# Cabbage Flea Beetles, P*hyllotreta*spp (Coleoptera: Chrysomelidae) Management on Ethiopian Mustard, *Brassica carinata* A. Braun, in Arsi Zone, Oromia

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## Abstract

*The effect of varying seed rate and screening of insecticides were done in Kulumsa Agricultural Research Center by sowing Yellow Dodolla mustard in year 2011. The experiments were laid-out in a randomized complete block design (RCBD) with four replications. Two rows of 1m length were used for sampling of flea beetles and their damage. Yield was obtained from 1.5m x 2m area of each plot and expressed in kg/ha. 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 lowest to the highest seed rates for all phonological stages of the crop. Productive plants and plant population reduction were maximum for plots of the highest seed rate (10.8g) and minimum for the lowest (2.7g) seed rate. Maximum mean seed 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 reduced significantly the 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. 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.*

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

## Introduction

Ethiopia is one of the major centers of origin and diversity for several oil crops. Gomenzer (*Brassica carinata*), noug (*Guizotia abyssinica*), sesame (*Sesamum indicum*) and linseed (*Lensculinaris*) are the major, indigenous oil crops having considerable diversity in the country (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 $4^{th}$ to $5^{th}$ Millennia BC (Alemayehu and Becker, 2002; Mnzava and Schippers, 2007). These crops are primarily used as sources of cooking oil and export crops (Bayeh and Bayou, 2009). Nearly 0.8 million ha is covered with oilseed crops, which accounts for 8% of the total cultivated area (IBC, 2007). The Ethiopian mustard, *B. carinata* "***gomenzer***" is the third most important source of vegetable oil in the world (Kidd, 1993) as well in the highlands of Ethiopia next to niger seed and linseed.

Ethiopian mustard and the exotic rapeseed (*B. napus*) are widely cultivated as sources of cooking oil (Ethiopian Ministry of Agriculture, 2010; Fekadu, 2004). And the area as well as the production has increased between 1982 to 2003 by 575% and 1044%, respectively (CSA, 2003) and covered over 40,000 ha with a total production of over 35,000 tons in 2006 (IBC, 2007). Although one study in Canada reported an average yield which ranged from 2000kg to 3000kg per hectare (IENICA, 2004), CSA (2006/07) the national average yield of Ethiopian mustard was 950 kg/ha.

In Ethiopia demand for edible oils for local consumption has been increasing from time to time, but the current level of production could not meet such high demand. Thus, the price of edible oils is soaring high 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).

Regarding its production historically, *B. carinata* had been a backyard crop and it is quite recently that it became an open field crop and started playing an important role to the increase in farmers' income. 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 tons in 2007 and increased to 7,405 ha and 12,820 tons in 2012 (Agricultural Bureau of Arsi Zone, 2012, Personal Communication).

In Ethiopia the yield of oil crops in general is very low and it appears that lack of breakthrough in breeding, lack of improved crop management and diseases and insect pests are contributing to such low yield (Bayeh and Bayou, 2009). Globally Brassica cultivation has been threatened by pests throughout its cropping period (Mayoori and Mikunrhan, 2009). Thirteen insect pests are known to attack the crop in Ethiopia and the most serious ones include cabbage flea beetles, golden plusia, cabbage white, cabbage aphid and diamond-back moth (Kemale *et al.,* 1986; Anonymous, 1987). The flea beetle species *Phyllotreta mashonana* Jacob and *P. weisei* Jacob are major pests of the Ethiopian mustard and rapeseed, especially at the early seedling growth period (Tadesse and Bayeh, 2002; Bayeh and Biruk, 2008).

Flea beetles, *Phyllotreta* spp (Coleoptera: Chrysomelidae), are the major insect pests of Brassica worldwide. 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 *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).

Predators and parasites provide limited regulation of flea beetle populations (Wylie, 1984). Although there is some level of resistance in Ethiopian mustard to insect pests attack, all species may require to be sprayed against the major insect pests (Hiruy, 1987). Currently, the most effective control measure is the use of insecticides (Lamb and Turnock, 1982, Weiss *et al.*, 1991, Hazzard *et al.*, 2002; Trdan *et al.,* 2005). 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). Moreover, planting seeds coated with insecticide with systemic activity has been the most commonly used method of control the flea beetles *P. cruciferae* (Goeze) and *P. striolata* (Fabricius) in western North America (Tansey *et al.*, 2009). The significance of cultural practices such as varying seed rate might also help to reduce flea beetle damage by compensating for the lost seedlings due to flea beetles attack, but little is known about this. Therefore, considering that flea beetles are confirmed major insect pest of Brassica crops and the Brassica crop acreage in Ethiopia is on the increase (Bayeh and Biruk, 2008) and since predators and parasites are ineffective (Wylie, 1984), at present insecticides are the only viable option for controlling of the crucifer flea beetles (Hiiesaar *et al.,* 2003) but including seed rate as one practice might help to reduce flea beetle damage. Therefore, this study work was conducted to identify appropriate seed rate and effective insecticides and their respective rates to manage flea beetle on *Brassica carinata*.

