International Journal of Tropical Agriculture
Volume 43, Numbers (3-4) • 2025 : pp. 295-306
ISSN: 0254-8755

Management of Chemical Insecticides and Their Frequency Against Bollworm in Pepper Varieties in Bako, Western Ethiopia

Shiferaw Talga[1], Tadele Shibiru[1*] and Abraham Negera[2]

[1]*Department of Plant Sciences, School of Agriculture, Guder Mamo Mezemir Campus, Ambo University, Ambo, Ethiopia*
[2]*Bako Agricultural Research Center, Oromia Agricultural Research Institute, Bako, Ethiopia*

Abstract: Hot pepper, Capsicum species, is the most widely cultivated and economically important crop in Ethiopia, particularly in Western Oromia. Helicoverpa armigera (Lepidoptera: Noctuidae) is a major factor and constraint to hot pepper production and yield losses in Ethiopia. The research was conducted at Bako Tibe in 2023. The treatments consisted of three hot pepper varieties (Local variety, Bako local, and Marako fana), different frequencies of insecticide application, and three different insecticides (Pyriban 48% EC, Karate 5% EC, and Sivanto energy 85 EC). The experiment was laid out as a Randomized Complete Block Design (RCBD) and replicated thrice. Insect infestation parameters were assessed from 10 pre-tagged plants per plot. The results revealed that the frequencies interacted significantly ($P \leq 0.05$) with differences in yield and insect-infested pod per plant. The result of variety, chemical, and frequency indicated that the application of Sivanto Energy EC 85 on Marako fana (0.01) and Bako local (0.03) two times significantly managed bollworm on hot pepper pod infestation. However, the Mareko fana with Sivanto Energy EC 85 repeated two times gave the highest yield per hectare. Therefore, the application of Sivanto Energy EC 85 on Mareko Fana with two applications is recommended for hot pepper production in the study area and food security in Ethiopia.

Keywords*:* Frequency, Hot pepper, *Helicoverpa armigera*, Insecticides, Variety, Yield.

INTRODUCTION

Hot pepper (*Capsicum species*) belongs to the family of Solanaceae and originated in the New World tropics and subtropics (Mexico, Central America, and Andes of South America) over 2000 years ago (Dessie and Birhanu, 2017). It is the world's second most important vegetable crop, ranking after tomatoes, and is the most-produced type of spice flavoring and coloring food while providing essential vitamins and minerals (Dias et al., 2013). It is believed to have originated in Central and South America, after which it spread into the New World Tropics before its subsequent introduction into Asia and Africa in 1493 (Bosland and Votava, 2000). Recent Carbon dating research indicates that Mexico is the origin of hot peppers (Kraft et al., 2014).

Hot pepper (*Capsicum species*) dominates the world spice trade (Bekele, 2022), with the world production area estimated at 3.7 million ha (FAOSTAT, 2018). In Ethiopia, hot pepper serves as a high-value vegetable and spice and is used in dishes, fresh "karia," and"berbere" proceed products. In the processing industries (coloring agent) locally and exported in the form of oleoresin (red pigment) and ground powder in different forms (Yemane, 2017). The total area of hot pepper production for green

Article History: Received: 06 July 2025; Revised: 14 September 2025; Accepted: 25 September 2025; Published: 30 November 2025

pods was about 54,376 ha, with a total output of about 770,349 quintals (CSA, 2018).

Ethiopian climate and edaphic conditions favor Capsicum production under both rainy season and irrigated conditions (Dessie and Birhanu, 2017). The largest parts of Ethiopian regions are suitable for hot pepper production (Rutgers, 2010). The planting of red peppers occupies 180,701.46 hectares of land, and the cover of 9,832.28 ha of green peppers received 1.83 t ha^{-1} red pepper and 6.3 t ha^{-1} green pepper in Ethiopia, respectively (CSA, 2021).

Bollworm, *Helicoverpa armigera* (Hubner) (*Lepidoptera: Noctuidae)* is a polyphagous insect pest that attacks several economically important crops such as cereals, sorghum, cotton, pepper, sunflower, safflower, flax and Niger seed. During the pest outbreaks, the larvae damage leaves, tender shoots, apical tips, flower buds, and pods (Tebkew & Ojiewo, 2017). It causes considerable yield loss both in quality and quantity, thus leading to various socio-economic problems. Hot pepper is a crucial crop in Ethiopia, particularly in the production of paprika and capsicum oleoresins for the export market. However, the management of bollworm (*Helicoverpa armigera*) in hot pepper, especially in the Bako Tibe district, has not been adequately addressed. The majority of hot pepper production is carried out by small-scale farmers, primarily as mono-crops during the main rainy season, often rotated with cereals or legumes. Despite the increasing productivity of hot peppers in Ethiopia, several constraints are affecting the production system for both green and dry pods. Hence, to tackle these challenges, the application of insecticides at different varieties of hot pepper is one to two times the frequency of applications.

