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Original Research

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Efficacy of Synthetic Insecticides against Barley Shoot Fly (*Delia Arambourgi)* in Barley cultivation in the Central Highlands of North Shewa, Ethiopia

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ABSTRACT

Barley Shoot Fly (BSF) *Delia Arambourgi* Seguy causes tremendous yield loss in barley. Five foliar and two seed dressing insecticides were evaluated on variety HB-1307 against shoot fly at Debre Birhan Agricultural Research Center DBARC and Ankober station in 2021, the primary cropping season. The experiment aimed to select an effective and economical insecticide for barley shoot fly. Randomized Complete Block Design with three replications was used for the study, and data were analyzed using R software with a generalized linear mixed-effect model. Treatment means were separated using Duncan's Multiple Range Test (DMRT) at a 5% significance level. Seed dressing insecticides were applied on barley seed immediately before planting, and insecticides were used according to factory recommendations. Combined result showed that from foliar insecticides lambda cyhalothrin 5% EC, from seed dressing insecticides Thiamethoxam 25% WG were effective in decreasing the number of larvae and dead heart shoots, and gave maximum marginal rate of return and higher net benefit than the rest of the treatments. Therefore, we recommend proper use of Lambda cyhalothrin 5% EC at a rate of 0.25 lt/ha using 200 L water/ha and 4 g Thiamethoxam 25%WG 1/kg seed dissolved in 600 ml water for effective management of barley shoot fly. Based on this finding, examining sowing date and seed dressing insecticides in future research may provide yield increments in barley.

Keywords: Barley, *Delia arambourgi*, Efficacy, Foliar insecticides, Seed dressing.

INTRODUCTION

Barley is one of the most important cereal crops cultivated in Ethiopia. It is the fifth important cereal crop next to teff, maize, sorghum and wheat covering an area of 926,106.90 hectares with an annual production of about 2.34 million tons in main season (CSA, 2021). Barley which includes both food and malt barley grain is mostly used as food for human consumption, malt, and feed for animals (Yosef *et al*., 2011). In most parts of Ethiopia, barley is grown twice a year, in the main rainy season locally called *meher* (June to October) and in the short rainy season locally called *belg* (February to July) (Bayeh and Grando, 2011).

Beyond the importance of barley and the efforts made so far to generate improved production technologies, its productivity under subsistence farmers' condition in Amhara region is estimated to be 728902.31 ton/ha which is below the national average yield of 2.34 tons/ha (CSA, 2021). The low yielding is attributed to a multitude of abiotic and biotic factors. Among the biotic factors insect pests particularly the Russian wheat aphid and barley shoot fly are considered as key insect pests (Tafa and Bayeh, 2011).

Barley shoot fly (*Delia* spp) is one of the most important insect pests of barley recorded in Ethiopia (Tafa, 2003; Tafa and Tadesse 2005; Muluken *et al.,* 2009). Two shoot fly species; *Delia arambourgi* Seguy and *Delia flavibasis* Stein was recorded in Ethiopia, resulting in considerable yield losses. Research conducted research at Holleta and recorded up to 90 percent infestation of the seedlings and concluded that *D. arambourgi* could cause substantial reduction in yield on the Ethiopian plateau.

The biology of barley Shoot fly *D. flavibasis* studied using resistant (Dinsho and Harbu) and susceptible (Holker) barley cultivars at Sinana Agricultural Research Center result showed that higher number of eggs was laid on Holker (17 eggs/female) than on Dinsho (11eggs/female) or Harbu (12 eggs/female). under normal conditions, young barley seedlings (two to three leaf stages) are most preferred for oviposition. However, oviposition can occur on tillers of older plants and their leaves Muluken *et al*., 2009).

The damaging stage of barley shoot fly is the larval stage. Infestation commenced with a mine in the first or second leaf or both and the larvae make its way down through the tissues to the growing point. The attack results in death of the central shoot, producing dead heart (Muluken *et al.,* 2009). Infestation normally occurs in the 1-4 weeks after seedling emergence. Maggot causes injury to the growing tip, which results in withering of central leaf popularly known as ‘dead heart. The damaged seedling is killed but may produce side tillers. However, the tillers are also attacked under high shoot fly pressure (Balikai, 2006).