## Materials and Methods

Field experiment was conducted at Kulumsa Agricultural Research Center (8°01'N latitude and 39°09'E longitude) in Arsi Zone Southeastern Ethiopia in 2011 cropping season (June- December). Arsi Zone is one of the oil seed Brassica growing areas in the country. The soil type of the center is luvisol/eutricnitosols with a good drainage system.

### Experiment 1: Effect of seed rate on the population of cabbage flea beetles

Yellow Dodolla was sown in 2m x 3m plots arranged in a randomized complete block design (RCBD) with four replications under field conditions to see whether there was compensation for lost seedling caused by cabbage flea beetles. The recommended seed rate of *B. carinata* in Arsi Zone is 10kg/ha. In this trial six different seed rates: 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, respectively) 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 leaf stage until the crop matured. At a time two rows of one meter length each were considered for data collection and finally the average was taken. The number of productive plants was counted after the crop was harvested by counting the rootstalks. Plant population reduction was determined by subtracting the productive plants 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.

### Experiment 2: Screening of insecticides for the control of flea beetles on *B. carinata*

Yellow Dodola was sown in rows on similar plot size as in experiment 1 to select an effective chemical insecticide(s) with an appropriate rate. Three insecticides: Fenitrothion, Malathion and Carbaryl were evaluated. The treatments were: (1) each insecticide applied at recommended rates (Fenitrothion 50% EC (1.5l/ha), Malathion 50% EC (2l/ha) and Carbaryl 85% WP (1kg/ha)), (2) each insecticide applied 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 starting before the insecticides were sprayed and 24 hours later, at primordial, at first true leaf, and at second true leaf stages, and at latter vegetative growth stage, at flowering and at maturity stages from the two marked 1m rows. Yield was taken from 1.5m x 2m area and expressed as kg per hectare.

## Data Analysis

The collected data were analyzed using *SAS (version 9.2)* software (SAS Institute Inc. 2008) and ANOVA procedure was used. In the seed rate experiment, 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. In the insecticide screening experiment, 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 rates 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. A significance level of 0.05 was used.

# Results and Discussions

## Experiment 1: Effect of seed rate on the population of cabbage flea beetles

### 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 1. There was no statistically significant difference in mean number of beetles among the six seed rates in all the assessed growth stages. The mean number of flea beetles present 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 1. Mean (±SE) number of cabbage flea beetle on *B. carinata* at primordial and subsequent leaf stages of the crop

| | Growth stages of gomenzer plant | | | | | |
|---|---|---|---|---|---|---|
| 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 significant difference among the six different seed rates in affecting the population density of the flea beetles. This result fully agree with 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.

## Flea beetle damaged *B. carinata*

Flea beetle damaged on *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 2). 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 2. Percentage of flea beetle damaged plants at primordial, first true leaf, second true leaf, vegetative, flowering and matured stages

| | Growth stages of gomenzer plant | | | | | |
|---|---|---|---|---|---|---|
| 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. Dosdall *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.

## Productive plants, plant population reduction and seed yield

The mean number of the productive stalks and consequent plant population reduction are summarized in Table 3. 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) for the lowest seed rate but in percent it was 47.10% and 63.00%, respectively. The absolute plant population reduction was maximum for the highest seed rate and minimum for the least seed rate but in percentage terms 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 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 of 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 3: Mean emerged seedlings, productive stalks, plant population reduction per 1m row length and yield per 3m² 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) who 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 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 recommended rates are likely to be weaker and not to have many branches and with productive pods.

