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Efficacy of Seed Treatment Insecticides against Major Early Season Sucking Pests on Cotton in the Middle Awash, Afar Region, Ethiopia

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Abstract

The sucking pest (whiteflies, aphids, cotton jassids, thrips, and cotton mealy bug*)* complex is a serious pest of cotton that causes a 22% decrease in yield. This research was carried out at Werer Agricultural Research Center in the Middle Awash of the Afar Region during the 2021 and 2022 cotton growing seasons to evaluate the efficacy of seed-dressing insecticides against an early-season sucking pest complex. Five treatments, including imidacloprid 70%, thiamethoxam 20% + metalaxyl - 20% + difenoconazole 2%, thiamethoxam 35% FS, thiamethoxam 25% WG, and untreated control, were evaluated in a randomized complete block design replicated four times. The results showed that the use of seed-dressing pesticides had a significant (P<0.05) influence on the populations of aphids, whiteflies, cotton jassids, and mealybugs. The thiamethoxam 25% WG was the most effective insecticide, with the highest pest reduction percentage and the lowest pest population resulting in significantly higher yield. This finding implies that thiamethoxam 25% WG can control early season sucking pests in cotton from emergence to six weeks in irrigated areas. Therefore, the use of thiamethoxam 25% WG as a seed dresser can be recommended as an option for controlling early season sucking pest complexes of cotton to prevent yield loss.

Keywords*:* cotton, industrial crop, seed treatment, sucking pests, thiamethoxam

Introduction

Cotton (*Gossypium hirsutum* L.) is a significant industrial crop that grows continuously (Constable and Bange, 2015). Its production greatly affects the economic development of sub-Saharan Africa (Amanet et al., 2019). In Ethiopia, cotton is a crucial crop that serves as a raw material for textile industries and contributes to foreign currency earnings by exporting lint and finished garments (EIAR, 2017). The crop faces significant threats from a diverse array of pests; among those, sucking insects plays a particularly detrimental role. Notable pests include whiteflies (*Bemisia tabaci*), aphids (*Aphis gossypii*), jassids (*Amrasca biguttula*), and thrips (*Thrips tabaci*), which have been documented to target cotton at various growth stages due to the allure of lush green foliage (Ermias et al., 2013). Additionally, cotton mealybugs (*Phenacoccus spp.*) further exacerbate the situation by infesting the crops, highlighting the complexity of pest management in this vital agricultural sector (Nurhussein et al., 2023). An increase in damage from sucking pests can lead to significant yield reductions of up to 22%, exacerbating economic challenges for growers (Hassan et al., 2021).

Cotton aphids feed on plant fluids, infesting leaves, stems, fruits, and roots, while also causing indirect harm by secreting honeydew on open lint (Sandhi and Reddy, 2020). Additionally, they transmit various viral diseases that can further compromise crop health (Edula et al., 2023). Whiteflies, prevalent worldwide, directly damage crops, hinder photosynthetic activity, and degrade cotton fiber quality. They are vectors for several economically significant viral diseases affecting crops (Mustapha et al., 2022). Thrips target dicotyledonous leaves during seedling emergence, feeding on cell contents and leaving characteristic black markings at feeding sites. Severe infestations during early growth stages can lead to the death of immature plants, especially if they lose their leaves (Abbas et al., 2020). Excessive feeding can stunt plant growth, reducing production or delaying crop maturity (Reay-Jones et al., 2017). Jassids cause leaf edges to curl and turn crimson, leading to leaf drop and the abortion of initial fruiting branches, as well as detachment of squares and immature bolls due to impaired photosynthesis (Hafeez et al., 2020).

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Cotton mealybugs are soft-bodied insects that extract sap from the phloem tissues of host plants, leading to stunted growth and fewer, smaller bolls. Infested plants exhibit twisted, yellowing leaves that eventually fall off (Waqas et al., 2021). Effective pest control strategies are essential to mitigate the impacts of these pests on cotton production in Ethiopia.

Using chemical pesticides is often seen as a necessary measure for protecting cotton from various pests, which is essential for achieving higher yields and quality (Kanwal et al., 2019). Even technologically advanced countries allocate approximately 3% of their agricultural market value to pesticide use and applications (Hanif et al., 2022). In the Middle Awash Valley, cotton growers frequently spray insecticides to safeguard their crops. However, foliar applications can disrupt ecosystems by harming beneficial organisms such as predators, parasitoids, and pollinators (Moser and Obrycki, 2009).

