C genomes, with three monogenomic diploid species, namely *B. rapa* syn. *campestris* (AA, 2n=20; Chinese cabbage and turnip), *B. nigra* (BB, 2n=16; black mustard) and *B. oleracea* (CC, 2n=18; cabbage, brussel sprouts, cauliflower and broccoli). The remaining three cultivated species, *B. napus* (AACC, 2n=38; canola, swede), *B. carinata* (BBCC, 2n=34; Ethiopian mustard), and *B. juncea* (AABB, 2n=36; Indian mustard) are amphidiploid hybrid taxa, evolving through hybridisation between the monogenomic diploid species (Redden *et al.*, 2009).

Ethiopia is the centre of genetic diversity of *B. carinata* A. Braun (*n* = 17). The cultivation of *B. carinata* as an oil crop is restricted to Ethiopia plateau, but as a leafy vegetable it is often grown in East and southern Africa, less so in West and Central Africa (Mnzava and Schippers, 2007). It is an amphidiploid species derived from interspecific crosses between *B. nigra* (*n* = 8) and *B. oleracea* (*n* = 9). No wild forms of *B. carinata* have been reported (Rakow, 2004; Mnzava and Schippers, 2007). It might have originated from hybrids between kale, which has been grown in the plateau since ancient times, and wild or cultivated *B. nigra*. *B. carinata* grows slowly, a trait which it might have inherited from its *B. oleracea* parent, and its seed contains mustard oil comparable to *B. nigra* (Rakow, 2004).

Ethiopian mustard is widely cultivated in the highland and semi-highland parts of the country with altitudes ranging from 1800-2600 m above sea level (Anonymous, 1987) but is well adapted to areas in Ethiopia with a cool (14–18 ^{o}C), moist (600–900 mm), long growing season at elevations between 2200 and 2800 m (Warwick *et al.*, 2006). The major mustard growing areas are located in Arsi, Gojjam, Sidamo, Eastern Wellega, Horo

Guduru Wellega and Central and Southern Shewa. It is cultivated in the highlands, often planted early in the rainy season. Field research in the central highland of Ethiopia confirmed that late May to late June planting at the onset of the main rainy season is important for yield of oilseed. The seeding rate of 6 to 10 kg/ha was found to be optimum. Row spacing of 30 cm was found suitable for good yield (Anonymous, 1987).

Normally, flowering starts 12 weeks after sowing depending on cultivar and growing conditions. Flowering is delayed by regular harvesting of leaves and young shoots. When grown with adequate moisture it produces seeds in 5-6 months (Mnzava and Schippers, 2007).

2.2. Importance of Brassica

Brassica has many uses. Among these oil production is the most economic value. Brassica oilseed production has increased over the last 40 years and has become one of the most important world sources of vegetable oil after soybean and cotton seed (Rakow, 2004).

Brassica vegetables contain little fat and are sources of vitamins, minerals, and fiber (Cardoza and Stewart, 2004) and about 40% erucic acid and the meal is high in glucosinolates (Getinet, 1996). They also contain a large number of novel phytochemicals, some of which protect against carcinogenesis (Steinmetz and Potter, 1996). Hence, Brassicas are believed to be useful in the prevention of cancer (Cardoza and Stewart, 2004).

Farmers in Ethiopia grow *B. carinata* as a leafy vegetable in their gardens and also harvest seed for oil. Since long ago, it has saved the lives of many Ethiopians. This is because in localities where there is a shortage of grain in the annual cycle of production, when the families have little or no stored supply of food before the next harvest time, the shoots and leaves of the crop are used to sustain on by tinning or topping (Abel, 2007).

This is due to the fact that *B. carinata* needs less time of harvest compared to other vegetable crops locally grown. Ground seeds are used to grease ‘injera’ and bread baking clay pan, cure certain ailments or stomach upsets and prepare beverages; the leaves of young plants are good source of vegetable relish. Ethiopian mustard is currently being evaluated as an option to the traditional canola /mustard cultivation, especially for low rainfall areas of the world (Sheikh *et al.,* 2010).

Moreover, its adaptation in semi-arid environment makes it an ideal candidate in a country like Ethiopia where drought is a common feature at intervals (Abel, 2007). Studies conducted on Ethiopian mustard landraces for oil content and productivity reveal that the indigenous crop is more productive, resistant to diseases and more drought tolerant compared to their exotic ones (Anonymous, 2009). In most parts of Africa, the primary use of *Brassica carinata* is as a cooked leafy vegetable. Outside Africa, especially in western and southern Asia, it is occasionally grown as an oilseed crop or for mustard (Mnzava and Schippers, 2007). The oil has limitations for cooking because of high contents of glucosinolates and erucic acid. In Ethiopia it is also used for oiling the baking plates of earthenware ‘injera’ stoves. The seed is used in folk medicine to treat stomach-ache. People in Ethiopia use the sharp-tasting seeds as a spice to flavour raw meat (Mnzava and Schippers, 2007). Seed oil from *B. carinata* has industrial applications wherever oils with high erucic or linolenic acid contents are required but its use as a biodiesel is only now being explored (Warwick *et al*., 2006). It is also vital in Ethiopian agricultural system. It is a break crop of cereals in different agro ecology highlands of Ethiopia, used as green manure (Eyasu *et al*., 2007)

2.3. Cabbage Flea Beetle, *Phyllotreta* spp

The adult is a small, oval-shaped, blackish beetle with a bright blue sheen on the elytra, measuring about 1/32 to 1/8 in. (2-3 mm) in length (Knodel and Olson, 2002). Flea beetles have large hind legs that enable them to jump long distances when disturbed like flea, hence the name "flea beetle" (Nielsen, 1997; Hazzard *et al*., 2002).

The crucifer flea beetle was introduced into North America in the 1920s and is now distributed across southern Canada and the northern Great Plains of the United States (Knodel and Olson, 2002).

2.3.1. Biology of cabbage flea beetles

Life history varies somewhat with species, but most appear to pass the winter in the adult stage, sheltering under plant debris in the field, field margins, and adjacent areas (Kuepper, 2003). In the autumn, flea beetles move into the brushy areas beside fields. They spend the winter hiding in leaves near the soil. These adult beetles are known as “overwintering adults” because they start their life cycle in one summer, survive over the winter, and stay alive into the next summer (Hazzard et al., 2002). Depending on the temperature, it may take up to three weeks for the adults to leave their overwintering sites (Knodel and Olson, 2002).

Flea beetles are favored by stable warm spring weather and hampered by alternating periods of hot and cold temperatures with intermittent rains (Kuepper, 2003). In late spring the female beetle lays her eggs at the base of garden plants, which hatch in 5 to 8 days. The larvae feed on the roots for 2 to 3 weeks and then enter the pupal stage for 2 weeks. The larvae of most flea beetles are whitish, slender, worms 1/8- to 1/3-inch long when full grown, with tiny legs and brownish heads. Adults emerge from the pupal stage in midsummer and the cycle is repeated (Nielsen, 1997). The adult flea beetles are active leaf-feeders that can, in large numbers, rapidly defoliate and kill plants (Kuepper, 2003).

2.3.2. Feeding and crop preference

The crucifer flea beetle has a narrow host range restricted to plants primarily in the mustard family (Cruciferae) and all of the flea beetles prefer plant families that produce mustard oil (or allylisothiocyanate), which is a known aggregation pheromone of the crucifer flea beetle (Knodel and Olson, 2002). The most-preferred hosts are in the genus

Brassica (Cruciferae), which include the major agricultural host attacked by flea beetle, oil rapeseed or Argentine canola (*B. napus*) and Polish canola (*B. rapa*/campestris). Mustard (*Brassica* spp) and crambe (*Crambe abyssinica*) are also susceptible to flea beetle attack but not preferred over canola (Hazzard et al., 2002; Knodel and Olson, 2002). Other hosts that flea beetles can attack in the garden setting are cabbage, turnip, cauliflower, kale, Brussel sprouts, horseradish, and radish and as well some weeds attacked in the cruciferous group are flixweed, field pennycress, peppergrass, and wild mustard (Knodel and Olson, 2002).

Phyllotreta spp are among the most important pests of cultivated Brassicas in Europe and North America (Stoner, 1992; Ester *et al.,* 2003) with *P. cruciferae* as the most common and destructive (Mayoori and Mikunrhan, 2009). Symptoms of flea beetle feeding are small, rounded, irregular holes; heavy feeding makes leaves look as if they had been peppered with fine shot (Kuepper, 2003). They consume leaf tissue and reduce the area of photosynthetic material available to the plant. Intense feeding damage can kill plants, especially young seedlings and even when plants do not die, the damage is often enough to reduce yield (Hazzard *et al.,* 2002).

Seedlings of crops are most vulnerable to flea-beetle feeding when stressed, particularly by inadequate moisture (Kuepper, 2003) and this lasts until the appearance of 4–6 true leaves (Hiiesaar *et al.,* 2003) and older plants can 'resist' the pest with greater leaf surface(Trdan *et al.,* 2005). Crop losses from flea beetle attack include reduced crop stands, uneven plant growth, delayed maturity and lowered seed yields (Westdal and Romanow, 1972; Lamb and Turnock, 1982).

2.3.3. Management options of cabbage flea beetles

To prevent the loss which can be caused due to the feeding of flea beetles the growers should practice different management options. Critical stages for control cabbage are the seedlings and transplants (Weinzierl, 2000). The different management options are cultural, chemical and biological options.

2.3.3.1. Chemical control

It is often impossible to fight flea beetles without chemical control (Hiiesaar *et al.,* 2003) and the principal means of flea beetle control in western Canada has been and continues to be chemical (Soroka and Elliott, 2011). Crop rotation and biological agents provide limited control of flea beetles so producers are dependant on several methods of chemical control including seed treatments, granular insecticides and field sprays (Lamb 1984, 1989; Whaley, 2010). Pesticides are used in agriculture to secure high and reliable production. Synthetic pesticides have been used during more than six decades (Ahmed *et al.,* 2011). Insecticides for the control of flea beetle are available in dust (D), wettable powder (WP), flowable liquid (F), and emulsifiable concentrate (EC) (Nielsen, 1997). Apply sprays when it is sunny and warm, and the beetles are active and exposed on plants and soil (Whaley, 2010) and application of foliar insecticide may be required when feeding damage encompasses 25% of the leaf surface. Treatments on cole crops are recommended when 10 to 20% of a stand shows feeding damage (Hines and Hutchison, 1997). Although they have positive effects on crop yield, pesticides may have environmental drawbacks (Devine and Furlong, 2007).