Previous attempts on barely shoot fly research primarily focused on cultural practices and germplasm screening (SARC, 2004, 2005, 2006; Tafa and Bayeh, 2011). Integrating early sowing, resistant varieties and seed dressing insecticides imidacloprid (Gaucho), thiamethoxam (apronstar) were found effective to manage *D. flavibasis* in the high lands of Bale (SARC, 2004; Tafa and Bayeh, 2011). Efficacy of botanicals against shoot fly applied by three sprays (7th, 14th and 21th day after germination) revealed that the minimum infestation was recorded in the neem oil (2%). Among the tested botanicals, neem oil (Azadirachta indica) (2%) was better than the rest of the treatments followed by karanj oil (2%) (Joshi *et al*., 2016).

Tamene *et al*., 2016) suggested that seed dressing with chemical insecticides such as, Imidacloprid (Gaucho), Criuser, Thiamethoxam (Apronstar) and others have been identified for the control of *D. flavibasis* (SARC, 2004). On the other hand, resistant barley lines have been recognized and others mechanisms of resistance studied (Tafa, 2003; Tafa *et al.,* 2004).

Imidacloprid treatment was significantly superior to other chemicals which showed the order of efficacy as Thiamethoxam (22.1) > Chlorpyriphos ethyl (23.9) > Endosulfan (29.9) > Dimethoate (30.9) (Sridhar and Muthukumar 2016).

However, in the central highlands of Ethiopia, control measure for barley shoot fly *is* lacking. Seed dressing chemicals such as imidacloprid and thiamethoxam have been identified to be effective for the control of barley shoot fly but these chemicals not easily available in the local market as well as unaffordable so that alternative effective and economically feasible insecticides for the control of barley shoot fly is urgently need.

Therefore, the objectives of this study were to evaluate the efficacy and cost effectiveness of synthetic insecticides against barley shoot fly in the study areas

MATERIALS AND METHODS

Description of the study area

The experiment was conducted at Debre Birhan Agricultural Research Center (DBARC) and Ankober experimental station in 2021 main cropping season. Debre Birhan Agricultural Research Center is located at 09º 35" N latitude and 39º 29" to 39º31'' E longitudes with an altitude of 2850 m.a.s.l and has unimodal rainfall pattern. It has annual rainfall of 58.87mm and annual temperature of maximum and minimum 20.99 ºC and 6.3 ºC respectively. The Centre is located at a distance of 120 km North of Addis Ababa on the way to Dessie. Ankober is located 9° 38' N latitude and 39° 44' E longitude (Figure 1). The elevation of the site is 3152 m.a.s.l. It has 122.5 mm Annual rainfall, a bimodal rainfall pattern, Meher season (June to November) and Belg season (February to June). Barley is the dominant cereal crop (DBARC, 2016).