In contrast to foliar applications, numerous studies have indicated that seed treatment with systemic insecticides represents a more promising, eco-friendly, cost-effective, and selective method for controlling sucking pests with minimal risks to mammals and non-target natural enemies (Karolayne et al., 2023). Despite these advantages, there is limited research on the effectiveness of seed-dressing pesticides for managing early-season sucking pests on cotton in the Middle Awash area of the Afar region. Therefore, this study aims to evaluate the efficacy of seed treatments against early-season sucking insect pests affecting cotton in this region of Ethiopia.

Methodology

Description of Experimental Site

The experiment was conducted at the Werer Agricultural Research Center (WARC) under field conditions during the 2021 and 2022 growing seasons. The WARC is 90 20’ 31” N and 400 10’ 11” E. The area has an inconsistent annual rainfall of 540 mm, with mean maximum and minimum temperatures of 34.4 and 19.6°C, respectively (Wondimagegne and Abere, 2012).

Treatments and Experimental Design

Five treatments, including untreated control, were arranged in a randomized complete block design (RCBD) replicated four times. In total, there were 20 plots in the experiment. The specific details of each treatment are summarized in Table 1.

Treatment Application and Agronomic Practices

Appropriate dosage of each insecticide namely imidacloprid at 5 $g.kg^{-1}$, thiamethoxam 20% + metalaxyl 20% + difenoconazole 2% at 2.5 $g.kg^{-1}$, thiamethoxam at 4 $mL.kg^{-1}$, and thiamethoxam at 7 $g.kg^{-1}$ (Table 1) were weighed separately and mixed thoroughly with the polyvinyl alcohol (PVA) polymer sticker. The seeds from each cotton gram were placed in separate polythene bags, and chemicals were added and mixed until fully coated. The seed dressings were applied one day before sowing, after which the seeds were left to dry at 32°C under the shade. Seeds for a control treatment (without insecticide) were shaken with water rather than an insecticide solution.

The cotton variety “Werer-12”, obtained from the research center, was sown in the first week of May. The area of each plot size was 63 m^2. The spacing between the rows and plants was 90 cm and 20 cm, respectively. The plots were irrigated eight times at 10-day intervals with the amount of 125 mm following the initial irrigation and watered every 15 days until 65% of the bolls had opened. Hand hoeing was performed to control weeds at 20, 35, and 75 days after the crop emerged.

Inspection and Data Collection

An inspection was conducted on each plot starting two weeks after the crop emergence and continuing through the seventh week. Five plants were randomly

Table 1. Description of treatments used in the experiment

Treatment No.	Active ingredient and formulation	Trade Name	Rate per kg of seed	Classification
T1	Imidacloprid 70% WP	Fighter 70%WP	5 g	Neonicotinoid
T2	Thiamethoxam 20% + metalaxyl - 20% + difenoconazole 2%)	Apron Star 42 WS	2.5 g	Neonicotinoid+ Carcinogen+ dioxolanes
T3	Thiamethoxam 35% FS	Cruiser 35% FS	4 ml	Neonicotinoid
T4	Thiamethoxam 25%WG	Amicoster 25% WG	7 g	Neonicotinoid
T5	Untreated (control)	-	-	-

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selected for statistical representation and minimizing variability and tagged for data collection. The numbers of aphids, whiteflies, and thrips on the top, middle, and bottom leaves on both sides of leaves, respectively, were counted using the visual method with the help of a hand lens. This counting was performed every seven days in the early morning. Additionally, beneficial insects were also recorded. At crop maturity, the total boll weight of the seed cotton plants in each plot was harvested separately and weighed as kg per plot, which was finally expressed as a ton per hectare.

Percentage reduction in pest population or inhibition rate (percentage IR) was calculated as per the method described by Tapondju et al. (2002) using the following formula:

$$Inhibition\ Rate\ (\%) = \frac{(Cn - Tn)}{Cn} * 100$$

Where,
C_n = the number of pest populations in the untreated plots and
T_n = the number of pest populations in the treated plots

Data Analysis

All data were analyzed using PROC GLM (SAS Version 9.0, SAS Institute, 1999). The PROC UNIVARIATE test was used to test the data's normality and homogeneity of variance based on the Shapiro–Wilk test. To satisfy the assumptions of ANOVA, insect count data were square root-transformed (√x+0.5) employed to stabilize variance and improve normality and homogeneity of the data. When F values were significant (P < 0.05), means were compared by Fisher's least significant difference (LSD) test.