Brassica seedlings can hardly recover from severe attack by flea beetles, thus the use of insecticides is still the most common pest control strategy applied in the early stages of plant development in white cabbage production (Trdan *et al.,* 2005). One of the more common and efficacious insecticides for flea beetle management in Brasssicas is Carbaryl (trade name Sevin) (Hazzard *et al*., 2002). Seed treatments with systemic insecticides are effective for reducing flea beetle damage to seedling canola (Elliott *et al.* 2004). However, *P. cruciferae* and *P. striolata* respond differently to the Neonicotinoid insecticides Thiamethoxam and Clothianidin (Tansey *et al.,* 2009). *Phyllotreta cruciferae* is more susceptible to these compounds when applied as seed treatments and exhibits greater treatment-associated reductions in feeding and greater mortality than *P. striolata*. Differential responses of these beetles to Neonicotinoid compounds were particularly apparent when sublethal effects of insecticides interacted with intraspecific crowding, interspecific competition and stresses associated with overwintering (Tansey *et al.*, 2009).

2.3.3.2. Cultural control

Although using effective cultural and biological control options does not eliminate the need for conventional insecticides, the application of such products can be reduced on farms where an integrated approach is practiced (Weinzierl, 2000). Agronomic practices that promote good stand establishment and rapid seedling growth will reduce the impact of flea beetles on canola seed yield (Soroka and Elliott, 2011). In organic systems, the preferred approaches to pest management are those that enhance the diversity of the farm system, such as cover cropping, rotation, and interplanting; those that use special knowledge of pest biology, such as delayed planting; and those that take advantage of existing on farm resources (Kuepper, 2003).

Crop rotation is not an effective means of controlling flea beetles. Adults overwinter inside and outside of the cropped areas and are capable of long-range migration (Whaley, 2010). Proper weed control in and around planting sites will deprive flea beetle larvae of food sources needed for successful development, and may help to lessen the flea beetle population. Planting crops as late as possible, during warmer temperatures will help plants outgrow flea beetle feeding damage (Burkness and Hahn, 2007).

2.3.3.3. Biological control

In healthy agroecosystems, there are populations of beneficial predators and parasites that work to control the number of flea beetles and other pests (Kuepper, 2003). Commercial formulations of entomopathogenic nematodes are effective agents for controlling flea beetles (Ellis *et al.,* 1992). Applied to the soil, the nematodes attack the beetles' larval stage, reducing root feeding and helping to prevent the next cycle of adults from emerging (Kuepper, 2003). *Microctonus vittatae* is a native braconid wasp found more commonly in the Eastern half of the U.S. *M. vittatae* not only kills the adult flea beetle as the wasp emerges, but the larval wasp sterilizes the female flea beetle while developing in her body (Burkness and Hahn, 2007). Flea beetles emerge in large numbers during a relatively short period of time and tend to overwhelm the parasites and predators (Whaley, 2010).

3. MATERIALS AND METHODS

3.1. Description of Experimental Sites

Field experiment was conducted at Kulumsa Agricultural Research Center (KARC) (8^o01'N latitude and 39^o09'E longitude) in Arsi Zone Southeastern Ethiopia in 2011 cropping season (June- December) and on farm monitoring was carried out in three Woredas; Hetosa, Tiyo and Lemu Bilbilo of Arsi zone in the same season. The center is located 167kms southeast of Addis Ababa and 8km north of Asella town at altitude of 2200 meters above sea level. The area received seasonal average rainfall of 686.5mm. The average seasonal minimum and maximum temperatures were 9.12^oC and 22.67^oC, respectively. Arsi Zone is one of the oil seed Brassica growing areas in the country. The soil type of the center is luvisol/eutric nitosols with a good drainage system.

3.2 On Farm Monitoring of Cabbage Flea Beetles on *B. carinata*

On farm monitoring was conducted in Arsi Zone on three Woredas namely Hetosa, Tiyo and Lemu Bilbilo. It was carried out by taking purposive samples of mustard fields. A total of three *Brassica carinata* fields were visited in each Woreda. Farms were designated by assigning numbers for three sites in each Woreda as fm1, fm2 and fm3 for farms in Lemu Bilbilo, fm4, fm5 and fm6 for farms in Tiyo and fm7, fm8 and fm9 for farms in Hetosa Woreda. Five one-square meter plots were selected per field randomly and marked for data collection. The fields were visited four times at primordial, first true leaf, second true leaf stages and after harvesting. The numbers of emerged seedlings were counted from these selected one-square meter area at the primordial stage. Numbers of flea beetle and their damage were counted at primordial, first true leaf and second true leaf stages. Finally the numbers of productive plants were counted after the crops were harvested from fields.

3.3 On Station Experiments

3.3.1 Monitoring of cabbage flea beetles population

The Yellow Dodolla mustard variety was sown in rows with seed rate of 10kg per ha on four plots having 5m x 5m each. Standard commercial fertilizers N/P05 46/69 kg/ha, respectively were applied and weeding was carried out manual1y twice at 35 and 89 days after sowing. Seeds of Ethiopian mustard and fertilizers were obtained from Kulumsa Agricultural Research Center. One plot having 2m x 3m with 6 rows per plot was selected and from these selected plots four rows of 1m length were considered for data collection except for yield. The target sample unit was approached so that the plants were not shadowed before sampling. Monitoring was made with adult flea beetles because according to Vincent (1982), the eggs, larvae and pupae of flea beetles cannot be monitored efficiently. Cheapest method of population assessment relies on visual the observation of adult populations, as used by Hamid (2006) was used in this study. Samples were taken between 10:00am and 4:00pm h since flea beetles are more active at this time of the day.

The number of emerged seedlings was taken at primordial growth stage. Counting of flea beetle and their damage was done six times when the crop was at primordial, first true leaf, second true leaf, third true leaf , vegetative, flowering and matured stages. Yield was obtained from 3m x 4m area for each plot and expressed as kg/ha. Finally the number of productive stalks was counted from the marked four one meter length after harvest.

3.3.2 The effect of seed rate on the population of cabbage flea beetles

The Yellow Dodolla mustard variety was sown in 2m x 3m plots arranged in a randomized complete block design (RCBD) with four replications under field conditions to see the effect of seed rate on the population of cabbage flea beetles and their crop damage statuses. The recommended seed rate of *B. carinata* in Arsi Zone is 10kg/ha. In this trial six different seed rates namely; 2.7g, 4.1g, 5.4g 6.8g, 8.1g and 10.8g seeds per 6 m^2 (equivalent to 5kg, 7.5kg, 10kg, 12.5kg, 15kg and 20kg seeds per hectare) were used as treatments. The crop was sown on four blocks having six plots each. The distance between the plots was 50cm and between rows, 30cm. Flea beetle damage and flea beetles present were assessed starting from the primordial growth stage until the crop reached the maturity stage as in the monitoring trial. Two rows of one meter length were considered for data collection and finally the average was taken. Finally, the number of productive plants was counted after the crop was harvested by counting the rootstalks and the number of plant population reduction was determined by subtracting from the plant stand at primordial leaf stage. Yield was obtained from 1.5m x 2m area of each plot and expressed in kg/ha.

3.3.3 Screening of insecticides for the control of flea beetles on *B. carinata*

Yellow Dodola mustard cultivar was sown in rows to select an effective chemical insecticide(s) with an appropriate rate. The insecticides were from Holetta Agricultural Research Center. Three insecticides namely Fenitrothion, Malathion and Carbaryl were evaluated. The treatments were: (1) each insecticide at recommended rates (Fenitrothion 50% EC (1.5l/ha), Malathion 50% EC (2l/ha) and Carbaryl 85% WP (1kg/ha)), (2) each insecticide at twice the recommended rate, and (3) unsprayed check as control (Antwi *et al*, 2007). All foliar applications were done using a backpack sprayer after arrival of flea beetles, i.e., when the seedlings emerged (14/07/11) and continued twice when it was at first (22/07/11) and second true leaf stages (29/07/11). Two rows of one meter long were marked for fixed data collection. The numbers of emerged seedlings were counted from these selected rows at primordial growth stage. Numbers of flea beetles and their damage were counted nine times before the insecticides were sprayed and 24 hours later, at primordial growth stage, at first true leaf stage, at second true leaf stage at the sprayed stages and at latter vegetative growth stage, at flowering and at matured stages from the marked one meter rows. Yield was taken from 1.5m x 2m area and expressed as kg per hectare.

3.4 Data Analysis

The collected data were analyzed using *SAS (version 9.2)* software (SAS Institute Inc. 2008) and ANOVA procedure was used.

3.4.1 On farm monitoring of cabbage flea beetles on *B. carinata*

The percentage productive stalks and plant population reduction were determined as follows:

$$PR\% = \frac{(ES-PS)}{ES}100\%$$

$$PS\% = \frac{(ES-PR)}{ES}100\%$$

Where, ES= emerged seedlings

PS= Productive Stalks

PR= Plant reduction

Multiple comparisons of means of collected data were carried out using Tukey's multiple comparison (Tukey's honestly significant difference test/TSD) to determine which means amongst a set of means differ from the rest. Correlation was made for number of flea beetle, flea beetle damage, productive plant stalks and plant population reduction.

3.4.2 On station monitoring of cabbage flea beetles

Analysis of variance and mean separation was done for the flea population and their damage at different stages of plant growth using Tukey's multiple comparison.

3.4.3 The effect of seed rate on the population of cabbage flea beetles

Percent survived plant population and reduced plant population were determined. The percent plant population reduction was obtained from the percentage productive plants. To stabilize the coefficient of variance they were transformed by adding 0.5 to each count and taking the square root (Lamb, 1988). Analysis of variance was made and Tukey's honestly significant difference test was used to determine which means amongst the set of means differ from the rest. A significance level of 0.05 was considered for the comparison.

3.4.4 Screening of insecticides

Percent survived plant population and reduced plant population were determined from the mean numbers of emerged seedlings and productive plants. The interaction effect between insecticides and their rate was found to be non-significant so that interaction was not considered in data analysis. Data were transformed as stated under seed rate trial. Tukey's multiple comparison test (Tukey's honestly significant difference test) was used to determine which means amongst the set of means differ from the rest. Correlation was made for number of flea beetle, flea beetle damage, productive plant stalks, plant population reduction and yield. A significance level of 0.05 was used.

4. RESULTS AND DISCUSSION

4.1. On farm monitoring of cabbage flea beetles on *B. carinata*

4.1.1. Cabbage flea beetles count at seedling stage

The mean number of flea beetles observed infesting *B. carinata* presented in the Table 1. During the primordial stage significant difference was detected among some farms and relatively higher in plots from farms of Tiyo Woreda (fm4, fm5 and fm6) and of Hetosa (fm8) (F= 2.55, P= 0.0259). There was no significant difference among fm1, fm2, fm3, fm5, fm7, and fm9. Fm6 was significantly different in mean number of flea beetles from fm1, fm2, fm3, fm7 and fm9 and recorded with relatively higher mean number of flea beetles. Fm5 was statistically found to be similar with all the farms. At first true leaf stage, all the farms except fm6 were not statistically different (F=2.41, P=0.0342) from each other in mean number of flea beetles where the number was highest for fm6 and lowest on fm1. During second true leaf stage, fm3 was significantly different in mean number of flea beetles (F=5.12, P=0.0003) from fm4, fm5, fm6 and fm8 whereas all the rest farms were not statistically different from each other. Farm fm6 was planted and visited later and this might be the reason why higher numbers of flea beetles were recorded eventhough the effect of seeding date on flea beetle damage varies from region to region (Soroka and Elliott, 2011). Carcamo *et al.*, (2008) investigated that in southern Alberta, canola planted in April has fewer flea beetles and suffers less damage than canola planted in May, while the opposite is true in central and northern Alberta.