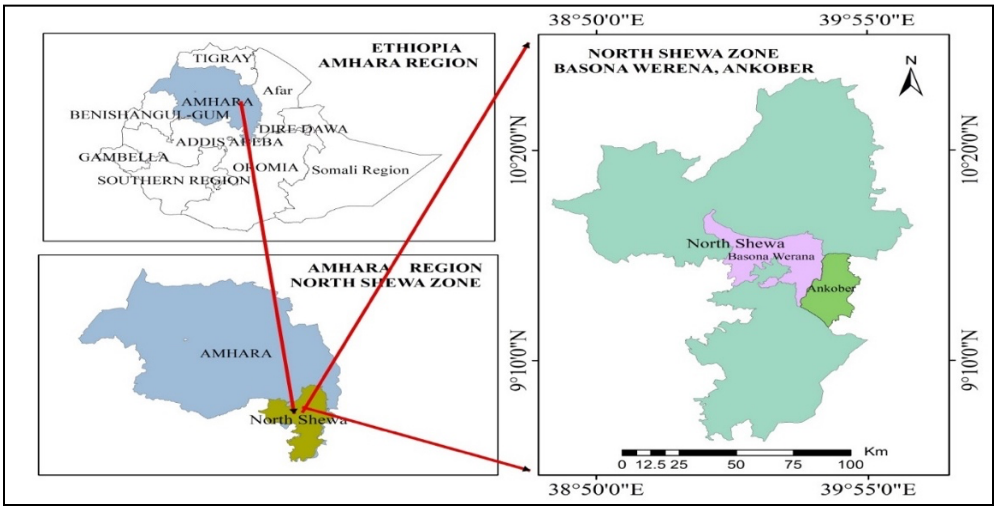

Figure 1. Study area Map

Description of experimental materials

Variety HB-1307 planting dates was July 4, 2020 for DBARC and July 12, 2020 for Ankober. Fertilizers were applied as per the recommendation for the areas, 46 kg P_2O_5 applied during sowing and 41 kg N ha^{-1} (split application of urea in two equal portions at planting and at knee height stage). Moreover, other agronomic practices were applied as per the recommendation of the area.

Experimental design and treatments.

Treatments were laid out in Randomized Completely Block Design (RCBD) in three replications planted on a plot size of 1.2m by 2.5m with row spacing of 0.2m (six rows per plot). The distance between plots and blocks were 0.4m and 1m, respectively.

Two seed dressing (to reduce the number of eggs laid and the developing maggots) and five foliar spray insecticides were used (to act on plant physiology and evaluate the efficacy of theses treatment against number of dead heart and infestation caused by barley shoot fly. Before planting the seed dressing insecticide 4gm (Thiamethoxam 25%WG) 600ml water and 4gm (Deltamethrin 25%WP) 500ml water dissolved properly and mix well in 1 kg barley seed then after drying in shade place planting performed.

Whereas the foliar spray insecticides (Chlorpyrifos-ethyl 48% EC, Dimethoate 40% EC, and Diazinon 60% EC 1Lt each with 200Lt water/ha, Selecron 500% EC 0.6Lt/ha, Lambda cyhalothrin 5% EC 0.25Lt/ha, Malathion 50% EC with 150Li water/ha were used. The foliar insecticide applied directly on the leaf whorl three times at 14, 21 and 28 days after emergence using hand sprayer via converting each insecticide for 3m^2 per plot size. untreated check included for comparison purpose. Infestation normally occur in the 1 to 4 weeks after seedling emergence maggot causes injury to the growing tip, which results in withering of central leaf popularly known as 'dead heart.

Data collection

Dead heart counts or number of infested plants were recorded from 0.5 x 0.5m quadrat per plot at each period of spray. To avoid recounting, the infested shoot of the already recorded plants were tagged immediately after each time of the data collection and maturity date was recorded. In addition, grain yield was harvested after the crop attained its physiological maturity by taking the crop from four central rows and threshed separately for each treatment. Mean grain yield of the respective treatments were converted to kg per hectare. Biomass yield also taken. Plant height was measured by taking ten randomly selected plants from the central four rows for each plot at physiological maturity. Number of barley plants showing dead heart symptom was calculated and convinced into % dead heart by applying specified formula (Sathish *et al*, 2017).

$$\text{Dead heart}(\%) = \frac{\text{Number of plants with dead heart}}{\text{Total number of plants}} \times 100$$

Statistical analysis

Analysis of variance (ANOVA) was performed using R-software version 4.4.0. computer software data were examined with a generalized linear mixed-effect model using the packages "lme" (Bates *et al.*, 2015) and "emmeans" (Lenth 2021). Treatment means were separated using Duncan's Multiple Range Test (DMRT) at 5% least significant level (LSD).

