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Efficacy of Selected Insecticides Against Wheat Aphids on Irrigated Wheat in North Western Amhara, Ethiopia

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Abstract

Aphid infestations cause significant losses in wheat production. The experiment was conducted at the Koga irrigation site during 2021 to evaluate the efficacy of commercial insecticides for the management of wheat aphids. Seven types of insecticides with unsprayed control were laid in a completely randomized block design with three replications. The result showed a reduced aphid infestation with maximum grain yield were from dimethoate, imidacloprid, lambda-cyhalotrin, profenfos + lambda-cyhalothrin, imidacloprid + lambda-cyhalothrin, and profenofos-sprayed plots. However, the greater net benefit and marginal rate of return were provided by the applications of imidacloprid and dimethoate insecticides. The economically feasible insecticide application can be considered as an effective aphid management practice in wheat production.

Keywords: wheat, aphid, insecticide

Introduction

Wheat (*Triticum aestivum* L.) is the most widely cultivated cereal crop in the world, with more than 220 million ha planted annually under wide ranges of environmental conditions (FAOSTAT, 2022). The global wheat production amounts to an annual average of around 750 million tons (t) (FAOSTAT, 2022). Thirty-two (32) African countries produce an average of 26.1 million tons of wheat per year on 9.9 million hectares of land, accounting for only 3.5% of the world wheat production system. Among African wheat-producing countries, Ethiopia is the second-largest producer, accounting for about 18.98% of total production on the continent. According to recent estimates, 4.96 million tons of wheat were produced on 1.75 million hectares of land (FAOSTAT, 2022).

Wheat is a major imported commodity all over the African continent. Based on an average of five years (2016–2020) of FAOSTAT data, 48.2 million tons of wheat were imported into Africa every year in the form of grain, flour, and macaroni. The average wheat self-sufficiency in Africa is about 17%, indicating that the region is significantly dependent on imports. This makes the continent highly vulnerable to global market and supply shocks. For example, the occurrence of the COVID-19 pandemic and the Russian-Ukraine war significantly disrupted the global wheat trade.

The fact that Ethiopia has become increasingly dependent on external sources of food supply has become a major concern for policy makers and agricultural researchers. Therefore, the question of how to make Ethiopia self-reliant in food production has received major attention in recent years. Wheat is a key crop for ensuring food security. Ethiopia's wheat production is insufficient to meet domestic demand, forcing the country to import more than 1.6 million metric tons annually. Ethiopia's government intends to reduce imports by boosting domestic production. One of the strategies is to produce wheat under irrigation. Remarkable achievements are recorded in the past.

However, aphids are a serious pest of irrigated wheat in Ethiopia, causing production losses ranging from 15% to 93% depending on variety and season (Damte, 2015). It can be managed by planting resistant varieties or by employing cultural practices such as alternate host destruction, adjusting planting dates, and producing a healthy, stress-free crop (by maintaining adequate soil moisture and fertilization) (Chemeda, 2015; Singh and Rajaram, 2002). The varieties released so far, either for rainfed or irrigated wheat production, in Ethiopia were developed in the absence of wheat aphid or under an insecticide-protected condition in the presence of the pest (Damte, 2015). Therefore, in the absence of resistance varieties and the buildup of aphid populations against cultural practices, the management of wheat aphids relies primarily on the application of insecticides. Currently, insecticide-based management is the most essential measure for controlling aphids in agricultural production since it can effectively suppress aphid populations in a short period of time (Luo et al., 2022). Hence, the objectives of this study were to evaluate the efficacy of different insecticides on aphids to avoid yield loss in irrigated wheat.

Materials and Methods

The experiment was conducted in Koga irrigation site during 2021. Koga Irrigation scheme is located within the Abay river basin in Mecha woreda in West Gojjam zone of Amhara region. It is located between 11°20'N _ 11°30'N (latitude) and 37°3'E _37°9'E (longitude) in the west of Merawi town, 35 km south of Bahir Dar. It lies at an altitude of 1979 m.a.s.l. The soil of the study area was dominantly sandy clay soil type. The average pH and organic matter content of the soil were 5.5 and 3.4 g.kg^{-1}, respectively. The annual mean rainfall in the area was about 1507 mm. The average maximum and minimum temperatures were 27.5°C and 12°C, respectively. The monthly average relative humidity (RH) was 58.5%.