In all the three Woredas, during the first true leaf stage the mean number of flea beetles exceeded that of the primordial leaf stage and slightly decreased at the second true leaf stage. Inline with Hummel *et al*., (2009) reported that the first true-leaf stage of canola development experienced the greatest flea beetle damage and this is perhaps because by this stage flea beetles have located and colonized the plant stand in sufficient numbers to cause considerable damage, whereas plants at later developmental stages rapidly outgrow damage they sustain.

Table 1: Mean (±SE) number of flea beetles per $1m^2$ area at seedling stage of growth *B. carinata*

	Plant Growth Stages		
Farm	Primordial	First True Leaf	Second True Leaf
Fm1	19.6c	29.0b	28.6ab
Fm2	23.4bc	35.0ab	27.8ab
Fm3	21.2bc	29.4b	24.2b
Fm4	29.0ab	35.8ab	34.0a
Fm5	25.4abc	36.6ab	34.2a
Fm6	32.2a	42.4a	37.0a
Fm7	20.4bc	33.0b	30.0ab
Fm8	29.2ab	36.8ab	35.4a
Fm9	23.2bc	32.0b	29.4ab
CV (%)	8.1	17.7	17.6
SE	0.94	0.93	0.86
F Value	2.55	2.41	5.12
P Value	0.0259	0.0342	0.0003

CV, coefficient of variability, SE, standard error. Means followed by the same letter(s) are not significantly different from each other at p= 0.05 level of probability (HSD).

4.1.2. Cabbage flea beetle damaged plant count at the seedling stage

The mean number of damaged plants of the farms at the three plant growth stages was recorded and presented in Table 2. During primordial growth stage, the highest mean number was observed at fm6 which was significantly different (F=15.11, P=<.0001) from the other farms. Counts were statistically similar among fm2, fm5, fm8 and fm9 and among fm1, fm3, fm4, fm5, fm7, fm8 and fm9. Flea beetle damage increased at first true leaf stage than the primordial stage. Significantly higher flea beetle damage to *B. carinata* was found in fm6 and less (F=9.84, P=<.0001) damage was detected in fm1 and fm7. At the second true leaf stage, flea beetle damage slightly decreased but greater than that of primordial stage. At this stage significantly (F= 6.79, P= <.0001) higher flea beetle damage to *B. carinata* was detected at fm6 and at all the other farms the level of damage was not significantly different from each other statistically. It can be concluded that the peak of the beetle damage was at first true leaf stage. This result generally revealed significant variation in flea beetle damage was detected among some farms and this agrees with the report of Lamb (1988). According to this report, the damage caused by flea beetles varied spatially.

Table 2: The mean (±SE) number of flea beetle damaged to *B. carinata* at seedling stage per 1m^2 area

		Plant growth stages	
Farm	Primordial	First True Leaf	Second True Leaf
Fm1	85.6c	151.0cd	127.4b
Fm2	111.0b	174.2ab	140.6b
Fm3	86.6c	162.4bc	133.4b
Fm4	89.8c	164.2bc	147.8b
Fm5	93.6bc	163.6bc	148.0b
Fm6	138.2a	189.8a	182.6a
Fm7	80.2c	140.6d	121.6b
Fm8	96.4bc	164.6bc	136.2b
Fm9	96.8bc	163.0bc	139.4b
CV (%)	10.10	5.90	11.40
SE	2.85	2.34	3.31
F Value	15.11	9.84	6.79
P Value	<.0001	<.0001	<.0001

CV, coefficient of variability, SE, standard error. Means of column followed by the same letter(s) are not significantly different from each other at p= 0.05 level of probability (HSD).

4.1.3. The emerged seedlings, productive plant stalks and plant population reduction

The mean of seedlings count, productive stalk and plant population reduction are presented in Table 3. Fm2 had large mean number of seedlings, which was similar to fm6 but different from the rest of the farms (F = 12.07, P<.0001). Fm7 was observed to have the least mean number of seedlings which was statistically similar to fm1, fm4, fm5 and fm9. The mean number of productive stalks was statically similar for fm2, fm3 and fm8.

Except fm2, all the farms were statistically similar (F=6.79, P <.0001) in mean number of productive stalks although highest (164) in fm2. The mean plant population reduction in fm6 was similar to fm2 and fm4. Mean plant population reduction was similar for the rest of the farms (F=3.33, P= 0.0059). Maximum reduction was observed at fm6 which sustained maximum damaged seedlings.

The percentage productive stalks was minimum in farm6 (59.5%) and higher at fm1, fm2, fm3, fm8 and fm9. Plant population reduction was maximum in fm6 and minimum in fm1.

Table 3: Mean emerged seedlings, productive stalks, plant population reduction per $1m^2$ row length and yield

Farm	Number of Emerged Seedlings	Number of Productive Stalks	Productive Stalks (%)	Number of Plant Reduction	Plant Reduction (%)
Fm1	190.4bcd	137.0b	72.0a	53.4b	28.0b
Fm2	229.8a	164.0a	71.3a	65.8ab	28.7b
Fm3	199.6bc	140.4ab	70.4ab	59.2b	29.6ab
Fm4	180.0cd	117.0b	65.8ab	63.0ab	34.2ab
Fm5	180.0cd	121.2b	67.4ab	58.8b	32.2ab
Fm6	207.4ab	122.8b	59.5b	84.6a	40.5a
Fm7	171.2d	117.4b	68.8ab	53.8b	31.2ab
Fm8	196.4bc	138.4ab	70.3ab	58.0b	29.7ab
Fm9	189.6bcd	134.2b	70.8ab	55.4b	29.2ab
CV (%)	5.80	9.70	8.10	18.80	17.70
SE	2.91	2.75	0.94	2.06	0.93
F Value	12.07	6.79	2.55	3.33	2.41
P Value	<.0001	<.0001	0.026	0.0059	0.034

CV, coefficient of variability, SE, standard error. Mean (s) of the same column sharing similar letters are not significantly different at P=0.05 level of probability (HSD).

4.1.4. Correlation of plant damage, number of flea beetles, productive plant stalks and plant population reduction

Significant positive correlation was observed between plant damage and flea beetle population at the three stages considered in this study although the correlation was only moderate (Table 4). No significant correlation was detected between the number of damaged plants and number of productive stalks but negative significant and weak correlations were found between flea beetle population and number of productive stalks at the three considered stages. Positive association was found between population of flea beetle and plant population reduction. The association was moderate.

Table 4: Correlation of damaged plants, flea beetle population, productive stalks and plant population reduction at primordial, first true leaf and second true leaf stages

	Plant Reduction	Beetles at Primordial	Beetles at 1st True Leaf	Beetles at 2nd True Leaf
Damage at Primordial	0.665**	0.567**	0.560	0.308
Damage at 1st True Leaf	0.604**	0.488	0.349*	0.222
Damage at 2nd True Leaf	0.520**	0.530	0.521	0.413**
Productive Stalks	-0.303	-0.441**	-0.423**	-0.447**
Plant Reduction		0.613**	0.479**	0.394**

*, ** Indicate correlation is significant at 0.05 and 0.01 level, respectively.

4.2. On Station Monitoring of Cabbage Flea Beetles on *B. carinata*

Monitoring is the first step in averting yield loss from flea beetle feeding of Brassica. The seedlings were examined for the peculiar shoot hole damage of flea beetles especially for the first two to three weeks.

4.2.1. Emerged seedlings

Counting of the emerged seedlings was carried out to determine the number of plants that could survive the damaging effects of the flea beetles and able to set pods. In relation to this the average number of emerged seedlings per 1m of row length was found to be 52.2±1.06 (Table 6).

4.2.2. Flea beetle population and damaged plants

The mean number of flea beetles on the crop is presented in Table 5. Infestation of the beetles was increased at the first true leaf stage. The mean number is statistically similar with second true leaf stages and declined at the succeeding growth stages and finally decreased close zero at maturity stage. Flea beetle damage to Brassica plants occurred early at the seedling stage. Foliar damage was maximum at the first true leaf stage and it was also high at second true leaf stage. Starting from the vegetative stages the damage declined and less in number was recorded at maturity stage.

Table 5: Mean (±SE) number of cabbage flea beetles and plants damaged at different stages of plant per 1m row

Plant Growth Stages	Flea Beetles	Damaged Plants
Primordial	10.4b	23.3b
First True Leaf	17.5a	40.9a
Second True Leaf	16.1a	36.2a
Vegetative	6.7bc	23.9b
Flowering	3.2cd	5.3c
Matured	1.5c	2.3c
CV (%)	24.06	10.66
SE	1.32	3.01
F Value	35.64	179.21
P Value	<.0001	<.0001

CV= Coefficient of variance, SE= Standard Error, Mean (s) of the same column sharing similar letter(s) are not significantly different at P=0.05 level of probability (HSD).

Flea beetles have been considered as pests of seedling stage of Brassica. They appeared after the emergence of the crop. At the first true leaf stage the mean number of flea beetles was lower. Then after a week the mean number increased. This might be due to continuous pest establishments. This result agreed with what was reported by Hiiesaar *et al*. (2003). Their report shows that, at the time of the sprouting of rape plants first flea beetles appeared in the field simultaneously, initially in small numbers then the number increased. Beetles in the field were almost similar in density during first and second true leaf stages. From the vegetative stage to the matured stages the mean number was decreased and they were not important to cause significant damage to the crop during these stages. This result agrees with many researches done previously. For example it was stated by Andersen, *et al.* (2005) that until recently, flea beetle has been viewed as primarily an early season pest of *Brassica* crops. There was also evidence from the work of Bracken and Bucher (1986). According to their report, in canola yield was reduced by feeding of flea beetles mostly when plants were damaged during stages 1.0–2.2, 5–10 days after germination, but the yield was not reduced when they were damaged after reaching stages 2.3–2.4, 20 days after germination. It might be also to some extent inline with the recommendation of Hiiesaar *et al*. (2003) that they have recommended constant inspection of *B. napus* starting from the period of sprouting to the stage of 4 to 6 leaves.