## Experiment 2: Screening of insecticides for the control of flea beetles on *B. carinata*

### Flea beetle population

The mean number of flea beetles present at primordial to matured leaf stages is presented in Table 4a & b. 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 4a: Mean (± SE) number of flea beetle on *B. carinata* per 1m row of plots treated with different chemicals, rates and control check at different growth stages

| | Mean ±SE number of flea beetles at pre- and post-treatment | | | | | |
|---|---|---|---|---|---|---|
| Insecticide | Pre T 1 | Post T 1 | Pre T 2 | Post T 2 | Pre T 3 | Post T 3 |
| Carbaryl 1X | 4.5ab | 2.5b | 6.5c | 2.5b | 5.0c | 1.5bc |
| Carbaryl 2X | 4.3ab | 0.3c | 1.8d | 0.8c | 3.5cd | 0.5bc |
| Fenitrothion 1X | 3.5b | 0.8c | 2.0d | 0.5c | 2.3d | 0.5bc |
| Fenitrothion 2X | 5.0a | 0.0c | 3.0d | 0.0c | 3.5cd | 0.3c |
| Malathion 1X | 5.5a | 2.3b | 10.5b | 2.8b | 9.3b | 2.3b |
| Malathion 2X | 3.5b | 0.8c | 3.0d | 0.8c | 3.8cd | 0.8bc |
| Control | 4.3ab | 6.0a | 13.5° | 16.0a | 19.5° | 19.0a |
| CV (%) | 13.70 | 29.90 | 19.30 | 21.00 | 12.80 | 22.80 |
| | (6.20) | (14.20) | (9.50) | (12.60) | (6.80) | (14.80) |
| SE | 0.16 | 0.38 | 0.84 | 1.02 | 1.09 | 1.26 |
| | (0.04) | (0.12) | (0.16) | (0.21) | (0.18) | (0.23) |
| F Value | 6.03 | 61.08 | 69.8 | 264.93 | 204 | 292.39 |
| | (6.07) | (42.68) | (63.47) | (123.68) | (129.83) | (114.8) |
| P Value | 0.0009 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 |
| | 0.0008) | (<.0001) | (<.0001) | (<.0001) | (<.0001) | (<.0001) |

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).

Table 4b: Mean (± SE) number of flea beetle on *B. carinata* per 1m row of plots treated with different chemicals, rates and control check at different growth stages

| | Mean ±SE number of flea beetles at pre- and post-treatment | | |
|---|---|---|---|
| Insecticide | Vegetative | Flowering | Matured |
| Carbaryl 1X | 5.3a | 2.5a | 1.8a |
| Carbaryl 2X | 4.3a | 2.0a | 1.8a |
| Fenitrothion 1X | 5.0a | 2.0a | 1.8a |
| Fenitrothion 2X | 5.0a | 2.0a | 1.3a |
| Malathion 1X | 6.5a | 2.3a | 2.0a |
| Malathion 2X | 5.0a | 2.0a | 2.0a |
| Control | 5.8a | 2.0a | 1.2a |
| CV (%) | 20.00(8.90) | 44.1(18.30) | 38.9(16.90) |
| SE | 0.22(0.04) | 0.15(0.05) | 0.12(0.05) |
| F Value | 1.81(1.82) | 0.07(0.05) | 0.54(0.64) |
| P Value | 0.1464(0.145) | 0.998(0.999) | 0.773(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 plots consistently from primordial leaf stage to the second true leaf stage. This result reveals that as the rate of insecticide applied increased, the number of surviving insects or arrivers decreased and repeated spray suppressed the pests.

## Flea beetle damaged plants

The mean number of damaged plants is presented in Table 5a & b. Variations were detected in flea beetle damage to the *B. carinata* after treated with different insecticides 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 5a: 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

| Insecticide | Mean ±SE number of flea beetles at pre- and post-treatment | | | | | |
|---|---|---|---|---|---|---|
| | Pre T 1 | Post T 1 | Pre T 2 | Post T 2 | Pre T 3 | Post T 3 |
| Carbaryl 1X | 18.3ᵃ | 22.0ab | 16.3c | 19.3c | 16.3bc | 19.3c |
| Carbaryl 2X | 14.0a | 14.0c | 9.0e | 9.0e | 10.8c | 11.0e |
| Fenitrothion 1X | 16.5ᵃ | 16.8bc | 10.5de | 11.5de | 15.3bc | 16.8cd |
| Fenitrothion 2X | 15.0a | 15.3bc | 7.8e | 7.8e | 10.3c | 10.3e |
| Malathion 1X | 15.8ᵃ | 20.3abc | 21.5b | 24.3b | 21.3ab | 24.0b |
| Malathion 2X | 13.8ᵃ | 15.5bc | 13.8cd | 15.3cd | 13.8c | 14.3de |
| Control | 18.3ᵃ | 25.8a | 32.0a | 37.8a | 26.8ᵃ | 34.5ᵃ |
| CV (%) | 19.5 | 16.8 | 10.3 | 9.9 | 17.9 | 10.4 |
| | (9.4) | (8.3) | (5.0) | (4.8) | (8.5) | (5.2) |
| SE | 0.60 | 0.90 | 1.50 | 1.90 | 1.20 | 1.50 |
| | (0.08) | (0.11) | (0.18) | (0.21) | (0.14) | (0.17) |
| F Value | 1.42 | 7.6 | 109.13 | 144.07 | 16.3 | 77.58 |
| | (1.4) | (7.3) | (104.0) | (138.32) | (16.2) | (68.8) |
| P Value | 0.25 | 0.0002 | <.0001 | <.0001 | <.0001 | <.0001 |
| | 0.25 | (0.00030 | (<.0001) | (<.0001) | (<.0001) | (<.0001) |