MATERIALS AND METHODS

Description of Study Area

The experiment was carried out during the main cropping season (May to November) of 2023 at Bako Agricultural Poly Technic College, which is located in western Ethiopia. It is located at an altitude of 1634 m above sea level and 09^{o} 06.9263' N latitude and 37^{o} 03.3492'00" E longitude. The mean annual rainfall of Bako from January to December was 1335 mm, with a warm humid climate having mean minimum, mean maximum, and average atmospheric temperatures of 13.7^{o}C, 28.7^{o}C, and 21.1^{o}C, respectively. The predominant soil type of the area was Nitosols, which was characteristically reddish brown and clay in texture with a pH that falls in the range of very strongly acidic to strongly acidic (4.8-5.8), according to a rating done by Jones (2003).

Experimental Materials

The two released varieties and one local farmer's seed of hot pepper (Local Variety, Mareko Fana, and Bako Local), which were obtained from Bako Agricultural Research Center were used for the implementation of the experiment. Experimental material and features of varieties are shown in (Table 1), different insecticides (Karate 5 % EC, Pyriban 48 % EC, and Sivanto energy 85 EC) (Table 1) and different frequencies of insecticides (untreated control, one and two times chemical application) were used for the experiment.

Table 1: Description of insecticides used in the experiment

Common name	*Trade Name*	*Frequencies*	*Rate in liter/ha*
Deltamethrin + flupyradifurone	Sivanto energy 85 EC	1 2	1.2
Chlorpyriphos	Pyriban 48 % EC	1 2	2.0
Lambda-cyhalothrin	Karate 5 % SC	1 2	0.3
Untreated Control			

Treatments and Experimental Design

The experiment had 21 treatments with a combination of three hot pepper varieties, three insecticides, and different frequencies. The first sprays of insecticides were started soon after the initial infestation of pod appearance of bollworm symptoms and continued on the basis of treatment spraying frequency. The treatments were arranged in Randomized Completely Block Design (RCBD) with three replications.

Experimental Procedure

The experimental field was plowed once and harrowed and leveled to make it suitable for sowing and planting. Three different hot pepper seeds were on seedbed size of 1x3m. The seedbed was covered with dry grass for 20 days. Then, beds were covered by raised shade to protect the seedlings from strong sunshine and heavy rainfall until the plants were ready for transplanting. Watering was done based on climatic conditions with a fine watering cane and was hand weeded and fungicide (Mancozeb 80%WP) was applied at the rate of 3.6 kg/ha) before the fungal devastation as a preventive activity. Then the seedling was transplanted after 45 days of sowing at 30 × 70 cm spacing between plants and rows respectively in a gross plot size of 10.5m^2 (3.5 × 3 m) with 1 m between plots and 1.5 m between blocks. The middle three rows were used for data collection leaving the two rows as borders. Each insecticide is applied as frequencies assigned to each plot to get the maximum protection potential of insecticides (Hossain *et al.,* 2010) with the help of a "Solo Knapsack hand sprayer" with a 1-liter capacity bottle. The Periodic inspection of the hot pepper field was made to notice the phenology of the crop and target the insect population. The first application was made when the larval population crossed the economic threshold level (one larva per meter row) at the pod setting stage of the crop, and the second sprays were applied at a week interval to get maximum protection of the pest (Singh et al. 2018). The phonological parameters and growth characteristics, number of larva/plant, pod tunneled, and marketable and unmarketable yields of hot peppers were collected and measured at different stages.

The pod damage

The pod damage percent was noted during the harvesting of matured crops. Healthy and damaged pods were counted randomly from ten selected plants per plot, and then the percent pod damage was evaluated as Savary & Willocquet (2014).

$$\text{Percent pod damaged} = \frac{\text{Total number of pods damaged}}{\text{Total number of pods}} x100$$

In the experiments plot, a different frequency of spray was applied using a hand-operated knapsack sprayer based on natural infestation when the economic threshold level was 10 larvae per 100 plants. The first round of spray application was made when the economic threshold level coincided with the period of formation of the pod initiation of the hot pepper, and the subsequent sprays were applied at a 15-day interval insect scouting. Ten plants were tagged in each plot pod of plants to start infested and bolls were counted for data collection.

Data analysis

All data were subjected to analysis of variance (ANOVA) using the general linear model (GLM) procedure of SAS Statistical version 9.2 software (SAS 2009). The least significant difference (LSD) test was used to separate differences in treatment means of main factor effects where significant variation was observed at a 5% probability level.

RESULTS AND DISCUSSIONS

Phonological parameters of hot pepper

Days to 50% of flowering

The analysis of variance indicated that the main effect of variety had a significant effect ($P \leq 0.05$) on days to 50% flowering however, the main impact of chemicals and frequency as well as their interactions had no significant effect. The highest days to 50% of flowering (68.6 days) were recorded for the Bako local variety, while the lowest days to 50% of flowering (56.71 days) were recorded for the Local variety (Figure 1). Earliness or lateness in the days to 50% flowering might have been due to their inherited characteristics, early acclimatization to the growing area to enhance their growth and development, and due to the transplanting disturbance since it is subjected to loss of feeder roots during uplifting, and consumed their energy to repair damaged organs and thus the process demanded them more time to resume shoot growth. Moreover, the earliness or delay in days to flowering could also be affected by the high temperature of the growing area, which may enhance the flowering nature of the crop. This result is in line with the findings of Arega et al. (2023), who reported that the earliness or delay in the flowering of pepper plants was affected by the growing environment. Similarly, Haileslassie et al. (2015) also reported different flowering and maturity dates for different varieties.