The mean number of damaged plants was higher at first and second true leaf stages (Table 5). This was also with the agreement of Lamb's (1984) results that damage was occurred primarily during the first few weeks after emergence crop. He also reported that seedling mortality was high during the first week and growth was reduced at least during the first 2 weeks, which correspond to primordial and first true leaves in present study. Bayeh and Bayou (2009) reported similar result in of flea beetle damaged *B. carinata* in 2007/08 in Welmera Woreda of West Showa Zone. They detected from 11.2% to 71.76%, 21.77% to 95.71% and 56.64% to 100% flea beetle infested leaves of Brassica at different sites during primordial, first true leaf and second true leaf stages, respectively.

4.2.3. Emerged seedlings, productive plant stalks, plant population reduction and seed yield

After harvesting the crop, productive stalks were counted and the average number was 33±1.3 (Table 6). The average plant population reduction was obtained from the number of seedlings emerged and productive stalks and found to be 19.3±1.3. The mean percent of productive plants and plant population reduction were 63 and 37, respectively. Field plot yield samples were weighed after drying of the seeds and the average seed yield per ha for these plots was 1904.7±26.4 kg/ha (Table 6).

Table 6: Mean emerged seedlings, productive stalks, plant population reduction per 1m row and seed yield per $12m^2$

Variable	Mean (± SE) number	Mean (± SE) percent
Emerged Seedlings	52.2±1.1	-
Productive Plants	33±1.3	63±2.2
Plant Reduction	19.3±1.3	37 ±2
Seed Yield (kg/ha)	1904.7±26.4	-

SE= standard error.

Plant stand loss in this study was 37% which is substantial for the reduction yield. Bayeh and Bayou (2009) obtained different percent of plant stand losses from one hundred and eighty different genotypes. Their report shows that only twelve genotypes sustained less than 40% stand loss and eleven other genotypes sustained 80-100% losses. The rest of the genotypes tested are in between the two groups. This indicates that flea beetles are economic insect pest of *B. carinata*.

4.3. The Effect of Seed Rate

4.3.1. Flea beetle population

The numbers of flea beetles on *B. carinata* according to the six different seed rates at six different growth stages of the crop are summarized in Table 7. There was no statistically significant difference in mean number of beetles among the six seed rates during all the considered stages. The mean number showed significant increment from primordial to first true leaf stage. After the second true leaf stage, the pest population declined and reached close to zero.

Table 7: Mean (±SE) number of cabbage flea beetle on *B. carinata* per one meter row at primordial, first true leaf , second true leaf, vegetative, flowering and matured stages of the crop

	Plant Growth Stages					
Seed Rate	Primordial	1st True Leaf	2nd True Leaf	Vegetative	Flowering	Matured
2.7g	6.5	15.8	18.0	5.0	2.5	1.5
4.1g	6.0	16.0	15.3	5.3	2.3	1.8
5.4g	5.5	16.5	16.8	4.5	2.3	1.3
6.8g	6.0	15.0	15.0	5.5	2.8	1.8
8.1g	7.0	16.5	16.0	4.5	2.3	1.3
10.8g	5.5	15.3	13.3	5.5	2.5	1.5
CV (%)	16.9	13.1	16.9	27.6	32.3	52.1
	(7.9)	(6.4)	(8.1)	(12.2)	(14)	(22)
SE	0.22	0.39	0.57	0.27	0.15	0.15
	(0.04)	(0.05)	(0.07)	(0.05)	(0.04)	(0.06)
F Value	1.29	0.36	1.5	0.44	0.27	0.33
	(1.28)	(0.37)	(1.52)	(0.41)	(0.27)	(0.38)
P Value	NS	NS	NS	NS	NS	NS

NS= Non significant, CV (%), SE and F value of the transformed data are placed in the parenthesis.

There was no statistically reliable difference among the six different seed rates in affecting the population density of the flea beetles. This result fully agree with what Dosdal *et al*. (1999) who found in their study of the effect of seed rate on population density of flea beetles on *Brassica rapa* and *Brassica napus*. Flea beetle populations in plots of high plant density may have been similar to those in plots of low plant density, but spread among more host plants. In the same manner, Mayse (1978) found that in different soybean row-spacing treatments, the numbers of certain arthropod species sampled were significantly different on a per plant basis, whereas when those same population values were converted to an m^2 soil area basis, they were not statistically different. In contrary to this other previous researches have showed that an increase in seed rate resulted in less infestation by different insect pests.

4.3.2. Flea beetle damaged *B. carinata*

Flea beetle damaged *B. carinata* was recorded from each seed rate used. Statistically significant difference was observed in flea beetle feeding damage among the different seed rates (Table 8). Percent damage was higher in plots with lower seed rates and decreased from the lower to the higher seed rate. The maximum percent of flea beetle damage to *B. carinata* was recorded at the lowest seed rate (2.7g) and the minimum damage was recorded at the highest seed rate (10.8g). Damage was found to increase from primordial to first true leaf stage at the different seed rates.

Table 8: Percentage of flea beetle damaged plants at primordial, first true leaf, second true leaf, vegetative, flowering and matured stages

	Plant Growth Stages					
Seed Rate	Primordial	1st True Leaf	2nd True Leaf	Vegetative	Flowering	Matured
2.7g	49.2a	86.9a	82.8a	50.4a	19.2a	8.0a
4.1g	47.1ab	83.5a	73.7ab	41.2ab	14.5ab	4.8ab
5.4g	44.6ab	82.6a	64.3abc	39.9ab	12.6abc	3.5ab
6.8g	42.4ab	73.5a	65.9abc	34.2bc	8.1bc	3.7ab
8.1g	35.6ab	55.6b	53.0bc	29.2bc	8.6bc	3.4ab
10.8g	30.1b	47.2b	43.2c	24.9c	6.4c	1.7b
CV (%)	19.2	10.9	17.1	17.2	21.2	24.5
SE	2.02	3.42	3.34	2.08	1.07	0.55
F Value	3.37	17.72	6.78	8.54	9.99	4.17
P Value	0.0253	<.0001	0.001	0.0003	0.0001	0.0108

Means within a column sharing the same letter(s) do not differ significantly at P=0.05. Means of column followed by the same letter(s) are not significantly different from each other at p= 0.05 level of probability (HSD).

Different cultural practices have been used by growers to reduce the effect of insect pests on plants they produce. Seed rate significantly affect the feeding damage of flea beetles. Significantly higher mean percent of damaged plants were observed in the lower seed rates and the number is less in the higher seed rates. Plants of higher density shared beetles and damage level could be less. Throughout all the stages of growth, the percentage of plant damage due to flea beetle feeding decreased with the increase in seed rate and this is similar with the findings of other researches. Desdall and Stevenson (2005) reported that flea beetle damage to canola decreases with the increase in seed rate and they suggested this decrease in damage is due to a dilution effect that is in dense plantings there is much more seedling leaf biomass than when stands are less dense, so damage by a given population of flea beetles is greater per seedling when plant density is low. Dosdal *et al.* (1999), reported that flea beetle damage was usually greatest for plants of *B. rapa* and *B. napus* grown at the lowest seeding rate (5 kg/ ha) than at higher rates (7.5 and 10.0 kg/ ha). They found that increasing plant density and widening row spacing in canola plantings tended to reduce seedling damage by flea beetles.

4.3.3. Productive plants, plant population reduction and seed yield

The mean number of the productive stalks and consequent plant population reduction are summarized in Table 9. The mean maximum number of plant stalks was (49 per 1m row) for the highest seed rate and the mean number minimum stalks was (15.5 per 1m row) was for the lowest seed rate but in percent it was 47.10% and 63.00%, respectively. Plant population reduction was maximum for the highest seed rate and minimum for the least seed rate but in percentage it was similar for seed rate 2.7g, 4.1g, 5.4g and 6.8g. Highest percent (52.90%) (F= 5.11, P= 0.0043) of plant reduction was detected in plots of the highest seed rate which are probably due to higher intraspecific competition between the plants.

The percentage of plant productive stalks and plant population reduction are inversely related. Even though the percent plant survival looks high for seed rate 2.7g, the plant density was very sparse and might have contributed to seed yield reduction after harvest.

Variation was found in yield for the different seed rates and the maximum (1917.8kg/ha) yield was obtained from plots of 5.4g and the minimum (1542.8kg/ha) for plots that were sown 2.7g seed. Statically no significant difference was detected among seed rates of 5.4g, 6.8g and 8.1g whereas they were significantly different (F= 14.57, P<.0001) from seed rate 2.7g and 10.8g in yield.

Table 9: Mean emerged seedlings, productive stalks, plant population reduction per 1m row length and yield per 3m^2 as affected by seed rate

Seed Rate	Number Emerged Seedlings	Number Productive Stalks	Productive Stalks (%)	Number Plant Reduction	Plant Reduction (%)	Seed Yield (kg/ha)
2.7g	24.8e	15.5e	63.0a	9.3c	37.0b	1542.8c
4.1g	37.5de	24.0d	64.4a	13.5c	35.6b	1664.2bc
5.4g	50cd	32.5c	65.0a	17.5c	35.0b	1917.8a
6.8g	56.0c	35.8bc	64.1a	20.3bc	35.9b	1853.3a
8.1g	72.8b	42.3ab	58.2ab	30.5b	41.8ab	1835.8ab
10.8g	104.5a	49.0a	47.1b	55.5a	52.9a	1576.7c
CV (%)	9.90	10.30	10.12	22.30	15.35	4.80
SE	5.50	2.40	1.71	3.40	1.71	33.50
F Value	97.37	50.62	5.11	38.26	5.11	14.57
P Value	<.0001	<.0001	0.0043	<.0001	0.0043	<.0001

Means within a column followed by the same letter(s) do not differ significantly at P=0.05 level of probability (HSD).

Increasing plant density to appropriate rate is important in insect pest population management in *B. carinata*. Dosdall *et al*. (1996) recommended that plant densities of approximately 200 plants/ m^2, which corresponds to increasing the seeding rate of canola to 7 kg/ ha from the presently recommended rate of 4 to 5 kg/ ha, could improve the control strategy of the root maggots *D. radicum* and *D. oralis.* The present study showed that as seed rate increased, the mean number of survived plant population increased and maximum number was detected in highest seed rate. Plant population reduction is also increased from the lowest seed rate to the highest seed rate. This might be due to an increased number of emerged plants from the lowest seed rate to the highest seed rates and intraspecific competition for the limited resources.