Results and Discussion

The effectiveness of various seed treatment insecticides for controlling sucking pests on cotton varieties under field conditions is presented in the tables below. In 2021, the results showed that, compared with the untreated control, seed treatment with different insecticides significantly (P< 0.05) reduced the number of aphids, whiteflies, jassids, and mealybugs while there were no significant differences among each treated seed (Table 2). Among the tested chemicals, thiamethoxam 25% WG had the greatest effect on the pest population compared to the control for whiteflies (73.53), jassids (75.97), thrips (83.33), and mealybugs (83.33) (Table 2). Thiamethoxam is a systemic neonicotinoid insecticide that acts as a nicotinic acetylcholine receptor agonist. It is absorbed by plants and translocated throughout their tissues, providing prolonged protection against existing and newly arriving pests due to its extended activity within the plant (Maienfich, 2005; Tomizawa and Casida, 2009). The control plots had the highest numbers of sucking pest populations, and these trends were consistent for both the 2021 and 2022 seasons.

In the 2022 season, the populations of aphids, jassids, and mealybugs were significantly lower (P< 0.05) in the treated plots than in the untreated controls (Table 3).

The activity of natural enemies was lower in the treated plots than in the untreated control, as the population of sucking pests was very low in the treated plots. Also, this might be due to insecticides used in the treated plots may have residual effects that could negatively impact the survival and activity of natural enemies. The sole reliance on insecticides, especially without considering their long-term impact on the natural enemy and soil-dwelling beneficial microbial populations, can undermine long-term pest control strategies, leading to more frequent pest outbreaks, reduced biological control, and higher economic and environmental degradation and increased overall costs (Tables 2, 3, and 4). This decline of natural enemy populations due to insecticide use can lead to increased pest pressures, resistance development, ecosystem imbalances, and challenges to sustainable pest management practices, ultimately compromising the effectiveness of long-term pest control strategies (Mohammed, 2021).

The combined results indicate that seed-dressing insecticides had a significant (P<0.05) impact on the populations of aphids, whiteflies, jassids, and mealybugs throughout the year, while the interaction effect was not significant (P< 0.05) (Table 4). The results showed that initially, all the insecticides had greater efficacy in reducing pest population (aphids 2.09 to 3.09, whiteflies 0.04 to 0.05, jassids 0.24-0.41, thrips 0.03-0.06, and mealybugs 0.71–1.01 population per leaf), but their toxicity gradually decreased over time. None of the treatments in both seasons resulted in a significantly greater yield than the untreated controls (Tables 2, 3, and 4). Although early season sucking pests are economically important (Geremew and Ermias, 2006; Ermias et al., 2013); but the past three years the weather variability incurred unexpected rainfall which reduce the economic impact of sucking pests in all the treatments caused non-significant differences in the yield of cotton which indicated the era of climate change are alarming. Although the study highlighted the importance of seed treatment in reducing pest populations, weather

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changes were found to influence yield variation. These results suggest the need for further research under normal weather conditions and with sufficient pest pressure. The greatest reduction in pests compared to the control was observed with Apron Star 42 WS for aphids (65.18%), whiteflies (78.24%), and thiamethoxam (25%) for jassids (69.9%), thrips (72.6%), and mealybugs (66.6%), respectively (Table 4).

The data indicated that using seed-dressing insecticides resulted in a noticeable decrease in early-season insect pests. However, no significant differences were observed between the treated and untreated plots in thrips populations. Moreover, the application of insecticides was significantly more successful at controlling target-sucking pests such as thrips, whiteflies, and jassid than was the control of these pests in untreated areas. Treating cotton seeds with Apron Star 42 WS and thiamethoxam 25% WG proved to be the most effective method against early-season sucking pests in cotton.

Table 2. Efficacy of different seed dressing insecticides against early season sucking insect pests on cotton