Days to 90% of Maturity

The analysis of variance indicated that the main effect of variety had a highly significant effect (P≤ 0.001) on days to 90% of maturity however, the main effect of chemicals and frequency as well as their interactions, had no significant (P ≥ 0.05) effect. The highest days to 90% of Maturity (149.71 days) were recorded for the Bako local variety, while the lowest days to 90% of Maturity (141.05) were recorded for the Local variety (Table 3). This might have been due to the late flower of Bako local variety more than other varieties, with days to 90% of the Maturity of Bako local variety delayed. Moreover, the variations in days to first harvest (maturity) could be due to the differences in the growing environment climatic conditions and or due to the genetic make-up of the varieties (Figure 1). This result is in line with the findings of Seleshi (2011) that the day to 90% of Maturity was affected significantly by the growing environment and the variety itself.

Plant height (cm) and number of branches per plant

The analysis of variance indicated that the main effect of variety had a highly significant effect (P≤ 0.05) on Plant height and the number

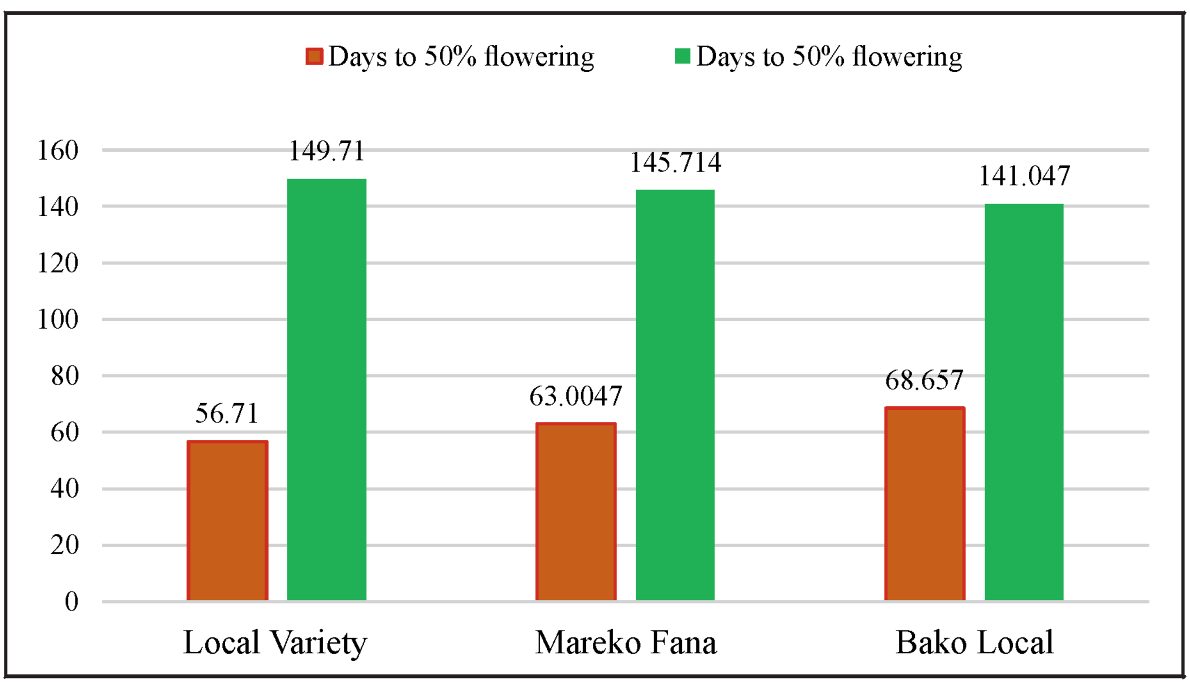

Figure 1: Main effects of Hot pepper variety on Phonological parameters

of branches per plant (Figure 2 1). However, the main effect of chemicals and frequency as well as their interactions, had no significant impact. The variations concerning plant height and number of branches ranged from 54.55cm to 60.96 cm and 2.00 to 2.28, respectively. However, the longest plant height and the highest number of branches were recorded from the Bako Local variety (60.95cm) and Marko fana (2.28) hot pepper varieties, respectively (Figure 2). This could be due to the genetic variations that existed between varieties and or due to the favorable influence of organic and inorganic nutrients present in the soils or the growing environment which goes in line with the findings of Seleshi (2011) stated the presence of an adequate amount of organic nutrients in the soil improves the growth of pepper plants. This result is in line with Kibiru et al. (2021), who state that plant height differences due to the varietal variability to absorb the nutrients from the soil.

Canopy diameter (cm)

The analysis of variance indicated that the main effect of variety had a significant effect (P 0.05) on canopy diameter (Figure 2); however, the main effect of chemicals and frequency, as well as their interactions, had no significant effect on Canopy diameter. The highest canopy diameter (46.29cm) was observed under the Bako local variety, while the lowest canopy diameter (36.36cm) was observed under the Local variety. This variation in canopy diameter between varieties might be due to their inherited traits, the growing environment's soil type, rainfall, and soil pH. Moreover, on the other hand, it may determine the yielding potential of the crop since varieties with wider canopy diameter could produce more fruit (pods) than varieties with narrow canopy due to the increased number of secondary and tertiary branches, which are the locations for fruit bud formation. This conforms with the work of Kibiru et al. (2021), who reported the widest canopy diameters from the variety Melka Awaze (45.8 cm) and the narrowest (33.56 cm) from the Bako Local variety.