Crop seed rate can impact levels of infestation and yield loss from insect pests (Litsinger *et al*. 2003; Desdall and Stevenson, 2005). The yield showed significant difference and maximum for plots with seed rate of 5.4g. The plots with lowest seed rate were low yielder which agrees with the reports of Stout *et al*. (2009) which suggested that weevil-infested rice at low seeding rates may sometimes suffer proportionately higher yield losses than weevil-infested rice at high seeding rates, even when infestation levels do not differ. For seed rates beyond the recommended one, the yield was reduced and this agrees with Stout *et al. (*2009). Their data indicated that increasing seeding rates beyond recommended rates (“over seeding”) is likely to have little economic benefit and the reason may be intraspecific competition between crop plants. Due to pest attack and higher intraspecific competition, plant mortality could be high. When mortality is high, plants in these stands cannot compensate enough to maintain yield (Johnson and Hanson, 2003). Brassica plants with seed rates beyond the rates are likely to be weaker and not to have many branches and with productive pods.

4.4. Screening of Insecticides

4.4.1 Flea beetle population

The mean number of flea beetles present at primordial to matured leaf stages is presented in Table10. The maximum mean number of flea beetles was recorded in the untreated control from primordial to the second true leaf stages ($P<.0001$). Plots sprayed with recommended rates of Carbaryl and Malathion had relatively higher mean number of flea beetles than the other treated plots. No significant difference was observed in mean number of flea beetles between the two rates of Fenitrothion and no beetle was detected in the higher rate treated plots ($P<.0001$). During the second pre-treatment count beetles were highest in control check plots and less ($F = 69.8$, $P<.0001$) in plots treated with twice the recommended rate of Carbaryl, the two Fenitrothion rates and twice the recommended rate of Malathion. After the third application no significant difference ($F = 292.39$, $P<.0001$) was observed among all the treated plots in mean number of flea beetles except plots treated with the recommended rate of Malathion and maximum number was detected in control check plots. Starting from the vegetative stage to the maturity stage, the mean number of flea beetles showed no significant difference among all the plots of the study.

Table 10: Mean (± SE) number of flea beetle on *B. carinata* per 1m row of plots treated with different chemicals, rates and control check during different stages

	Seedling								
CHEM	Pre TRT1	Post TRT1	Pre TRT2	Post TRT2	Pre TRT3	Post TRT3	Vegeta tive	Flow ering	Matur ed
Carb. 1X	4.5ab	2.5b	6.5c	2.5b	5.0c	1.5bc	5.3a	2.5a	1.8a
Carb. 2X	4.3ab	0.3c	1.8d	0.8c	3.5cd	0.5bc	4.3a	2.0a	1.8a
Fenit. 1X	3.5b	0.8c	2.0d	0.5c	2.3d	0.5bc	5.0a	2.0a	1.8a
Fenit. 2X	5.0a	0.0c	3.0d	0.0c	3.5cd	0.3c	5.0a	2.0a	1.3a
Mala. 1X	5.5a	2.3b	10.5b	2.8b	9.3b	2.3b	6.5a	2.3a	2.0a
Mala. 2X	3.5b	0.8c	3.0d	0.8c	3.8cd	0.8bc	5.0a	2.0a	2.0a
Control	4.3ab	6.0a	13.5a	16.0a	19.5a	19.0a	5.8a	2.0a	1.2a
CV (%)	13.70	29.90	19.30	21.00	12.80	22.80	20.00	44.1	38.9
	(6.20)	(14.20)	(9.50)	(12.60)	(6.80)	(14.80)	(8.90)	(18.30)	(16.90)
SE	0.16	0.38	0.84	1.02	1.09	1.26	0.22	0.15	0.12
	(0.04)	(0.12)	(0.16)	(0.21)	(0.18)	(0.23)	(0.04)	(0.05)	(0.05)
F Value	6.03	61.08	69.8	264.93	204	292.39	1.81	0.07	0.54
	(6.07)	(42.68)	(63.47)	(123.68)	(129.83)	(114.8)	(1.82)	(0.05)	(0.64)
P Value	0.0009	<.0001	<.0001	<.0001	<.0001	<.0001	0.1464	0.998	0.773
	0.0008)	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(0.145)	(0.999)	(0.694)

TRT= Treatment, CV (%), SE, P Value and F value in parenthesis correspond to the transformed data. Columns sharing similar letter(s) are not significantly different at P= 0.05 level of probability (HSD).

The comparison among insecticide treatments and the untreated control accounted for most of the total variation of flea beetle number. The higher rate of Carbaryl reduced the number of flea beetles when compared with the lower rate. Weiss *et al*. (1991) investigated that Carbaryl was an effective insecticide against *Phyllotreta cruciferae.* The two rates of Fenitrothion were not statistically different and reduced the number of beetles to null in the higher rate. The number of flea beetles was significantly declined in plots treated with the higher rate of Malathion when compared with its lower rate. In comparison of all the treated plots, the recommended rates of Carbaryl and Malathion had significantly higher mean number of flea beetles than the other treated plots. Flea beetles were found higher in control check plots consistently from primordial leaf stage to the second leaf stage. This result reveals that as the rate of chemicals increased, the number of surviving insects or arrivers decreased and repeated spray of the chemicals suppressed the pests. Application of insecticides showed a reduction in number of flea beetles.

4.4.2. Flea beetle damaged plants

The mean number of damaged plants is presented in Table 11. Variations were detected in flea beetle damage to the *B. carinata* after treated with different chemicals at two different rates. Before the chemicals were sprayed there was no significant (F= 1.42, P= 0.2542) difference in the damaged plants present in each plot. After spraying the insecticides, there was a significant difference (F= 7.6, P= 0.0002) between the sprayed plots and unsprayed plots although the plots sprayed with the recommended rate of Malathion was not significantly different from the control after the first and before the third spray applications. Plots sprayed with Fenitrothion at twice the recommended rate were well protected from flea beetle damage but the insecticide caused phytotoxicity to the crop. It took more than a week for the pesticide damaged plants to recover. Flea beetle related plant damage was reduced from the first to the third treatments. So spraying showed a significant reduction in flea beetle damage (P=<.0001) compared with the untreated control. The maximum mean number of flea beetle feeding damage to *B. carinata* was detected in plots of untreated checks. Among the treated plots, those plots treated with producers recommended rate sustained higher damage than those treated with the higher rates. From vegetative stages onwards the mean number of flea beetle damage showed no significant (F=0.54, P = 0.7721, F= 0.58, P = 0.7391 and F=0.34, P = 0.91) difference for all treated and untreated plots.

Table 11: Mean (± SE) number of flea beetle damage to *B. carinata* per 1m length row treated with different chemicals, rate and control check at different stages

	Seedling								
CHEM	Pre TRT1	Post TRT1	Pre TRT2	Post TRT2	Pre TRT3	Post TRT3	Vegeta Tive	Flowe Ring	Matu Red
Carb. 1X	18.3°	22.0ab	16.3c	19.3c	16.3bc	19.3c	17.0a	6.8a	2.0a
Carb. 2X	14.0a	14.0c	9.0e	9.0e	10.8c	11.0e	16.5a	5.8a	2.0a
Fenit. 1X	16.5°	16.8bc	10.5de	11.5de	15.3bc	16.8cd	15.8a	6.0a	2.0a
Fenit. 2X	15.0a	15.3bc	7.8e	7.8e	10.3c	10.3e	15.5a	7.0a	1.8a
Mala. 1X	15.8°	20.3abc	21.5b	24.3b	21.3ab	24.0b	16.8a	6.8a	2.8a
Mala. 2X	13.8°	15.5bc	13.8cd	15.3cd	13.8c	14.3de	16.8a	6.5a	1.8a
Control	18.3°	25.8a	32.0a	37.8a	26.8a	34.5a	18.8a	6.5a	2.0a
CV (%)	19.5	16.8	10.3	9.9	17.9	10.4	10.2	17.9	57.0
	(9.4)	(8.3)	(5.0)	(4.8)	(8.5)	(5.2)	(5.0)	(8.4)	(23.0)
SE	0.60	0.90	1.50	1.90	1.20	1.50	0.30	0.20	0.20
	(0.08)	(0.11)	(0.18)	(0.21)	(0.14)	(0.17)	(0.04)	(0.04)	(0.06)
F Value	1.42	7.6	109.13	144.07	16.3	77.58	0.5	0.6	0.34
	(1.4)	(7.3)	(104.0)	(138.32)	(16.2)	(68.8)	(0.5)	(0.6)	(0.3)
P Value	0.25	0.0002	<.0001	<.0001	<.0001	<.0001	0.77	0.73	0.91
	0.25	(0.00030	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(0.77)	(0.74)	(0.93)

TRT= Treatment, CV (%), SE, P Value and F value in parenthesis correspond to the transformed data. Columns sharing the same letter(s) are not different at P= 0.05 level of probability (HSD).

The application of insecticides resulted in to a significant reduction of flea beetle population and hence reduction of plant damage. All the sprayed plots were statistically different from the control and less damaged. This result is agreed with Knodel *et al*. (2005). They reported that during the control of crucifer flea beetle in canola, all insecticide treatments had a significantly lower injury rating compared to the untreated check, during. Kinoshita, *et al*. (1978) also reported a significant reduction of crucifer flea beetle damage to radishes after the application of two sprays of Parathion, Carbaryl, or Endosulfan in the early part of the growing season under moderate insect pressure.

The result of this study revealed that irrespective of the type of insecticide used, as the rate increased, the plant was well protected from flea beetle injury and this result has agreed with that of Olson *et al.* (2006). Their investigation showed that the high rate of insecticide seed treatments had a lower injury rating compared to the higher injury rating for the low rate of insecticide seed treatments. Inline to this, Knodel *et al*. (2008) reported that seeds treated with higher rate insecticides were well protected from flea beetle damage than the seeds treated with lower rates of insecticides and untreated check. Increasing the rate of Fenitrothion caused phytotoxicity to the plant eventhough it resulted to a more declination of mean number of flea beetle damage. Farmoz (2008) reported that Fenitrothion has been known to be phytotoxic to cotton, Brassica crops, and certain fruit crops when high rates were applied

4.4.3. Emerged seedlings, productive plant stalks, plant population reduction and yield

The mean number of emerged seedlings, productive stalks and plant population reduction are listed in Table 12. The mean number of emerged seedlings revealed variation but statistically no significant difference observed. Maximum mean number of productive stalks was recorded from plots sprayed with the recommended rate of Fenitrothion. The minimum mean number was detected in untreated plots, which was significantly different from all treated plots ($F= 12.35$, $P<.0001$) except the recommended rate of Malathion. Plant population reduction was significantly ($F= 23.86$, $P<.0001$) lower in plots treated with the recommended rate of Fenitrothion and the twice recommended rate of Carbaryl whereas it was significantly higher for the control plots.

Higher percent (90.50% and 92.20%) of plants were survived in plots sprayed with twice recommended of Carbaryl and recommended rate of Fenitrothion, respectively and treatment effect was less (68.10%) in plots treated with recommended rate of Malathion and in plots of control check the percentage of survived plant population was (61.10%) (Table12). Highest percent of plant population reduction (38.30%) was detected in plots of the control whereas it was lower (9.50% and 7.80%) in plots sprayed with the twice recommended rate of Carbaryl and recommended rate of Fenitrothion, respectively.