No	Insecticides	Number of pest population per three leaves					Reduction of pest population over control (%)					Number of predators per leaf	Seed cotton yield ($ton.ha^{-1}$)
		Aphid	Whitefly	Jassid	Thrips	Mealybug	Aphid	Whitefly	Jassid	Thrips	Mealybug		
1	Imidacloprid 70% WP	1.35 (1.34)^{b}	0.07 (0.76)^{b}	0.25 (0.86)^{b}	0.14 (0.712)	1.78 (1.51)^{b}	60.60	70.59	72.87	66.67	36.88	0.33 (0.91)	3.5
2	Apron Star 42 WS	1.59 (1.41)^{b}	0.06 (0.75)^{b}	0.30 (0.89)^{b}	0.007 (0.712)	1.68 (1.47)^{bc}	53.85	76.47	67.44	86.33	40.30	0.52 (1.00)	3.3
3	Thiamethoxam 35% FS	1.40 (1.36)^{b}	0.09 (0.77)^{b}	0.44 (0.97)^{b}	0.007 (0.717)	1.79 (1.51)^{b}	59.25	64.71	52.71	66.67	36.50	0.40 (0.95)	3.4
4	Thiamethoxam 25%WG	1.39 (1.37)^{b}	0.06 (0.75)^{b}	0.22 (0.85)^{b}	0.014 (0.712)	1.15 (1.27)^{c}	59.67	73.53	75.97	83.33	59.19	0.44 (0.95)	3.3
5	Untreated Control	3.43 (1.96)^{a}	0.24 (0.86)^{a}	0.92 (1.18)^{a}	0.043 (0.736)	2.82 (1.82)^{a}	-	-	-	-	-	0.70 (1.09)	3.1
LSD		0.45	4.95	0.13	ns	0.21						0.19	ns
CV (%)		19.47	0.06	9.13	3.08	9.09						12.30	12.8

Notes: Values are means of four replications. The values in parentheses are square root-transformed values. Means followed by the same letter are not significantly different at the 5% level (LSD).

Table 3. Efficacy of different seed dressing insecticides against early-season sucking insect pests on cotton

No	Insecticides	Number of pest population per three leaves					Reduction of pest population over control (%)					Number of predator per leaf	Seed cotton yield ($ton.ha^{-1}$)
		Aphid	Whitefly	Jassid	Thrips	Mealybug	Aphid	Whitefly	Jassid	Thrips	Mealybug		
1	Imidacloprid 70% WP	4.81 (2.30)^{b}	0.03 (0.73)	0.29 (0.88)^{b}	0.08 (0.76)	0.41 (1.95)^{b}	56.43	60.00	60.00	38.89	60.81	0.42 (0.96)^{b}	4.6
2	Apron Star 42 WS	2.59 (1.75)^{b}	0.01 (0.72)	0.28 (0.88)^{b}	0.06 (0.75)	0.27 (0.87)^{bc}	76.50	80.00	62.00	50.00	74.66	0.60 (1.05)^{ab}	4.2
3	Thiamethoxam 35% FS	4.29 (2.18)^{b}	0.02 (0.72)	0.39 (0.94)^{b}	0.007 (0.75)	0.26 (0.87)^{b}	71.15	70.00	45.00	44.44	75.34	0.48 (0.98)^{ab}	4.2
4	Thiamethoxam 25%WG	3.64 (2.01)^{b}	0.01 (0.72)	0.26 (0.87)^{b}	0.05 (0.74)	0.28 (0.88)^{c}	66.98	80.00	64.00	61.11	73.99	0.57 (1.02)^{ab}	4.3
5	Untreated Control	11.63 (3.34)^{a}	0.07 (0.76)	0.71 (1.09)^{a}	0.13 (0.79)	1.06 (1.24)^{a}	-	-	-	-	-	0.81 (1.15)^{a}	3.8
LSD		0.64	ns	0.11	ns	0.18						0.18	ns
CV (%)		18.06	3.50	7.98	5.2	11.99						11.20	20.5

Notes: All values are means of four replications. The values in parentheses are square root-transformed values. Means followed by the same letter are not significantly different at the 5% level (LSD).

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Table 4. Efficacy of different seed dressing insecticides against early-season sucking insect pests on cotton: Werer, 2021 & 2022

No	Insecticides	Number of pest population per three leaves					Reduction of pest population over control (%)					Number of predators per leaf	Seed cotton yield (ton.ha^{-1})
		Aphid	Whitefly	Jassid	Thrips	Mealybug	Aphid	Whitefly	Jassid	Thrips	Mealybug		
1	Imidacloprid 70% WP	3.08 (1.82)^{b}	0.05 (0.74)^{b}	0.27 (0.87)^{c}	0.06 (0.74)	1.10 (1.23)^{b}	58.52	65.30	66.44	52.78	48.85	0.38 (0.94)^{b}	4.0
2	Apron Star 42 WS	2.09 (1.58)^{b}	0.04 (0.73)^{b}	0.29 (0.88)^{bc}	0.04 (0.73)	0.98 (1.17)^{bc}	65.18	78.24	64.72	68.17	57.48	0.56 (1.03)^{ab}	3.7
3	Thiamethoxam 35% FS	2.84 (1.77)^{b}	0.05 (0.74)^{b}	0.41 (0.96)^{b}	0.04 (0.74)	1.03 (1.19)^{bc}	65.20	67.36	48.86	55.56	55.92	0.44 (0.97)^{b}	3.8
4	Thiamethoxam 25%WG	2.51 (1.69)^{b}	0.04 (0.73)^{b}	0.24 (0.86)^{c}	0.03 (0.73)	0.71 (1.08)^{c}	63.33	76.76	69.99	72.22	66.59	0.51 (0.99)^{b}	3.8
5	Untreated Control	7.23 (2.65)^{a}	0.16 (0.81)^{a}	0.82 (1.14)^{a}	0.09 (0.76)	1.94 (1.53)^{a}	-	-	-	-	-	0.76 (1.12)^{a}	3.4
	CV (%)	18.40	4.66	8.31	4.64	10.84						10.54	17.3
	Treatment	***	**	***	Ns	***						*	ns
	Year	***	**	ns	**	***						ns	***
	Treatment *Year	ns	ns	ns	ns	ns						*	ns
	LSD (0.05)	0.36	0.04	0.08	0.04	0.14						0.11	0.67