Number of Pod per Plant, Pod Length, and Pod Width

The main effect of variety showed a highly significant effect on the Number of Pod per Plant, Pod Length and width, and a significant

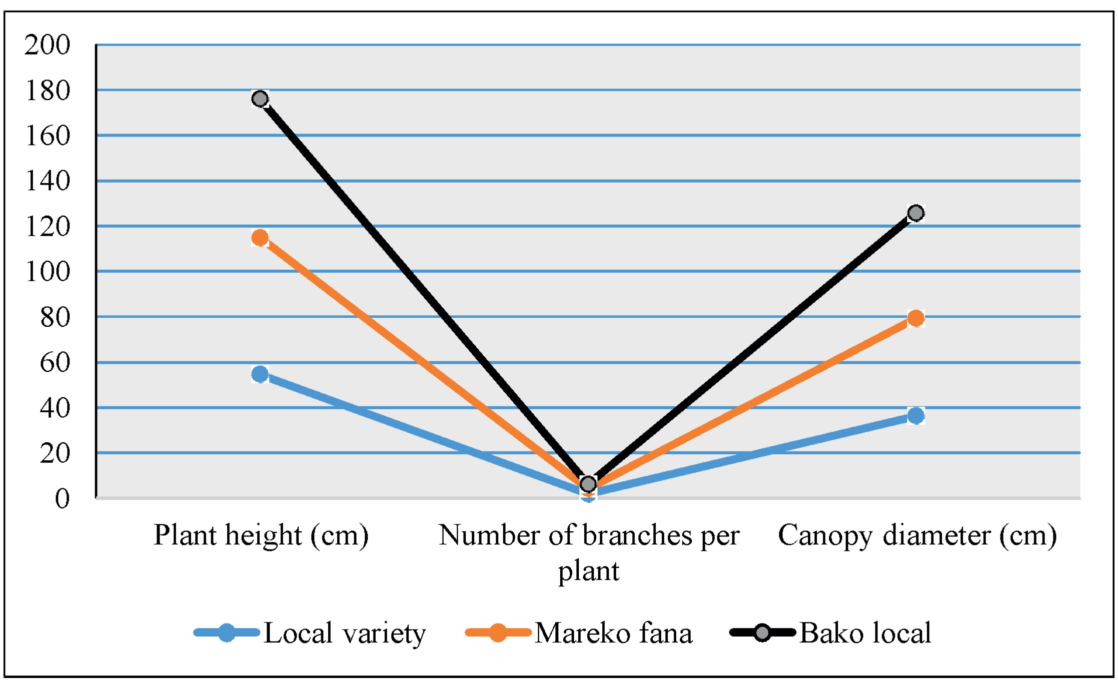

Figure 2: Main effects of Growth parameters of Hot pepper

effect on average pod weight; however, the main effect of chemicals and frequency, as well as their interactions, had no significant effect on Number of Pod per Plant, Pod Length and Pod width (Table 2). The highest number of pods per plant (48.52), and Pod Length (10.90cm) were observed from Bako local variety, while the lowest number of pods per plant (33.61) and Pod Length (9.28cm) were observed from the Local variety. However, the highest pod width (2.36cm) was observed from Marko Fana, and the lowest pod width (1.93cm) was observed from the local variety (Table 2). The varietal difference in pod per plant, pod length, and pod width might be due to the individual gene effect of each variety. Similarly, Shahzad *et al*. (2018) Pesticides affect the biochemical, physiological, and morphological functions of plants, damage cell organelles, and decelerate plant growth and development, ultimately abridging crop production. This study was under previous reports by Kibiru et al. (2021) who observed that the highest number of pods per plant (24.36) and pod length (9.63cm) were recorded from Malka Awaze and the lowest number of pods per plant (14.07) pod length (7.77cm) was recorded from Local check varieties. Similarly, they observed that the highest (5.94cm) and the lowest (4cm) pod diameters were recorded from Mareko Fana and Malka Shote varieties, respectively. Similarly, Seleshi et al. (2014) found that the significant difference in pod number, length, and pod width among varieties could be due to the genetic makeup of the varieties and or due to the agro-ecological variations in which the varieties were evaluated.

Pod infestation before chemical application

Analysis of variance showed that pod damage and larval count significantly (P≤ 0.05) differed between the varieties (Table 3). Pod damage per plant showed that the local variety has the highest score of 0.423, followed by the Bako local variety with a score of 0.395, and the Mareko Fana variety with a score of 0.386. A number of larvae counted per pod showed a similar pattern with the pod damage per plant. The local variety exhibits the highest score of 0.377, followed by Bako local 0.237, and the Mareko fana variety with a score of 0.20. The variation of the two parameters may be due to the difference in the varieties' resistance to the pest.

These results suggest that the local variety is more susceptible to bollworm infestation, as indicated by both the higher pod damage per plant and the higher number of larvae counted per pod. These findings highlight the importance of selecting resistant varieties when managing bollworm infestation in hot pepper crops. By choosing varieties with lower susceptibility to bollworms, farmers can potentially reduce pod damage and larval infestation, leading to improved crop productivity and quality.