Concerning seed yield there was observed substantial variation among the different chemicals. In plots treated with the recommended rate of Fenitrothion there was recorded maximum mean seed yield but there was no statistically significant difference (F= 2.53, P=.0527) for all treated and untreated plots.

Table 12: The mean (±SE) emerged seedlings, productive stalks, plant population reduction per 1m row and yield (kg/ha) per $3m^2$ area of *B. carinata*

CHEM	Number of Emerged Seedlings	Number of Productive Stalks	Productive Stalks (%)	Number of Plant Reduction	Plant Reduction (%)	Seed Yield (kg/ha)
Carb. 1X	53.5a	39.3bc	73.5bc	14.8ab	26.5bc	2023.5a
Carb. 2X	44.8a	40.5b	90.5a	4.3d	9.5d	2238.3a
Fenit. 1X	53.5a	49.5a	92.2a	4.0d	7.8d	2258.0a
Fenit. 2X	51.3a	40bc	78.1b	11.3bc	21.9c	2093.1a
Mala. 1X	46.3a	31.3cd	68.1bc	15.0ab	31.2ab	1924.2a
Mala. 2X	46.8°	38.3bc	79.0b	8.5cd	21.0c	2113.3a
Control	47.0a	29.0d	61.7c	18.0a	38.3a	1890.8a
CV (%)	9.01	9.98	6.32	20.63	17.39	8.6
	(4.44)	(4.97)	--	(9.41)	--	(4.26)
SE	0.98	1.35	2.08	1.03	2.1	39.08
	(0.07)	(0.11)	--	(0.16)	--	(0.43)
F Value	2.75	12.35	19.08	23.86	34.25	2.53
	(2.79)	(12.31)	---	(31.32)	---	(2.55)
P Value	0.0394	<.0001	<.0001	<.0001	<.0001	0.0527
	(0.037)	(<.0001)		(<.0001)		(0.0516)

CV (%), SE, P Value and F value in parenthesis correspond to the transformed data. Columns sharing the same letter(s) are not different at P= 0.05 05 level of probability (HSD).

The percentage of productive plants is higher for plants sprayed with higher rate of Carbaryl and lower rate of Fenitrothion, respectively and minimum for unsprayed plots. This result agrees with the report of Brown *et al.* (2004). Their investigation shows that significantly fewer *B. napus*, *B. rapa*, and *B. juncea* seedlings survived when no insecticides were applied in comparison with the treated plots. Soroka *et al*., (2008) found that there was a consistent pattern of increased plant density with increased ratio of insecticide-coated seed. Plant population reduction was inversely proportional to productive plants of the plots. Use of an insecticide treatment either as a seed treatment or foliar insecticide seemed to positively affect crop development of canola due to suppression of flea beetle feeding injury (Brown *et al.* 2004).

This study showed a variation in yield of *B. carinata* sprayed with different insecticides with two rates but statistically not significantly different. This non-significant variation is might be due to the moderate flea beetles infestation in the season of the study. This has agreed with report of Knodel *et al*. (2005). They have reported that the reduced flea beetle pressures were partially attributed to the lack of yield differences among treatments. Hummel et *al.* (2009) also reported similar results. According to their report, although the neonicotinoid seed treatment reduced flea beetle herbivory to canola compared to levels in untreated plots, it had little effect on crop grain, suggesting that flea beetle damage was insufficient to cause significant yield losses to the canola. In contrast to this, Brown *et al.* (2004) found that yields from untreated control plants were significantly lower than yields when insecticides were applied against *Phyllotreta cruciferae* for three *Brassica Spp.* namely *B. rapa*, *B. juncea*, and *Sinapis alba*. Yield was higher in all treated plots except in plots treated with lower rate of Malathion. The difference between the mean number of yield from plots treated with the recommended rate of Fenitrothion and untreated ones is 367.2kg/ha. Antwi *et al.* (2007) found that yields were always greater for chemical insecticide treatments compared with SpinTor, with differences being the smallest (68-374 kg/ha) at low levels of flea beetle feeding injury, and greatest (775-1,364 kg/ha) when canola seedling injury was high.

Applications of insecticide affect positively the plant to which it is applied on. Different research results revealed this. For example; Shah *et al*. (2008) reported that application of insecticides on mustard influenced plant height, branches per plant, pods per plant, pod length, seeds per pod and seed yield significantly as compared to control in Bangladesh and Brown *et al*., (1999) found significant increase in pods per plant and seed yield in insecticides treated plots as compared to untreated plots on late sown *S. alba B. juncea*, *B. napus* and *B. rapa* in USA. Similarly, Razaq *et al.* (2011) reported that application of insecticides significantly increased plant height of *B. carinata.*

The result of the present study revealed that plots treated with higher rate of Carbaryl and Malathion showed higher yield than their respective lower rates eventhough statistically they were not different. This is similar with the reports made by Brown *et al.* (2004) that insecticide seed treatments at the higher rate, were more efficacious and resulted in greater yields than that of low rate of insecticide seed treatments. It has also agreed with what was reported by Olson *et al.* (2006). Their finding was indicated that higher rates of insecticide seed treatment products generally had a higher yield than the lower rates.

Some times, increasing pesticide rate may become toxic to the plant itself as the higher rate of Fenitrothion in the present study. Plots treated with higher rate of Fenitrothion showed yellowing and necrosis of the foliage. Phytotoxicity of insecticides can be manifested mainly by distortions, scorches, yellowing and necrosis of the foliage or global wilt, thus, causing a decline in yield (Diallo, 1986). The pesticides also affect the microbial population of the soil even though microorganisms are responsible for most of the degradation of pesticides in the soil (Glover-Amengor and Tetteh, 2008). All the applied insecticides revealed as effective control measures against flea beetle when the right rates used at the right time of application. Dosdall *et al.*, (1999), stated that the only widely utilized control practice for flea beetles on canola is the application of Organophosphate, Carbamate, or Organochlorine insecticides as seed treatments or foliar sprays.

4.4.4. Correlation of flea beetle population and the damage caused to the plant

The correlation between plant damage and flea beetle was investigated at different stages of plant growth and summarized as in Table 13. Before the first spray, there was no significant correlation between plant damage and the mean number of flea beetles. Strong positive and significant correlation ($r = 0.7585$, $P = <.0001$) was detected at primordial stage after the first spray. The correlation was very strongly positive and significant at before and after the second spray counts ($r = 0.9340, 0.9069$, $P = <.0001$), respectively. For the third pre and post spray counts, significant and strong positive correlation ($r = 0.8500, 0.8447$, $P = <.0001$) was depicted between the mean number of damaged plants and flea beetles. At vegetative and flowering stages the correlation is also positive but weak and non significant ($r = 0.279, 0.168$; $P = 0.1507, 0.3933$) respectively. At matured stage significant positive and weak correlation was found between damaged plants and flea beetles recorded (r = 0.4420, P = 0.0185).

Table 13: Correlation coefficients index between flea beetles and damaged plants at different growth stages of the plant

	Damaged plants								
Beetle Count	Pre TRT 1	Post TRT1	Pre TRT2	Post TRT2	Pre TRT3	Post TRT3	Veget ative	Flower ing	Mature d
Pre TRT1	0.14	0.409	0.395	0.342	0.297	0.315	0.395	0.016	0.044
Post TRT1		0.759**	0.768	0.696	0.688	0.652	0.533	0.017	0.030
Pre TRT2			0.934**	0.904	0.942	0.873	0.448	0.052	0.195
Post TRT2				0.907**	0.94	0.873	0.449	0.083	0.164
Pre TRT3					0.850**	0.758	0.549	0.144	0.171
Post TRT3						0.845**	0.472	0.06	0.119
Vegetative							0.279	0.258	0.368
Flowering								0.168	0.273
Matured									0.442*

TRT=Treatment, *, ** Indicate significance at 0.05 and 0.01 probability levels, respectively.

4.4.5. Correlation of flea beetle with productive plants, plant population reduction and seed yield

Before the first treatment there was weak negative and non significant correlation (r =-0.347, P = 0.07) between number of productive plants and number of flea beetles and after the first spray significant negative correlation was detected (Table 14). For the second pre and post treatment application, significant negative correlation was detected (r = -0.730, -0.620; P = <.0001, 0.0004) (Table 14). For the third pre and post treatment application, significant negative correlations (r = -0.730, -0.598; P <.0001, 0.0008) were detected between the number of productive plants and number of flea beetles respectively. The number of productive plants was also negatively associated with flea beetle population and the association was weak and not significant from vegetative stage onward.

Flea beetle populations from primordial leaf stage to second true leaf stage were revealed significant positive correlation with plant population reduction. At vegetative stage, the correlation was weak (r= 0.4609) but significant and at the rest stages it was not significant. Seed yield of *B. carinata* was negatively associated with flea beetle population at different stages. Negative significant association was detected between mean number of flea beetles and seed yield of *B. carinata* from pretreatment one to vegetative stage but the association was weak (Table 14).

Table 14: Correlation coefficients of flea beetles with productive stalks, plant population reduction and yield

	Flea beetles								
	Pre TRT1	Post TRT1	Pre TRT2	Post TRT2	Pre TRT3	Post TRT3	Vegeta Tive	Floweri ng	Matur ed
MNOPS	-0.347	-0.609**	-0.730**	-0.620**	-0.730**	-0.598**	-0.361	-0.117	-0.090
MNOPR	0.502*	0.704**	0.845**	0.651**	0.730**	0.596**	0.461*	0.187	0.087
Yield	-0.448*	-0.584**	-0.631**	-0.468*	-0.561**	-0.419*	-0.351*	-0.393	-0.207

TRT= treatment, MNOPS= mean number of productive stalks, MNOPR= mean number of plant reduction*, ** Indicate significance at 0.05 and 0.01 probability levels respectively.

4.4.6. Correlation of flea beetle damage to Brassica to productive plants, plant population reduction and seed yield

Number of productive stalks was negatively associated with flea beetle damage to Brassica. For the first treatment, it was not significant but for the rest two treatments it was significant (Table 15). Correlation was not significant for vegetative, flowering and matured stages. The correlation between plant population reduction and damaged plants was positive. Before the first treatment it was weak but significant. From treatment one to the third treatment, it was strong and significant. Yield was significantly associated with flea beetle damage to the plant. Negative significant correlation was detected from the first spray to the third spray. The correlation was weak and not significant at vegetative and flowering stages but significant and weak correlation was detected at matured stage.