Cost-benefit analysis

Cost benefit analysis can be calculated using partial budget analysis method. Partial budgeting is a planning and decision-making framework used to compare the costs and benefits of alternatives faced by a farm business. Gross yield was adjusted from the output obtained lowered by 10% from the actual yield due to management and other production risk. The result of partial budget analysis which was carried out against the control check based on the input and output price and marginal rate.

Economic benefits of insecticides application for the management of barely shoot fly were analyzed. The net benefit or return was computed by subtracting the total protection costs from the gross return of barely per hectare.

RESULTS AND DISCUSSION

Effect of insecticide treatment on Plant height, Maturity date Grain yield and Biomass yield of barley

Significant differences were recorded among treatments on plant height ($p<0.05$). Plots treated on Thiamethoxam, Lambda cyhalothrin 5% EC Diazinon 60% EC and control treatment at ($p<0.05$) with regard to plant height (Table 1).

Table 1. Effect of Treatment on Plant height and maturity combined over location

Treatment	Plant height	Maturity date	GY kg ha^{-1}	BY kg ha^{-1}
Chlorpyrifos-ethyl 48% EC	84.9^{ab}	143.3^{a}	3060^{ab}	4820^{abc}
Deltamethrin 25% WP	83.5^{abc}	141.2^{ab}	2900^{ab}	5570^{ab}
Thiamethoxam 25 % WG	85.9^{a}	143.9^{a}	3200^{a}	4620^{bc}
Dimethoate 40% EC	81.1^{abc}	141.2^{ab}	2600^{ab}	5320^{ab}
Selecron 500 EC	84.4^{ab}	140^{ab}	2480^{ab}	4190^{bc}
Diazinon 60% EC	76.0^{bc}	140.7^{ab}	1750^{b}	3700^{bc}
Malathion 50% EC	80.0^{abc}	140.5^{ab}	1790^{b}	4050^{bc}
Treatment	**Plant height**	**Maturity date**	**GY kg ha^{-1}**	**BY kg ha^{-1}**
Lambda cyhalothrin 5% EC	93^{a}	141.5^{ab}	3460$^{a`}$	6280^{a}
Untreated Check	74.8^{c}	140.1^{ab}	1730^{b}	3200^{c}
Mean	82.6	141..4	2552	4639
CV (%)	25	5	20	18
Sig	*	*	*	*

Means followed by the common letter(s) with in a column (lowercase letter) are not significantly different from each other at p < 0.05.

Effect of insecticides on biomass and grain yield

The result indicated that there were significant differences ($p<0.05$) between plots treated with Lambda cyhalothrin 5% EC over thiamethoxam selecron 500 EC, diazinon 60% EC, Malathion 50% EC and Untreated check on biomass yield (Table 1).

Besides Significant difference ($p<0.05$) was found on grain yield between Lambda cyhalothrin 5% EC and thiamethoxam 25 % WG over diazinon 60% EC, Malathion 50% EC and untreated check moreover using thiamethoxam more economical and safer for the environment as well as for natural enemies. (Table 1).

Effect of insecticide treatments on plant dead heart.

The number of dead heart shoots in plot treated with seed dressing and sprayed insecticides were significant at ($p<0.05$) than untreated plots. Both seed dressing and foliar insecticides resulted in a smaller number of dead hearts and infestations. Among seed dressing insecticides, data collected at 14 to 28 DAE revealed a smaller number of dead hearts in Deltamethrin treated plots (3 to 1.6) followed by Thiamethoxam (5.7 to 3.9). Among foliar spray insecticides, exhibits less no of dead heart Chlorpyrifos-ethyl (4.7 to 3), followed by Lambda cyhalothrin (6.7 to 3.4) Selecron (5.2 to 3.8) and Dimethoate (13.1to 4) (Figure 2). An investigation studied in efficacy of some novel insecticides and bio products against shoot fly result revealed that all the treatments were found significantly effective in reducing the infestation of shoot fly and thus increasing the yield as compared to control (Kumar *et al.,* 2017).