Table 2: Main effects of yield Components of Hot pepper

Treatments	*Number of pods per plant*	*Pod length (cm)*	*Pod width (cm)*
Local Variety	33.61^{c}	9.28^{c}	1.93238^{c}
Mareko fana	43.89^{b}	9.92 ^{b}	2.3619 ^{a}
Bako local	48.52 ^{a}	10.90^{a}	2.066 ^{b}
Mean	42.005	10.03	2.12
LSD at 0.05	0.76	0.41	0.19
CV (%)	12.91	16.54	15.60

Note: Means with the same letter(s) in the columns are not significantly different for each other All treatment effects were significant at p ≤ 0.05 least significance difference (LSD)

Table 3: Number of larvae count/pods pre spray chemicals

Varieties	*Pod damage/plant*	No. of larvae count/pods
Local Variety	0.423^{a}	0.377a
Bako local	0.395^{b}	0.237b
Mareko fana	0.386^{c}	0.20c
LSD at 0.05	0.072	12.56
CV (%)	16.121	12.011

Note: Means with the same letter(s) in the columns are not significantly different for each other All treatment effects were significant at p<0.05 least significance difference (LSD

Pod infestation percentage (PODIFP)

The effect of different insecticide applications significantly affects pod infestation percentage (PODIFP) (Table 4). Amongst the hot pepper varieties that did not receive any chemical application, the local variety exhibited the highest PODIFP score at 14.64%, followed by Bako local at 9.04% and Mareko fana at 8.64%. These scores indicate the extent of pod infestation caused by bollworms on different hot pepper varieties. These results are in line with Sujayanand et al. (2020), while the highest percent infestation was recorded in the untreated plot.

The application of insecticide chemicals yielded significant reductions in the percentage of pod infestation. The application of Pryiban chemical resulted in pod infestation percentages of 1.96% for Bako local, 2.86% for the local variety, and 1.81% for Mareko fana. Similarly, the application of Karate and Sivanto chemicals also led to decreased pod infestation across the different varieties. Notably, the treatments involving Sivanto chemical exhibited the lowest pod infestation percentages, with scores of 0.69% for Bako local, 0.91% for Mareko fana, and 1.57% for the local variety. Therefore, the result suggests that the application of insecticide chemicals, particularly Sivanto, Karate, and Pryiban, effectively reduced the pod infestation percentage caused by bollworms in hot pepper plants, regardless of the variety.

The result showed that the local variety without chemicals exhibited higher damage percentages, higher pest occurrence, and longer infestation periods compared to the other tested varieties (Bakol ocal and Mareko fana). This indicates that the local variety may be more susceptible to bollworm infestation. These results are in line with Sujayanand et al. (2020), while the highest percent infestation was recorded in the untreated plot.

Table 4: Effect of chemical insecticides on Africa bollworm, ***Helicoverpa armigera*** **infestation in three varieties of peppers**

Varieties	*chemicals*	*PDAFCHA*	*IPASCHA*	*DPP*	*PODIFP*
Local	Untreated control	2.20^{a}	2.67^{a}	4.87^{a}	14.64^{a}
	Pyriban 48 % EC	0.40^{d}	0.57^{d}	0.97^{d}	2.86^{c}
	Karate 5 % EC	0.38^{d}	0.40^{f}	0.78^{e}	2.37^{d}
	Sivanto energy 85 EC	0.28^{ef}	0.25^{g}	0.53^{gh}	1.57^{efg}
Bako local	Untreated control	2.07^{b}	2.27^{b}	4.33^{b}	9.04^{b}
	Pyriban 48 % EC	0.45^{d}	0.50^{de}	0.95^{d}	1.96^{de}
	Karate 5 % EC	0.30^{e}	0.42^{ef}	0.72^{ef}	1.46^{fg}
	Sivanto Energy 85 EC	0.22^{f}	0.12^{h}	0.33^{i}	0.69^{i}
Mareko fana	Untreated control	1.60c	2.13^{c}	3.73^{c}	8.64^{b}
	Pyriban 48 % EC	0.38^{d}	0.42^{ef}	0.80^{e}	1.81^{ef}
	Karate 5 % EC	0.23^{ef}	0.35^{f}	0.58^{fg}	1.33^{gh}
	Sivanto energy 85 EC	0.22^{f}	0.18^{gh}	0.40^{hi}	0.91^{hi}
LSD (0.05)		0.1021	0.0065	0.19	0.62
CV (%)		11.20	12.58	9.72	12.7

Where: PDAFCHA = Pod damage after the first chemical application, PDASCHA = Pod damage after the second chemical application, POP = population percentage damage, PODINFP = Pod infestation percentage.
Treatments with the same letter in a column are not significantly different at $p<0.05$ least significance difference (LSD)

The main effect of varieties and frequency of chemicals had a highly significant effect (P≤ 0.001) on pod infestation after the second application, as their interaction had a significant effect (P ≤ 0.001) on pod infestation after two times of application (Table 4). Among the hot pepper varieties that did not receive any chemical application, the local variety had the highest pod damage at 2.66, followed by Bako local at 2.26 and Mareko fana at 2.13 (Table 4). The interaction of variety and chemical frequency showed significant variation in PDAFCHA, PDASCHA, PDP, and PODIFP. The lower (0.176) infested pod-infested pod was recorded on Marako fana sprayed twice followed by Bako local (0.177) with a similar frequency which was at par between them (Table 4). The frequencies of application of insecticides have resulted in a low *H. amigera* larva population due to highly effective controlling pest infestation. Salama *et al.* (2013). Similarly, the result reported that Sivanto and Karate proved to be the best over chlorpyriphos and methomyl in reducing the number of larvae based on post-spray results. Recently, the application of insecticides repeated times with a subsequent interval was reported to be effective in reducing the percentage of pod damage and mean larvae per plant and, as a result, increased grain yield ha^{-1} under field conditions and can be advised for the management of *H. armigera* (Mihretie et al., 2020).