Table 15: Correlation coefficients of damaged plants, productive stalks, plant population reduction and seed yield

	Flea beetle damage								
	Pre TRT1	Post TRT1	Pre TRT2	Post TRT2	Pre TRT3	Post TRT3	Vegetative	Flowering	Matured
PS	0.0295	-0.3742	-0.7287**	-0.7074**	-0.5263**	-0.5577**	-0.0752	-0.1882	-0.1218
PR	0.3896*	0.7022**	0.7716**	0.7657**	0.6402**	0.6798**	0.3486	0.2897	0.2799
Yield	-0.3138	-0.4928**	-0.5676**	-0.5846**	-0.6011**	-0.5198**	-0.3341	-0.2132	-0.5265**

TRT=Treatment , PS=Plant stalk, PR=Plant reduction, *, ** Indicate significance at 0.05 and 0.01 probability respectively.

4.4.7. Correlation of productive plants, plant population reduction and seed yield of *B. carinata*

An association was detected among number of productive plants, plant population reduction and yield. The result is summarized in Table 16. Productive plants showed negative significant ($r = -0.6920$; $P < .0001$) correlation with plant population reduction. Yield of the plant depicted positive correlation with productive plant population ($r = 0.5497$; $P = 0.0024$) and it also shown significant negative correlation ($r = -0.6908$; $P < .0001$) with plant population reduction.

Table 16: Correlation coefficients of productive stalks, plant population reduction and seed yield

	Plant Reduction	Yield
Productive Stalks	-0.6920**	0.5497**
Plant Reduction		-0.6908**

** Indicates significance at 0.01 probability level.

Number of flea beetles directly associated with plant damage. Plants with less number of flea beetles were less damaged. Knodel *et al.,* (2005), investigated that percent injured plants were directly influenced by insecticide Treatments. The present study shows that the number of productive plants was inversely proportional to the number of flea beetles and plant damage. When the number of flea beetles in the plots increased, plant damage level increased hence resulted in less number of surviving plants. The mean number of holes per plant on a given sample date and the mean proportion of beetles captured by the yellow sticky traps were strongly correlated (Andersen, *et al,* 2005). During the vegetative and the next stages the association was weak, which might have been be due to the small number of flea beetles hence less damage to the crop occurred. Direct association was detected between the number of flea beetles and plant population reduction. Higher number of flea beetles causes more plant reduction than lower number of flea beetles. Flea beetle density affects the yield of the plant negatively and yield was relatively correlated weakly to flea beetle population and the damage they caused. The number of productive plants was positively associated with yield and negatively associated with plant population reduction. Seed yields were inversely proportional to flea beetle feeding levels (Soroka *et al.,* 2008).

5. SUMMARY AND CONCLUSION

The information gathered here and the results obtained throughout this research will be useful for further researches which will be conducted in the future relating to this. This study has shown that cabbage flea beetle is a common insect pest of *B. carinata* in Arsi Zone.

Beetles appear early on seedlings at the primordial stage, attained peak population level at first true leaf stage and started declines after second true leaf stage. The reduction of the number and damage sustained to plants after the second true leaf stage is an indication of flea beetles are important at the early seedling stage of the plant hence management measures should start at early this stage based on the pest's population status. Previously flea beetles were considered as pests of seedling stage and most of the time their management targeted this stage. But during this study, severe flea beetle infestation on the pods of late planted *B. carinata* has been observed during this study.

Variation in yield among the different seed rates has been found indicating that choosing seed rate is important to compensate in the seedling reduction caused by flea beetle damage. The recommended seed rate of 10kg/ha provided the highest yield of *B. carinata*.

Spraying of the three insecticides showed good efficacy in controlling the pest and rate of the chemicals sprayed should be considered to get good return from their application. If they are applied in less or higher rates of their effective rates, the application is loss or the net return will be less. Fenitrothion at producers recommended rate, Carbaryl and Malathion at twice the recommended rate reduced flea beetle infestation and increased the yield in comparison with the untreated control.

- This study is not fully describing the current status of cabbage flea beetles because of the limitation of time and finance. Since flea beetle dynamics is not only varying spatially but also temporally (seasonally), additional research should be conducted in order to get better understanding of the population dynamics of cabbage flea beetle.

- Continuous monitoring activity should be done to prevent yield loss by high infestation of beetles since their population increase suddenly based on the presence of suitable conditions. Significant pod infestation has been observed hence monitoring of flea beetles on *B. carinata* in the future should involve pod setting stage.

- Seed rate of 10kg/ha is optimum to be used by farmers to reduce yield loss due to flea beetles.

- Among the tested insecticides the recommended rate of Fentirothion can be used for the management of beetles.

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7. APPENDICES

1. On farm Monitoring of cabbage flea beetles on *B. carinata*

Appendix 1: To show ANOVA table of emerged Seedlings

Source of variations	Degree of freedom	Sum of Squares	Mean square	F ratio	P value
Model	8	12211	1526.37	12.07	<.0001
Error	36	4553.6	126.489		
Corrected Total	44	16764.6			
CV (%)	5.8026				

Appendix 2: To show ANOVA table of damaged plants at primordial stage

Source of variations	Degree of freedom	Sum of Squares	Mean square	F ratio	P value
Model	8	12372.98	1546.62	15.11	<.0001
Error	36	3684.00	102.33		
Corrected Total	44	16056.98			
CV (%)	10.37				

Appendix 3: To show ANOVA table of damaged plants at first true leaf stage

Source of variations	Degree of freedom	Sum of Squares	Mean square	F ratio	P value
Model	8	7448.04	931.01	9.84	<.0001
Error	36	3405.20	94.59		
Corrected Total	44	10853.24			
CV (%)	5.94				

Appendix 4: To show ANOVA table of damaged plants at second true leaf stage

Source of variations	Degree of freedom	Sum of Squares	Mean square	F ratio	P value
Model	8	12317.64	1539.71	5.9	<.0001
Error	36	9390.80	260.86		
Corrected Total	44	21708.44			
CV (%)	11.38				

Appendix 5 : To show ANOVA table of flea beetles at primordial stage

Source of variations	Degree of freedom	Sum of Squares	Mean square	F ratio	P value
Model	8	779.91	97.49	5.12	0.0003
Error	36	686.00	19.06		
Corrected Total	44	1465.91			
CV (%)	17.57				

Appendix 6: To show ANOVA table of flea beetles at first true leaf stage

Source of variations	Degree of freedom	Sum of Squares	Mean square	F ratio	P value
Model	8	693.91	86.74	4.2	0.0012
Error	36	743.20	20.64		
Corrected Total	44	1437.11			
CV (%)	13.19				

Appendix 7: To show ANOVA table of flea beetles at second true leaf stage

Source of variations	Degree of freedom	Sum of Squares	Mean square	F ratio	P value
Model	8	700.58	87.57	6.18	<.0001
Error	36	510.00	14.17		
Corrected Total	44	1210.58			
CV(%)	12.07				

Appendix 8: To show ANOVA table of mean productive plant stalks

Source of variations	Degree of freedom	Sum of Squares	Mean square	F ratio	P value
Model	8	9013.24	1126.66	6.79	<.0001
Error	36	5972	165.89		
Corrected Total	44	14985.24			
CV (%)	9.72				

Appendix 9: To show ANOVA table of mean plant reduction

Source of variations	Degree of freedom	Sum of Squares	Mean square	F ratio	P value
Model	8	3564.31	445.54	3.33	0.0059
Error	36	4814.80	133.74		
Corrected Total	44	8379.11			
CV (%)	18.79				

Appendix 10: To show ANOVA table of plant reduction percent of productive plant stalks

Source of variations	Degree of freedom	Sum of Squares	Mean square	F ratio	P value
Model	8	628.49	78.56	2.55	0.0259
Error	36	1108.50	30.79		
Corrected Total	44	1737.00			
CV (%)	8.12				

Appendix 11: To show ANOVA table of plant reduction percent of plant reduction

Source of variations	Degree of freedom	Sum of Squares	Mean square	F ratio	P value
Model	8	600.44	75.06	2.41	0.0342
Error	36	1123.42	31.21		
Corrected Total	44	1723.86			
CV(%)	17.74				

Appendix 12: To Show ANOVA table of the correlation of plant damage with flea beetle

	DPPS	DPFTLS	DPSTLS	PS	PR	FBPPS	FBFLS	FBSTLS
DPPS	1	0.776	0.732	0.119	0.665	0.567	0.560	0.308
		<.0001	<.0001	0.4356	<.0001	<.0001	<.0001	0.0395
DPFTLS		1	0.813	0.267	0.604	0.488	0.349	0.222
			<.0001	0.0757	<.0001	0.0007	0.0189	0.1429
DPSTLS			1	-0.004	0.519	0.530	0.521	0.413
				0.9779	0.0003	0.0002	0.0002	0.0048
PS				1	-0.302	-0.441	-0.423	-0.447
					0.0434	0.0024	0.0038	0.0021
PR					1	0.613	0.479	0.394
						<.0001	0.0009	0.0074
FBPPS						1	0.730	0.560
							<.0001	<.0001
FBFLS							1	0.607
								<.0001
FBSTLS								1

2. Monitoring of Cabbage Flea Beetles on *B. carinata*

Appendix 13: To show ANOVA table of damaged plants at primordial stage

Source of variations	Degree of freedom	Sum of Squares	Mean square	F ratio	P value
Model	5	4917.98	983.60	179.21	<.0001
Error	18	98.79	5.49		
Corrected Total	23	5016.77			
CV (%)	10.66				

Appendix 14: To Show ANOVA table of damaged plants at first true leaf stage

Source of variations	Degree of freedom	Sum of Squares	Mean square	F ratio	P value
Model	5	877.20	175.44	35.64	<.0001
Error	18	88.60	4.92		
Corrected Total	23	965.80			
CV (%)	24.06				

3. The Effect of Seed Rate on reducing the Damaging Effect of Cabbage Flea Beetle

Appendix 15: To show ANOVA table of percent damaged plants at primordial stage, first true leaf stage, second true leaf stage, vegetative, flowering and matured stages

Plant Growth Stage	Source of variations	Degree of freedom	Sum of Squares	Mean square	F ratio	P value
	Model e	5	1088.04	217.61	3.37	0.0253
	Error	18	1161.39	64.52		
	Corrected Total	23	2249.43			
Primordial	CV (%)	19.21				
	Model	5	5380.47	1076.09	17.72	<.0001
	Error	18	1092.80	60.71		
	Corrected Total	23	6473.26			
FTLS	CV (%)	10.90				
	Model	5	4018.49	803.70	6.78	0.001
	Error	18	2134.65	118.59		
	Corrected Total	23	6153.14			
STLS	CV (%)	17.07				
	Model	5	1687.54	337.51	8.54	0.0003
	Error	18	711.40	39.52		
	Corrected Total	23	2398.95			
VS	CV (%)	17.17				
	Model	5	461.04	92.21	9.99	0.0001
	Error	18	166.17	9.23		
	Corrected Total	23	627.21			
FS	CV (%)	26.25				
	Model	5	90.86	18.17	4.17	0.0108
	Error	18	78.39	4.36		
	Corrected Total	23	169.25			
MS	CV (%)	49.89				