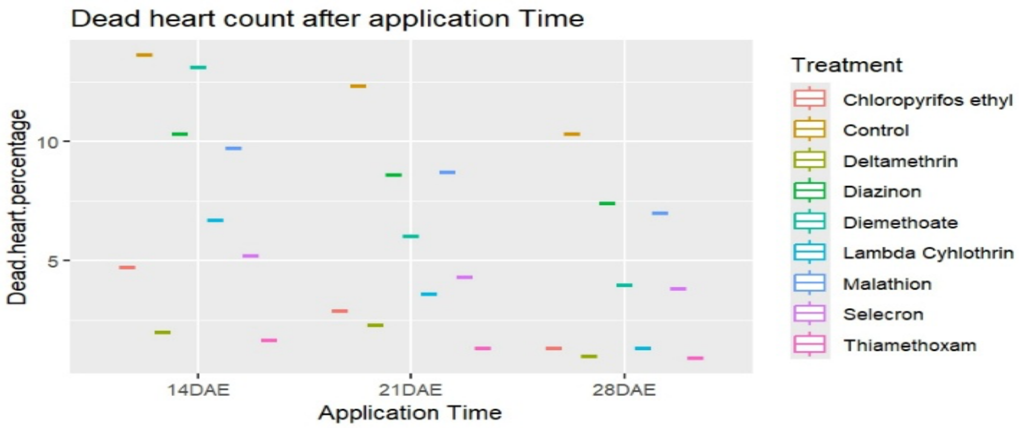

Figure 2. Dead heart counts among insecticides treated plots at 14, 21 and 28 DAE at DBARC station 2021 main cropping season

Similarly, at Ankober, data collected from both seed dressing and foliar or spray insecticides showed significant variation at ($p<0.05$) on the number of dead hearts. Accordingly, among seed dressing insecticides the least number of dead hearts were recorded from plots treated with Thiamethoxam (2.7 to 1) followed by Deltamethrin (3 to1.7).

Likewise, among foliar spray insecticides, Chlorpyrifos-ethyl (2.3 to 0.9) Lambda cyhalothrin exhibited few numbers of dead hearts (4.1 to1.3) followed by Dimethoate (4.6 to1.8), and Selecron (4.1to 2.7) (Figure 3). This result investigation is in line with results obtained in rates of two seed dressing insecticides have been treated with two seed dressing pesticides Joint TM 246 FS (23.3% Imidacloprid and 1.3%Tebuconazole) and Apron Star 42 WS in two rates: Joint TM 246 FS at 100ml and 200ml, reduced shoot fly infestation (Tekalgne and Bekele (2017).

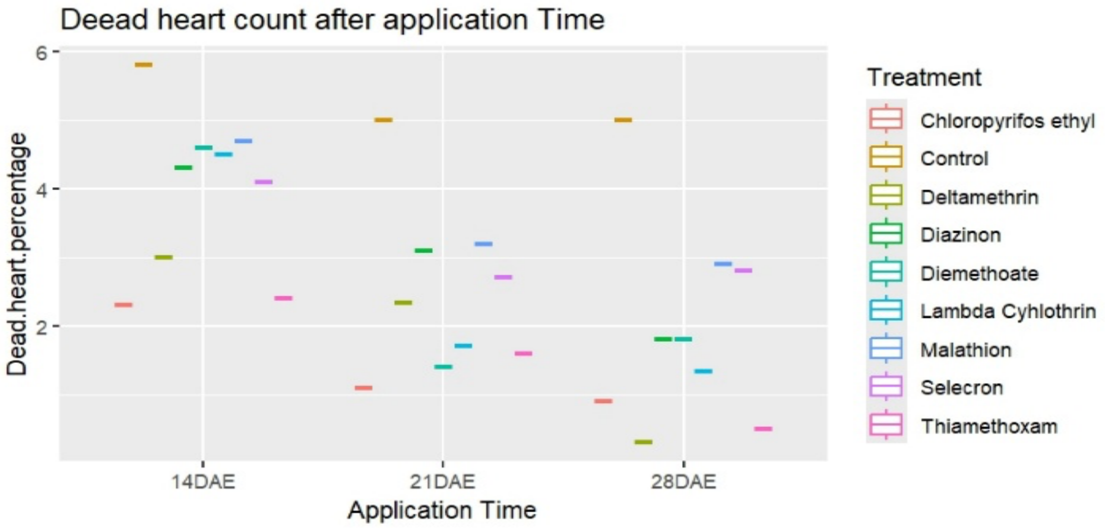

Figure 3. Dead heart counts among insecticides treated plots at 14, 21 and 28 DAE at Ankober in 2021 main cropping season