Marketable dry pod yield (kg ha^{-1})

The main effect of variety, chemicals, and frequency as well as their interactions, had a highly significant effect (P ≤ 0.001) on Marketable dry pod yield (kg ha^{-1}) (Table 5). The mean marketable dry pod yield across all treatments was 1414.87 kg/ha. Among the treatments, Bako local Svanto Energy 85 EC in frequency 2 had the highest marketable yield of 1666.7 kg/ha, followed closely by Bako local karate infrequency 2 at 1653.93 kg/ha. The lowest marketable yield was observed in the Bako local untreated treatment with 871.43 kg/ha. The statistical analysis indicated significant differences among the treatments, with a least significant difference (LSD) value of 1.9033. The recorded variations of varieties in marketable yield could be due to their differences in genetic makeup which is in line with the findings of Fekadu and Dandena (2006), and Seleshi (2011) who reported that the magnitude of genetic variability and heritability necessary in systematic improvement of hot pepper for fruit yield and related traits.

Moreover, it might be due to Sivanto energy EC 85 insecticide acting as an insect nicotinic acetylcholine receptor, this disrupts nerve transmissions resulting in the death of the treated insects that resulted in less pod infested. This result was agreed with the result obtained by Igyuve et al. (2018), who reported that the pyrethroid class of the insecticide was effective in reducing infestation at large scale.

Unmarketable yield (kg/ ha)

The main effect of variety, chemicals, and frequency as well as their interactions, had a highly significant effect (P ≤ 0.001) on Marketable dry pod yield (kg ha^{-1}) (Table 5). Regarding the unmarketable yield, the mean value across all treatments was 62.79 kg/ha. The treatment with the highest unmarketable yield was the Local variety untreated, untreated at 74.07 kg/ha, while the lowest unmarketable yield was observed in the Mareko fana treated with Sivanto energy 85 EC at two times application frequency gave 52.2 kg/ha.

This finding was in line with Biri and Gomathinayagam (2021), who observed that the unmarketable fruits were highly significantly by different varieties which could be due to several factors including physiological factors, biotic factors, and genetic makeup of the varieties. Moreover, the results could be due to low infestation in hot pepper crops grown with Sivanto Energy

Table 5: Main effects of yield and yield parameters of Hot pepper

Varieties	*Chemicals*	*Frequencies*	*Marketable dry pod yield kg/ha^{-1}*	*Unmarketable yield (kg ha^{-1})*
Local	Sivanto energy EC 85	1	13587^{h}	68.93^{abc}
		2	1384.17^{h}	68.23^{bcd}
	Karate 5 % EC	1	1346.07^{h}	71.37^{ab}
		2	1368.27^{h}	68.97^{abc}
	Pyriban 48 % EC	1	1355.6^{h}	71.7^{ab}
		2	1342.9^{h}	69.13^{abc}
	Untreated Control		776.0^{i}	74.00^{a}
Mareko Fana	Sivanto energy EC 85	2	1593.0^{cde}	54.5^{hi}
		1	1541.3^{f}	52.0^{i}
	Karate 5 % EC	2	1571.4^{def}	55.6^{hi}
		1	1482.6^{g}	54.0^{i}
	Pyriban 48 % EC	2	1549.23^{ef}	56.9^{ghi}
		1	1536.5^{f}	54.2^{i}
	Untreated Control		812.03^{j}	59.8^{fgh}
Bako local	Sivanto energy EC 85	1	1653.9^{ab}	62.6^{ef}
		2	1667.0^{a}	61.1^{efg}
	Karate 5 % EC	1	1609.6^{bcd}	63.0^{def}
		2	1628.60^{abc}	62.0^{ef}
	Pyriban 48 % EC	1	1617.7^{abc}	62.0^{ef}
		2	$1631.77^{a\ bc}$	61.5^{efg}
	Untreated Control		871.43^{i}	65.0^{cde}
Mean			1414.9	63.0
LSD (0.05)			44.0	5.3
CV (%)			19.0	15.07

Note: Means with the same letter(s) in the columns are not significantly different for each other
All treatment effects were significant at P≤ 0.05 least significance difference (LSD)

EC 85, the lowest unmarketable yield was recorded, and due to a high infestation level in the untreated control treatment, the highest unmarketable yield was recorded due to high damage occurred. Similarly,

Correlation Analysis

There was a significant ($P \leq 0.05$) difference and positive correlation between yield and yield components after the chemical application of hot pepper (Table 5). Dry yield pod was significantly and positively correlated with pod plant per (r=0.41***), Canopy (r=0.35***), infested pod before chemical application (r=0.19), after chemical application (r=0.43**), (r=0.67***), total yield (r=0.50***) (Table 5). The observation of a positive correlation between yields and these implies insecticide application was optimum and could result in dry pod yield improvement and economic benefit management resistance. Zemedkun *et al*. (2021) provided significantly good control against *H. armigera* for the correlation between parameters of insecticide application, yield, and yield components of hot pepper.