Notes: *, **, and *** significant at $P < 0.05$, $P < 0.01$, and $P<0.001$. All values are means of four replications. The values in parentheses are square root-transformed values. Means in the same column followed by the same letter are not significantly different at the 5% level (LSD).

This study uncovers new insights into pest management in cotton agriculture, particularly highlighting the effectiveness of thiamethoxam 25% WG. This aligns with previous research by Torres and Ruberson (2004), indicating the effectiveness of neonicotinoids; however, the extent of pest reduction observed in this study (e.g., 73.53% for whiteflies and 83.33% for mealybugs) is notably higher than reported in earlier studies, which often cited lower efficacy rates for similar treatments. Recent studies further support our findings; for instance, Sreenivas et al. (2019) reported that imidacloprid 60 FS at 10 mL.kg^{-1} seeds and thiamethoxam 35 FS at 15 mL.kg^{-1} seeds effectively managed thrips and leafhoppers in okra for up to 40 days after germination, leading to improved fruit set. Thiamethoxam, a seed-dressing insecticide, binds to nicotinic acetylcholine receptors, suppressing early sucking pests (Prasanna et al., 2004). Notably, recent research by Kumar et al. (2020) highlighted that thiamethoxam formulations (such as Cruiser and Actara) exhibited substantial initial reductions in pest populations two to seven weeks post-treatment, with reductions of 89.9%, 90.5%, and up to 100% for thrips, aphids, jassids, and whitefly adults and nymphs, respectively. Additionally, Maury et al. (2015) and Hong et al. (2018) found that treating tomato plants with thiamethoxam 70% WS at 4.2 g a.i. or 6 g.kg^{-1} was particularly effective against early-season sucking pests like aphids and thrips, maintaining efficacy for up to 49 days post-sowing. The combination of imidacloprid and thiamethoxam has also been shown to be effective against thrips (El-Naggar, 2006; Xiao-Rui et al., 2023) and cotton aphids (El-Zahi and Aref, 2011) for up to seven weeks after planting. Furthermore, recent studies indicate that thiamethoxam continues to effectively control aphids and jassids (Dhawan et al., 2008), reinforcing its role as a vital component in integrated pest management strategies. These findings collectively underscore the importance of thiamethoxam and imidacloprid in managing key agricultural pests, thereby enhancing crop yield and quality. Moreover, the study highlights the potential trade-off between pest control and the health of predator insect populations. While the treated plots exhibited lower pest populations, the corresponding decline in natural enemies raises concerns about long-term pest management sustainability. This finding is similar to Rabia et al. (2015), who found that using neonicotinoids led to fewer beneficial arthropods, with lower populations after higher rates. This contrasts with previous research suggesting that certain insecticides (imidacloprid doses of ≤5 g.kg^{-1}) could be used without affecting the abundance of natural enemies.

Conclusions

The present study demonstrated that the seed treatment of cotton seeds with thiamethoxam 25 WG was found to be the most effective method for controlling early-season sucking pests. Although it has no significant impact on cotton yield, this

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treatment was observed to be capable of reducing the pest population for up to six weeks after emergence in irrigated areas. The study suggests that seed treatment with thiamethoxam 25 WG can be included in a cotton Integrated Pest Management (IPM) package to provide effective solutions for early season sucking pest control for sustainable cotton production. In the future, studies should be conducted on the effects of seed dressings on beneficial insects and the cotton ecosystem of an agroecosystem. Moreover, there is a possible synergistic effect of combining seed treatments with other pest management strategies, such as biological control agents or resistant varieties for sustainable development.

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