Correlation of dead heart and infestation with other agronomic parameters

Number of Larvae (r = -0.47; p<0.05) and infestation percentage (r = -0.36; p<0.01) was negatively and significantly correlated with grain yield. biomass yield also significantly negatively correlated with number of larvae (r = -0.61; p<0.01) and infestation level (r = -0.54; p<0.01). Maturity date and plant height were also negative correlated with shoot fly infestation and larvae number but their association was not statistically significant at both locations (Figure 4).

Figure 4. Correlation coefficient of Dead heart and infestation with agronomic parameters of barley

Partial budget analysis of insecticides against BSF

Before conducting economic analysis, dominance analysis was done as it is a prerequisite for further economic analysis to identify the dominated treatments for which the net benefit decreased while cost that varies increased. So, treatments such as Malathion, Deltamethrin, Dimethoate, Selecron and Diazinon dominated as their cost was high as compared to the previous one with higher net benefits. Hence these treatments would be excluded from the further analysis (Table 2).

Table 2. Partial budget analyses for Barley shoot fly management

Treatment	Adj.Y (Kg ha^{-1})	Adj.BY (Kg ha^{-1})	Sale RG+S (ETBha^{-1})	TVC (ETB/ha^{-1})	NB G+S (ETB/ha^{-1})	MRR %
Untreated	1557	2880	1816	0	0	0
Chloropyrifos ethyl	2754	4338	30708	560	30148	2130
Thiamethoxam	2880	4158	31356	650	30706	1921
Malathion	1611	3645	20178	750	19428	D
Deltamethrin	2610	5013	28296	1290	27006	D
Dimethoate	2340	4788	28296	1290	34926	D
Lambda cyhalothrin	3114	5652	36216	1290	34926	1295
Selecron	2232	3771	25398	1803	24018	D
Diazinon	1575	3660	19920	1640	18280	D

***Note: Adj.Y =** Adjusted yield Of Barley, **Adj.BY** = Adjusted yield Of Barley, **Sale RG+S** =sale revenue grain plus straw, **TVC** = Total variable cost. **NBG+S** = Net benefit Grain + Straw. D=Dominated treatment*

Economic analysis result showed that from foliar insecticides Lambda cyhalothrin provide high marginal rate of return MRR (1295) and higher Net benefit (34926ETB) than the rest of treatments and whereas from seed dressing insecticides Thiamethoxam attain high MRR (1921) and higher Net benefit (30706ETB) (Table 2).

CONCLUSIONS

Barley shoot fly (BSF) *Delia Arambourgi* Seguy cause great amount of yield loss in barley the experiment result indicated that lowest number of dead heart and/or shoot fly infestation record from foliar insecticide Lambda cyhalothrin followed by Chlorpyrifos-ethyl and out of seed treatment Thiamethoxam, declined shoot fly infestation and less impact to natural enemies and the environment hence serves as an alternative in integrated insect pest management. Lambda cyhalothrin and Thiamethoxam besides provided maximum grain yield and marginal rate of return and net benefit.

Therefore; proper use of Lambda cyhalothrin (5%) EC at rate of 0.25Lt/ha with 200lt water/ha and Thiamethoxam 25%WG 4gm/1/kg seed dissolved in 600ml water provides effective protection for barley shoot fly. As recommendation future research examining injury reduction on choice sowing date together with seed dressing insecticides, under different cropping season may provide these yield increments in barley.

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