Table 5: Correlation coefficient among parameters of Yield and Yield Components chemical application of hot pepper

	PPP	*CA*	*IPBCHA*	*IPAFCHA*	*IPASCHA*	*DPP*	*PIF*	*MY*	*UMY*	*TY*
PPP		0.92**	-0.12ns	-0.08ns	-0.09ns	-0.09ns	-0.24ns	0.41***	-0.58ns	0.40***
CA	0.92***		-0.15ns	-0.03ns	-0.06ns	-0.04ns	-0.18	0.34***	-0.53	0.33**
IPBCHA	-0.12ns	-0.15		-0.06ns	-0.05ns	-0.03ns	0.014	0.12ns	0.16	0.024*
IPAFCHA	-0.08ns	-0.03	-0.06		0.96	0.98	0.96	0.35**	0.24	0.50**
IPASCHA	-0.09	-0.06	-0.05	0.9**		0.99321	0.97105	0.43***	0.24***	0.53***
DPP	-0.09s	-0.04	-0.03	0.9	0.99		0.97568	-0.9ns	0.25	-0.90ns
PIP	-0.23ns	-0.18	0.01	0.9	0.97	0.97		-0.90ns	0.36	-0.90ns
MY	0.41ns	0.34	0.01	-0.81	-0.89	-0.90	-0.90		-0.38	0.99***
UMY	-0.58ns	-0.53	0.16	0.24	0.25	0.24	0.33	-0.38ns		-0.35ns
TY	0.40***	0.33	0.02	-0.89	-0.90	-0.90	-0.90	0.99***	-0.35	

Where: PPP: pod per plant (number), IPBCHA: infested Pod before chemical application, IPAFCHA: infested Pod after first chemical application, IPASCHA: infested Pod after Second chemical application, DPP: Damaged pod population, PIP: Pod infestation percentage (%), MY: Marketable yield (kg ha^{-1}), Umy: unmarketable yield (kg ha^{-1}),,CA: Chemical Application, TY: total yield(kg ha^{-1}).

CONCLUSIONS

The management of *H. armigera* result indicated that the pests have been a serious pest of hot pepper pod borers in Ethiopia. Almost all parameters including 50% flowering, 90% maturity, plant height, canopy, and number of branches showed low pest infestation. The highest yields of dry pods (1666 kg ha^{-1}), the highest um marketable yields of local variety untreated (74.0 kg ha^{-1}), the highest total yields were Bako local Sivanto energy 85 % EC frequency two with (1727kg/ha^{-1}) lowest total yield was observed in the Local variety untreated treatment with (850.27 kg/ha^{-1}). the study could be concluded that the application of Sivanto energy EC 85 insecticide, particularly at two times application, showed promising results in managing bollworm infestation in hot peppers. The pod damage after the first chemical application varieties and chemicals had variation in pod infestation after the first chemical application of Sivanto energy 85 % EC insecticide on Bako local and Marako fana varieties while untreated local variety indicated that the highest number of damaged pods. Pod damage after the second application was significantly affected by the interaction of varieties, chemicals, and frequency of application.

ACKNOWLEDGMENTS

The authors thank to Bako Agricultural Research Center for facilitating farm field for this research study.

CONFLICT OF INTEREST: None

FINANCIAL SUPPORT: None

ETHICS STATEMENT: None

REFERENCES

Arega, A., Solomon, T. & Miressa M. (2023). Performance Evaluation of Large-pod Hot pepper

(*Capsicum annuum*) varieties in the midland areas of Guji Zone, Southern Ethiopia. Asian Journal of Basic Science & Research, 5(4) 135-144.

Biri, B. & Gomathinayagam, P. (2021). Response of hot pepper (Capsicum annuum L.) to major

fungal diseases under field and greenhouse conditions in Horo Guduru Wollega, Oromia, Ethiopia. African Journal of Agricultural Research, 17(6), 923-932.

Boseland, P. W. & Votava, E. J. (2000). Pepper: Vegetable and spice capsicum. New York: CABI publishing

CSA (Central Statistical Agency) .(2021). Agricultural sample survey 2019/2020. Vol. I. Report on area and production of major crops (private peasant holdings, meher season). Statistical Bulletin 584, Central Statistical Agency. Addis Ababa, Ethiopia

CSA (Central Statistical Agency) .(2018). Agricultural sample survey 2017/2018. Vol. I. Report on area and production of major crops (private peasant holdings, meher season). Statistical Bulletin 584, Central Statistical Agency. Addis Ababa, Ethiopia

Bekele, D. (2022) .Opportunities and Potential of hot pepper (Capsicum annuum L.) production in

Ethiopia. European Journal of Agriculture and Forestry Research, 10(2) 14-20.

Dessie, G. & Birhanu, H. (2017). Growth and Yielding Potential of Hot Pepper Varieties under

Rain-Fed Production at Woreta, Northwestern Ethiopia. International Journal of Research Studies in Agricultural Sciences, 3(3)11-18.