Appendix 16: To show ANOVA table of mean number of flea beetles at primordial stage, first true leaf stage, second true leaf stage, vegetative, flowering and matured stages and emerged seedlings, productive stalks, yield

Plant Growth Stage	Source of variations	Degree of freedom	Sum of Squares	Mean square	F ratio	P value
	Model	5	15890.33	3178.07	97.37	<.0001
	Error	18	587.5	32.64		
	Corrected Total	23	16477.83			
ES	CV (%)	9.921				
	Model	5	2945.83	589.17	50.62	<.0001
	Error	18	209.5	11.64		
	Corrected Total	23	3155.33			
PS	CV (%)	10.29				
	Model	5	951.73	190.35	5.11	0.0043
	Error	18	670.9	37.27		
	Corrected Total	23	1622.62			
PPS	CV (%)	10.12				
	Model	5	498106.83	99621.37	14.57	<.0001
	Error	18	123078.67	6837.7		
	Corrected Total	23	621185.5			
YLD	CV (%)	4.77				
	Model	5	6.83	1.37	1.29	0.3096
	Error	18	19	1.06		
	Corrected Total	23	25.83			
FBPS	CV (%)	16.89				
	Model	5	7.83	1.57	0.36	0.8665
	Error	18	77.5	4.31		
	Corrected Total	23	85.33			
FBFTS	CV (%)	13.11				
	Model	5	52.71	10.54	1.5	0.2381
	Error	18	126.25	7.01		
	Corrected Total	23	178.96			
FBSTS	CV (%)	16.86				

Plant Growth Stage	Source of variations	Degree of freedom	Sum of Squares	Mean square	F ratio	P value
	Model	5	4.21	0.84	0.44	0.8176
	Error	18	34.75	1.93		
FBVS	Corrected Total	23	38.96			

	CV (%)	27.56				
	Model	5	0.83	0.17	0.27	0.9221
	Error	18	11	0.61		
	Corrected Total	23	11.83			
FBFS	CV (%)	32.35				
	Model	5	1	0.2	0.33	0.8899
	Error	18	11	0.61		
	Corrected Total	23	12			
FBMS	CV (%)	52.12				

4. Screening Insecticides Against Cabbage Flea Beetles

Appendix 17: To show ANOVA table of mean and percentage of productive stalks, plant reduction and mean of seed yield

	Source of variations	Degree of freedom	Sum of Squares	Mean square	F ratio	P value
	Model	6	1081	180.17	12.35	<.0001
	Error	21	306.25	14.58		
	Corrected Total	27	1387.25			
PS	CV(%)	9.98				
	Model	6	704	117.33	23.86	<.0001
	Error	21	103.25	4.92		
	Corrected Total	27	807.25			
PR	CV(%)	20.63				
	Model	6	2704.58	450.76	18	<.0001
	Error	21	525.99	25.05		
	Corrected Total	27	3230.57			
PPS	CV(%)	6.4201				
	Model	6	3035.03	505.84	34.25	<.0001
	Error	21	310.14	14.77		
	Corrected Total	27	3345.17			
PPR	CV(%)	17.39				
	Model	6	484978.99	80829.83	2.53	0.053
	Error	21	670688.84	31937.56		
	Corrected Total	27	1155667.83			
YLD	CV(%)	8.60				

Appendix 18: To show ANOVA table of mean damaged plants at before and after the first, second and third spray, vegetative, flowering and matured stages

	Source of variations	Degree of freedom	Sum of Squares	Mean square	F ratio	P value
	Model	6	81.86	13.64	1.42	0.2542
	Error	21	202	9.62		
	Corrected Total	27	283.86			
DPPSB1	CV(%)	19.47				
	Model	6	443	73.83	7.6	0.0002
	Error	21	204	9.71		
	Corrected Total	27	647			
DPPSA1	CV(%)	16.847				
	Model	6	1753.86	292.31	109.13	<.0001
	Error	21	56.25	2.68		
	Corrected Total	27	1810.11			
DPFTLSB2	CV(%)	10.34				
	Model	6	1753.86	292.31	109.13	<.0001
	Error	21	56.25	2.68		
	Corrected Total	27	1810.11			
DPFTLSA2	CV(%)	10.34				
	Model	6	834.86	139.14	16.3	<.0001
	Error	21	179.25	8.54		
	Corrected Total	27	1014.11			
DPSTSB3	CV(%)	17.9				
	Model	6	1728.86	288.14	77.58	<.0001
	Error	21	78	3.71		
	Corrected Total	27	1806.86			
DPSTSA3	CV(%)	10.38				
	TRT	6	9.21	1.54	0.54	0.7721
DPVS	Error	21	59.75	2.85		
	Corrected Total	27	68.96			
DPFS	CV(%)	10.25				
	TRT	6	4.71	0.79	0.58	0.7391
DPFS	Error	21	28.25	1.35		
	Corrected Total	27	32.96			
DPMS	CV(%)	17.94				
	TRT	6	2.71	0.45	0.34	0.91
DPMS	Error	21	28.25	1.35		
	Corrected Total	27	30.96			
	CV(%)	56.97				

Appendix 19: To show ANOVA table of mean flea beetle at before and after the first, second and third spray, vegetative, flowering and matured stages

	Source of variations	Degree of freedom	Sum of Squares	Mean square	P value
	TRT	6	12.93	2.15	0.0009
	Error	21	7.5	0.36	
	Corrected Total	27	20.43		
FBPSB1	CV(%)	13.72			
	TRT	6	104.71	17.45	<.0001
	Error	21	6	0.29	
	Corrected Total	27	110.71		
FBPSA1	CV(%)	29.93			
	TRT	6	513.5	85.58	<.0001
	Error	21	25.75	1.23	
	Corrected Total	27	539.25		
FBFTLSB2	CV(%)	19.26			
	TRT	6	775.86	129.31	<.0001
	Error	21	10.25	0.49	
	Corrected Total	27	786.11		
FBFTLSA2	CV(%)	21.03			
	TRT	6	888.86	148.14	<.0001
	Error	21	15.25	0.73	
	Corrected Total	27	904.11		
FBSTLSB3	CV(%)	12.76			
	Farm	6	1190.43	198.4	<.0001
FBSTLSA3	Error	21	14.25	0.68	
	Corrected Total	27	1204.68		
	CV(%)	22.84			
	TRT	6	12	2	0.1464
FBVS	Error	21	23.25	1.11	
	Corrected Total	27	35.25		
	CV(%)	20.04			
	TRT	6	0.36	0.06	0.998
FBFS	Error	21	17.5	0.83	
	Corrected Total	27	17.86		
	CV(%)	44.07			
	TRT	6	1.5	0.25	0.773
FBMS	Error	21	9.75	0.46	
	Corrected Total	27	11.25		
	CV(%)	38.94			

Appendix 20: To show ANOVA table of damaged plants counts at different growth stages with productive plant stalks, plant reduction and yield

	DPPSB1	ATMT1	DPFT LSB2	ATMT2	DPSTL SB3	ATMT3	DPVS	DPFS	DPMS	PS	PR	Y
DPPSB1	1	0.810	0.361	0.374	0.434	0.478	0.243	0.123	0.225	0.029	0.390	-0.359
		<.0001	0.0592	0.0496	0.021	0.0101	0.2137	0.5319	0.25	0.8816	0.04	0.0607
ATMT1		1	0.745	0.763	0.764	0.820	0.211	0.079	0.152	-0.374	0.702	-0.542
			<.0001	<.0001	<.0001	<.0001	0.2819	0.6904	0.44	0.0498	<.0001	0.0029
DPFTL SB2			1	0.99	0.88	0.94	0.25	0.14	0.16	-0.73	0.77	-0.58
				<.0001	<.0001	<.0001	0.1995	0.4888	0.425	<.0001	<.0001	0.0011
ATMT2				1	0.91	0.96	0.22	0.18	0.16	-0.71	0.77	-0.58
					<.0001	<.0001	0.2562	0.3655	0.409	<.0001	<.0001	0.0013
DPST LSB3					1	0.95	0.14	0.09	0.14	-0.53	0.64	-0.59
						<.0001	0.4798	0.6415	0.462	0.004	2E-04	0.0009
ATMT3						1	0.15	0.07	0.12	-0.56	0.68	-0.51
							0.4582	0.7314	0.528	0.002	<.0001	0.0061
DPVS							1	0.15	0.40	-0.08	0.35	-0.40
								0.4583	0.034	0.7038	0.069	0.0333
DPFS								1	0.361	-0.188	0.29	-0.142
									0.059	0.3375	0.135	0.4717
DPMS									1	-0.122	0.28	-0.453
										0.5369	0.149	0.0156
PS										1	-0.69	0.5455
											<.0001	0.0027
PR											1	-0.708
												<.0001
YLD												1

Appendix 21: Woredas, farms, owner, farm size, surrounding crops and cultural management practices

Farm no.	Woreda	Owner	Farm size	Surrounding crops	Management Practice(s)
1	Lemu Bilbilo	Abera	60x86m	wheat, Grazing land and Brassica	no
2	Lemu Bilbilo	Jemal	92x108	Wheat, Brassica, wheat and barely	no
3	Lemu Bilbilo	Kemale	50x70	Grazing land, Bean and wheat	sowing date
4	Tiyo	Tadecha	68x90	Sesame, sorghum, grazing land and wheat	no
5	Tiyo	Solomon	95x80	wheat, bean, Brassica and wheat	sowing date
6	Tiyo	Bulbulo	50x65	grazing land and sesame	no
7	Hetosa	Kedir	80x90	road, wheat and barely	no
8	Hetosa	Ahimed	55x85	Bean, wheat, Brassica	crop rotation
9	Hetosa	Chala	70x80	road, barely ant wheat and pea	no

Appendix 22: Kulumsa and Bekoji monthly rainfall data (2011) in mm

Place	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Kulumsa	58.10	120.50	68.70	113.90	153.90	167.40	0.00	4.00	0.00	686.50
Bokoji	21.10	132.70	130.50	122.90	159.80	94.80	9.60	47.80	12.00	731.20

Appendix 23: Kulumsa and Bekoji monthly mean maximum temperature data (2011) in ^{o}c

Location	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kulumsa	23.90	22.20	21.00	21.20	23.26	22.90	22.70
Bekoji	18.40	16.10	16.80	16.30	19.00	19.30	18.00

Appendix 24: Kulumsa and Bokoji monthly mean minimum temperature data (2011) in ^{o}c

Location	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kulumsa	9.30	9.10	9.10	8.20	9.00	9.20	6.80
Bekoji	0.50	1.20	13.20	0.50	-5.10	-1.10	7.90