Seven commercial insecticides registered in Ethiopia (Table 1) with untreated control were laid down in completely randomized block design (RCBD) with three replications. Each plot was consisting of 10 rows of 3 m length. The space between furrow, rows, plots and replications were 0.4 m, 0.2 m, 1 m and 1.5 m, respectively. A widely cultivated variety 'Kekeba' was used as a test variety. Planting was done at the mid December with the recommended seeding rate of 125 kg.ha^{-1}. Recommended fertilizer rate (92 kg of P2O5 per hectare) was applied during planting. Furthermore, the recommended N rate of 138 kg.ha^{-1} was applied in split at tillering and near booting. Weeds were managed through hand weeding. The experimental fields were irrigated regularly with furrow irrigation every 14 days.

Insecticides were used at the rate of factory recommendation per hectare when the aphid population reaches economic threshold level. The insecticides were sprayed using hand sprayer of 2.5 liter capacity. Spraying was started at heading stage of the crop and repeated in every two weeks interval for three times. All sprays were applied when the wind velocity was low to avoid any drift effect from the sprayed plot to neighboring ones. The crop was protected from the infections of foliar fungal disease including rust through application of Tilt (propiconazole) and Natura (tebuconazole) fungicide based on the factory recommendation rate in all experimental fields uniformly to avoid the yield losses due to disease.

Data Collection

Aphid Count

Data on aphid population were recorded starting from initial occurrence up to maturity of the crop. Numbers of aphids per plant were counted on ten (10) randomly selected plants from each plot with only live aphids counted. Aphid count was taken one day before each application of insecticide and after 24 and 72 hours of each insecticides spraying from the base of plant up to the top.

Number of Grains per Spike

It was determined by counting the number of grains per spike expressed as average of ten randomly selected spikes in a harvestable plot.

Grain Yield per ha (tonnes per ha)

At maturity, the dried crop were harvested by the help of sickle from harvestable rows of each plot. Wheat bundles of each plot were sun dried and then threshed separately. The grain weight of each plot was recorded in kg by the help of sensitive balance. Simultaneously, moisture content of each plot were measured by the help of moisture tester. Finally the yield obtained from each plot were converted in to t/ha and adjusted in to 12.5% grain moisture content.

Table 1. Commercial insecticides used as treatments

No.	Trade name	Active ingredient	Recommended rate
1	Agro plus	Imidacloprid + lambda-cyhalothrin	400 ml.ha^{-1}
2	Nehisa	Dimethoate 400 g.L^{-1}	750 ml.ha^{-1}
3	Agro-Lambacin Super 315 EC	Profenfos 30% + lambda-Cyhalothrin 1.5%	400 ml.ha^{-1}
4	Hunter	Abamectin + Acetamiprid	500 ml.ha^{-1}
5	Profit 72% EC	Profenofos	750 ml.ha^{-1}
6	Gain 20 SL	Imidacloprid	110 ml.ha^{-1}
7	Karate 5% EC	Lambda-cyhalotrin	400 ml.ha^{-1}

One-thousand Grain Weight (g)

1000 seeds were randomly sampled in a harvested grains of each plot and counted by the help of seed counter. Subsequently, the weight of counted seed were measured using analytical balance.

All the collected agronomic data were subjected to analysis of variance as suggested by Gomez & Gomez using SAS software (Gomez and Gomez, 1984). Significant means were separated by using LSD method at 5% probability.

Relative Yield Losses

Losses were calculated separately for each of the treatments with different levels of aphid populations, based on the following formula (Savary and Willocquet, 2014).

$$\text{Relative Yield Loss} = \frac{\text{yield of protected plot} - \text{yield of un protected plot}}{\text{yield of protected plot}} \times 100$$

Partial Budget Analysis

The cost and benefit of each treatment were analyzed partially, and marginal rate of return were computed by considering the variable cost available in the respective treatment (CIMMYT, 1988). To compare the benefits of insecticide treatment, yield and economic data were collected. The grain yield obtained from each treatment was adjusted downwards by 10%. Following harvesting, the total gross benefit of the field was computed by multiplying the wheat grain yield with the local market price (Birr 35 per kg). Variable costs such as insecticide and labour costs for insecticide application were included. The price of profenfos + lambda-cyhalothrin and lambda-cyhalothrin was similar 3300 ETB per litter. While the price dimethoate was 2490 ETB per litter. The most expensive pesticide used as a treatment was imidacloprid, which cost 4560 ETB per litter. The price of abamectin + acetamiprid and imidacloprid + lambda-cyhalothrin per litter was 3900 and 3930 ETB, respectively. In addition, the labour cost per man-day was 200 ETB. Total variable cost (TVC) is the sum of all variable costs associated with insecticides and labour. The net benefit (NB) is calculated by subtracting all variable costs from the gross benefit, as follows: NB = GB -TVC. For dominance analysis, the variable costs that varied for each treatment were ranked in ascending order. The marginal rate of return (MRR) was calculated for two non-dominated treatments (say 1 and 2) using the formula: [change in net benefit (NB2−NB1)/change in TVC (TVC2−TVC1)] × 100. Marginal rate of return (MRR) provides the value of benefit obtained per the amount of additional cost incurred percentage.