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).

Table 5b: 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

| Insecticide | Mean ±SE number of flea beetles at pre- and post-treatment | | |
|---|---|---|---|
| | Vegetative | Flowering | Matured |
| Carbaryl 1X | 17.0a | 6.8a | 2.0a |
| Carbaryl 2X | 16.5a | 5.8a | 2.0a |
| Fenitrothion 1X | 15.8a | 6.0a | 2.0a |
| Fenitrothion 2X | 15.5a | 7.0a | 1.8a |
| Malathion 1X | 16.8a | 6.8a | 2.8a |
| Malathion 2X | 16.8a | 6.5a | 1.8a |
| Control | 18.8a | 6.5a | 2.0a |
| CV (%) | 10.2(5.0) | 17.9(8.4) | 57.0(23.0) |
| SE | 0.30(0.04) | 0.20(0.04) | 0.20(0.06) |
| F Value | 0.5(0.5) | 0.6(0.6) | 0.34(0.3) |
| P Value | 0.77(0.77) | 0.73(0.74) | 0.91(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 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 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. 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. In line with 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 even though 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

## 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 6. 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 survived in plots sprayed with twice recommended rates of Carbaryl and 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%) (Table6). 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 6: The mean (±SE) emerged seedlings, productive stalks, plant population reduction per 1m row and yield (kg/ha) per $3m^2$ area of *B. carinata*

| Insecticides | Number of *Brassica plants* | | Productive plants (%) | Number of *Brassica plants* | | Seed Yield (kg/ha) |
|---|---|---|---|---|---|---|
| | At seedling stage | Productive | | Dead | Reduction (%) | |
| Carbaryl 1X | 53.5a | 39.3bc | 73.5bc | 14.8ab | 26.5bc | 2023.5a |
| Carbaryl 2X | 44.8a | 40.5b | 90.5a | 4.3d | 9.5d | 2238.3a |
| Fenitrothion 1X | 53.5a | 49.5a | 92.2a | 4.0d | 7.8d | 2258.0a |
| Fenitrothion 2X | 51.3a | 40bc | 78.1b | 11.3bc | 21.9c | 2093.1a |
| Malathion 1X | 46.3a | 31.3cd | 68.1bc | 15.0ab | 31.2ab | 1924.2a |
| Malathion 2X | 46.8° | 38.3bc | 79.0b | 8.5cd | 21.0c | 2113.3a |
| Control | 47.0a | 29.0d | 61.7c | 18.0a | 38.3° | 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 was statistically not significantly different. This non-significant variation 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*. Nevertheless, yield was higher in all treated plots except in plots treated with lower rate of Malathion. The difference between the mean yield from plots treated with the recommended rate of Fenitrothion and untreated ones was 367.2kg/ha. 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 indicated that higher rates of insecticide seed treatment products generally had a higher yield than the lower rates.

Applications of insecticide affect positively some agronomic characteristics of plants. 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.*

Sometimes, 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.

# Conclusions

Variation in yield among the different seed rates has been found indicating that choosing seed rate is important to compensate for seedling reduction that may be caused by flea beetle damage. The recommended seed rate of 10kg/ha provided the highest yield of *B. carinata*. Seed rate of 10kg/ha is optimum to be used by farmers to reduce yield loss due to flea beetles.

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. Fenitrothion at producers recommended rate, Carbaryl and Malathion at twice the recommended rates reduced flea beetle infestation and increased the yield in comparison with the untreated control.Among the tested insecticides the recommended rate of Fentirothion can be used for the management of beetles.

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