Dias, G. B., Gomes, V. M., Moraes, T. M. S., Zottich, U. P., Rabelo, G. R., Carvalho, A. O., Moulin, M., Goncalves, L. S. A, Rodrigues, R., da Cunha, M. (2013). Characterization of Capsicum species using anatomical and molecular data. Genetics and Molecular Research 4(2):1-14.

FAOSTAT (2018). FAO Statistics Division 2014. Crops/ World Regions/Production Quantity/Chillies and Peppers, Green and Dried from Pick List.

Fekadu, M. & Dandena, G. (2006) Status of vegetable crops in Ethiopia. Ugandan Journal of Agriculture.

Haileslassie, G., Haile, A.,Wakuma, B. & Kedir, J. (2015). Performance evaluation of pepper (*Capsicum annum* L.) varieties for productivity under irrigation at Raya Valley, Northern, Ethiopia. Basic Research Journal of Agricultural Science and Review, 4(7): 2315-6880.

Hossain, M. S., Islam, M. S., Salam, M. A., Hossain, M. A. & Salma, M. U. (2010).

Management of chickpea pod borer, Helicoverpa armigera (Hubner) using neem seed extract and lambda-cyhalothrin in high barind tract. Journal of Bio-science, 18, 44–48.

Igyuve, T. M., Ojo, G. O. S., Ugbaa, M. S.& Ochigbo, A. E. (2018). Fall army worm (*Spodoptera frugiperda*); it'sbiology, impact and control on maize production inNigeria. Nigerian Journal of Crop Science, 5(1), 78

Jones, J. B. (2003). Agronomic Handbook: management of crops, soils, and their fertility. CRC Press, Boca Raton, Florida, USA. Pp. 482.

Kibiru, K., Alemayehu, L.& Zewdu, T. (2021). Adaptability and Performance Evaluation of

Improved Large Pod Hot Pepper (Capsicum annum L.) Varieties in West and Kellem Wollega Zones. American Journal of Agriculture and Forestry, 9(6): 366-371

Kraft, K. B., Cecil, N., Gary, L., Eike, L., Jose, D., Geo H. & Robert, G. (2014). Multiple lines of evidence for the origin of domesticated chili pepper, Capsicum annuum, in Mexico. Proceedings of the National Academy of Sciences of the United States of America.

Mihretie, A., Yimer, D., Wudu, E. & Kassaw, A. (2020). Efficacy of insecticides against African bollworm (*Helicoverpa armigera* Hubner) on chickpea (Cicer arietinum) in the lowlands of Wollo, Northeastern Ethiopia. Cogent Food & Agriculture, 6(1), 1833818a

Rutgers, T. (2010). An analysis of supply-side constraints on Ethiopian red pepper and paprika capsicum production and export: a global value chain approach. Master thesis. International Development Studies. Utrecht University.

Salama, N. R., Hartung ,M. L. & Müller, A. (2013). Life in the human stomach: Persistence strategies of the bacterial pathogen Helicobacter pylori. Nature Reviews Microbiology, 11(6).

SAS Institute (2009**).** SAS/STAT 9.2 users guide, 2nd ed. SAS Institute, Cary, NC.

Savary, S. & Willocquet, L. (2014). Simulation modeling in botanical epidemiology and crop loss analysis. The Plant Health Instructor, 173.

Seleshi, D. (2011). Evaluation Of Elite Hot Pepper Varieties (Capsicum Species) for Growth, Dry

Pod Yield andQuality Under Jimma Condition, South WestEthiopia. In Partial Fulfillment of the Requirements for the Degree ofMaster of Science in Horticulture (Vegetable Science), Jimma

Seleshi, D., Derebew, B. & Ali, M. (2014). Pepper varieties (Capsicum Spp.) for growth, dry pod yield and quality under Jimma conditions, South-West Ethiopia. Int. J Agric. Res. 9(7):364-374.

Shahid, M., Ahmed, B. & Khan, M. S. (2018). Evaluation of microbiological management

Strategy of herbicide toxicity to green gram plants. Biocatal Agric Biotechnol 14:96–108

Singh, M. C., Shukla, J.P., Pandey, U. K. & Seema, B. (2018). Efficacy of some plant products as repellent to control Helicoverpa armigera (Hübner) (Lepidoptera: Noctuidae) fed on Tomato (Lycopersicon esculentum). International of research in botany.

Sujayanand, G. K., Dibendu, D. & Farindra, S. (2020). Insect pest succession and screening for spotted pod borer tolerance in short duration pigeonpea. Journal of FOOD Legumes, 33(2): 71-76.

Tebkew, D. & Ojiewo, C. O. (2017). November). Incidence and within field dispersion pattern of pod borer, Helicoverpa armigera (Lepidoptera: Noctuidae) in chickpea in Ethiopia. Archives of Phytopathology and Plant Protection, 50(17–18), 1–17.

Yemane, K. (2017). Evaluation of hot pepper varieties (capsicum species) for growth, dry pod yield and quality at M/Lehke District, Tigray, Ethiopia, J. Nat. Natu. Sci. 2(2):25- 34

Zemedkun, A., Ferdu, A. & Geremew, T. (2021). Sequential Application of Various Insecticides for the Management of Cotton Bollworm (Hubner) *Helicoverpa armigera* (Lepidoptera: Noctuidae) in Cotton Production. East African Journal of Sciences, 15 (1) 41-50.