Results and Discussions

Insecticides and Wheat Aphid Population

Aphid infestations on wheat plants first appeared in the first week of March, approximately 65 days after sowing (DAS), when the crop reached flowering stage (Zadoks stage 65), and the population continued to grow until the first week of April on unsprayed control plot (Figure 1). Damte (2015) reported similar results, with the RWA population rapidly increasing from the second week of March and peaking in the last week of March on unsprayed wheat. The main reason for this is most likely a rise in temperature in March (Figure 2). Temperature is a key environmental variable that regulates insect population growth through its influence on development, fecundity, and survival (Deutsch et al., 2008; Wang et al., 2021).

The number of aphids per plant counted prior to any insecticide spray was between 5 and 10, except in the abamectin + acetamiprid treated plot (Figure 1). However, aphid count data collected after the first spray revealed a reduced trend, with approximately 1 aphid per plant in dimethoate, lambda-cyhalotrin, and imidacloprid + lambda-cyhalothrin sprayed plots (Figure 1). Aphid numbers increase on unsprayed plots and ineffective insecticide (abamectin + acetamiprid) sprayed plots during the second phase of assessment (2 weeks after the first spray). Even though the aphid population increased from counts conducted after first spray, the numbers of aphids were reduced (between 1 and 5) on effective insecticide-sprayed plots after the second spray (Figure 1). Similar trends were observed in the third phase of assessment (one month later than the first spray). As with all others, aphid numbers per plant are high before spraying and reduced after spraying. The difference is that aphid populations reach a peak (40) in both the unsprayed and abamectin + acetamiprid sprayed plots (Figure 1).

Generally, the aphid count data showed that all the insecticides except abamectin + acetamiprid were superior to untreated control in all date of assessments. However, the mean number of aphids/tiller differed between effective treatments across all assessments. Dimethoate, lambda-cyhalotrin, and imidacloprid + lambda-cyhalothrin were found to be the most effective. Profenfos + lambda-cyhalothrin, profenfos, and imidacloprid were the next best. Our findings confirm the results of Ahmad et al. (2016), who found that dimethoate and imidacloprid have excellent insecticidal activity against wheat aphids. Shafique et al. (2016) used lambda-cyhalothrin and imidacloprid insecticides as foliar applications against wheat aphids and found that both insecticides effectively

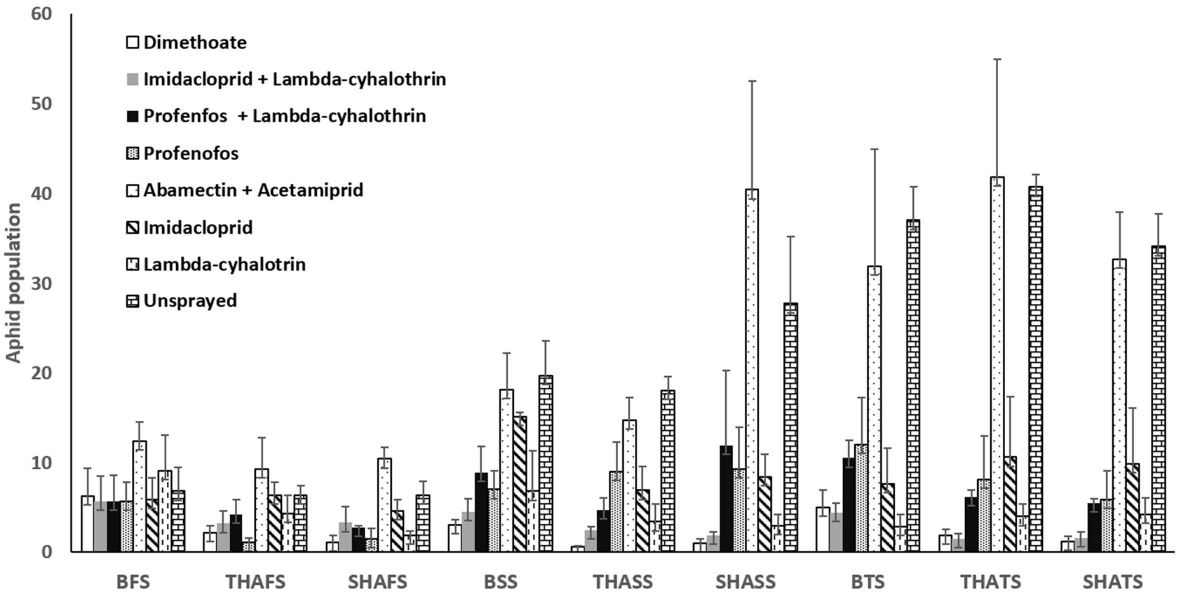

Figure 1. The effects of insecticides on aphid population. BFS= before the first spray; 24 HAFS= 24 hours after the first spray; 72 HAFS= 72 hours after the first spray; BSS= before the second spray; 24 HASS= 24 hours after the second spray; 72 HASS= 72 hours after the second spray; BTS= before the third spray; 24 HATS= 24 hours after the third spray; 72 HATS= 72 hours after the third spray.

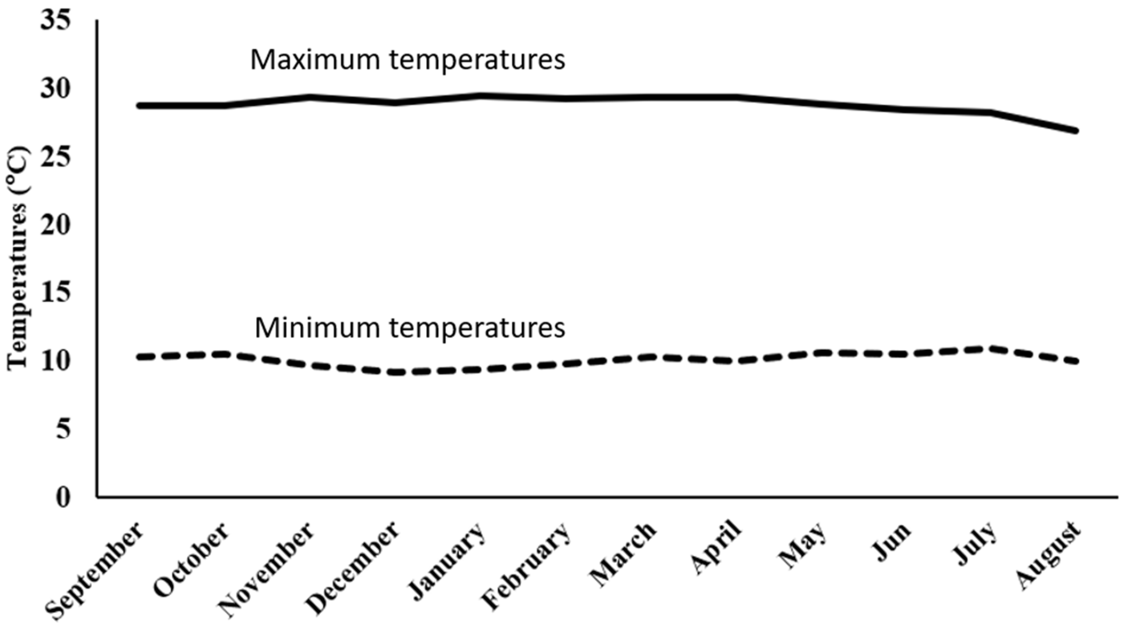

Figure 2. Minimum (**---**) and maximum ( ) temperatures of the study location during 2021

controlled aphids. Asif et al. (2017) also reported that imidacloprid, lambda-cyhalothrin and profenofos + cypermethrin has outstanding insecticidal activity against sucking insect pest complex of cotton.

The Effects of Aphid on Grain Yield, One Thousand Seed Weight, and Grains Per Spike

Insecticide application had a significant ($P < 0.001$) effect on the grain yield and one-thousand seed weight (Table 2). However, grains per spike were not significantly affected by wheat aphid infestation, even though there were numerical differences between treatments. The highest yield (3.8 $t.ha^{-1}$) of wheat was obtained with the treatment dimethoate (Table 2). However, except for abamectin + acetamiprid, the yields obtained from dimethoate were not significantly different from the rest of the insecticides (Table 2). The lowest wheat yield (1.8 $t.ha^{-1}$) was obtained from unsprayed control. Statistically, the wheat yield (2.5 $t.ha^{-1}$) produced from experimental plots treated with abamectin + acetamiprid was not significantly different from the unsprayed control (Table 2). The result is in agreement with those of Ahmad et al. (2016), who reported the highest wheat yield from imidacloprid and dimethoate insecticide applications. In their study, Shafique et al. (2016) also reported that imidacloprid and lambda-cyhalothrin applications improved wheat yield compared to an unsprayed control. Similar to grain yield, dimethoate (44.3 g) and the unsprayed control (29.6 g) yielded the highest and lowest thousand seed weights, respectively (table 2). One thousand seed weights obtained from imidacloprid (42.9 g), lambda-cyhalotrin (43.5 g), and combinations of imidacloprid plus lambda-cyhalothrin (44.0 g) treated plots did not differ significantly from dimethoate (Table 2). Generally, the unsprayed control had a lighter seed weight, fewer grains per spike, and a lower grain yield. As a result, the avoidable loss in grain yield was 51.8%. Damte (2015) reported a reduction in one thousand seed weight and grains per spike, resulting in a 15 to 93% percentage yield loss due to Russian wheat aphid, depending on variety and season.

Partial Budget Analysis

The partial budget analysis indicates that some insecticide treatments resulted in high net benefits and marginal rates of return (Table 4). Among the insecticides, imidacloprid and dimethoate provided the greatest net benefit and marginal rate of return. Although the net benefit calculated from other insecticide treatments is lower than that of imidacloprid and dimethoate, it is two times greater than the unsprayed control (Table 4).

Table 2. The effects of different insecticides against wheat aphid on yield and yield components of wheat

Insecticides	GPS	TSW (g)	GY(t/ha)	RYL
Abamectin + Acetamiprid	41.1	33.3d	2.5bc	33.3
Dimethoate 400 g.L^{-1}	45.0	44.3a	3.8a	0.0
Imidacloprid + Ambdacyhalothrin	37.3	44.0ab	3.3ab	12.3
Imidacloprid	38.3	42.9abc	3.5a	7.9
Lambda-cyhalotrin	38.1	43.5abc	3.6a	5.3
Profenfos 30% + Lambda-cyhalothrin 1.5%	42.3	41.6c	3.4a	9.7
Profenofos	38.1	41.8bc	3.3ab	12.3
Untreated	36.3	29.6e	1.8c	51.8
CV (%)	9.1	3.2	14.6	
Significance	ns	**	**	

Note: Values followed by the different letters within one column are highly significant (**) according to LSD at 0.05; ns = not-significant; GPS= grain per spike; TKW= thousand seed weight in gram; GY= grain yield in ton per hectare; RYL= relative yield loss; CV = coefficient of variation.

Table 3. Partial budget analysis of all treatments

Items	Adjusted yield (10%) t.ha^{-1}	Gross benefit (ETB.ha^{-1})	Total cost of Insecticide (ETB.ha^{-1})	Total cost of labour	Total variable cost	Net benefit	MRR%
Control	1.62	56700	0	0	0	56700	
Imidacloprid	3.06	107100	501.6	1800	2301.6	104798.4	2089.7
Profenfos 30% + Lambda-cyhalothrin 1.5%	2.97	103950	1320	1800	3120	100830	D
Lambda-cyhalotrin	2.97	103950	1320	1800	3120	100830	D
Imidacloprid + Lambda-cyhalothrin	2.25	78750	1572	1800	3372	75378	D
Dimethoate 400 g.L^{-1}	3.42	119700	1867.5	1800	3667.5	116032.5	13757.8
Abamectin + Acetamiprid	3.15	110250	1950	1800	3750	106500	D
Profenofos	3.24	113400	2250	1800	4050	109350	D

Note: ETB= Ethiopian birr; t= tone; ha= hectare; MRR= Marginal rate of return; D= Dominated

Conclusion

Results in this study demonstrated that the application of insecticides dimethoate, imidacloprid, lambda-cyhalotrin, profenfos + lambda-cyhalothrin, imidacloprid + lambda-cyhalothrin, and profenofos significantly decreased the aphid population and increased yield by 40 to 52% as compared to the untreated control. The results also showed that aphids in the irrigated wheat caused up to 52% grain yield loss if not controlled. Despite the fact that the applications of imidacloprid and dimethoate are more profitable, wheat producers can also use lambda-cyhalotrin, profenfos + lambda-cyhalothrin, imidacloprid + lambda-cyhalothrin, and profenofose if they need to rotate insecticides to prevent the emergence of insecticide resistance.

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