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ASSESSMENT OF OPTIMAL RATE AND FREQUENCY OF CYPERMETHRIN FOR THE CONTROL OF TOMATO FRUIT BORER (*Helicoverpa armigera* HÜBNER IN ABEOKUTA SOUTH-WESTERN NIGERIA

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SUMMARY

The study was carried out at the Teaching and Research Farms of the Federal University of Agriculture, Abeokuta (FUNAAB) in 2017 and 2021. Trials were laid out in a split-split plot arrangement fitted into Randomized Complete Design with three replications. The main plots comprised of tomato genotype: "Kerewa" and Roma-VF; the sub-plots comprised of Cypermethrin spray-frequencies (twice-a-week, once-a-week, twice-a-month and once-a-month). The sub-sub-plots also consisted of five Cypermethrin applications rate: 20 %, 40 %, 60 %, 80 %, and 100 % using recommended rate (2.4 litres/ha). Data were collected on the population density of *H. armigera* larvae, fruit damage and fruit yield. All data collected were subjected to Analysis of Variance and mean significant differences were separated using Least Significant Difference (LSD) at $P \leq 0.05$. Cost benefit analyses of using Cypermethrin at different rates and frequencies were carried out. The results showed that population density of *H. armigera* larvae was not significantly influenced by genotype but by rate and frequency of application of Cypermethrin in both 2017 and 2021 cropping seasons. However, there was, reduction in TFB population, fruit damage and higher fruit yield when Cypermethrin was applied at 60 % and 80 % rate once-a-week in both trials. Higher economic returns were obtained with Cypermethrin applications at 60 % and 80 % rate once-a-week. 60 % and 80 % Cypermethrin application once-a-week was therefore, effective rates and frequency of Cypermethrin required for the control of *H. armigera* on tomato in the study area.

Keywords: Tomato; *Helicoverpa armigera*; Cypermethrin; Rate; Frequency; Cost-benefit.

Tomato (*Solanum lycopersicum* L.) an essential vegetable and industrial crop of the family Solanaceae accounts for about 18 % of the average daily consumption of vegetables in Nigeria (2, 18). It is a major part of the human diet contributing to a healthy and well-balanced diet (7). Tomato fruits are consumed fresh in salads and essential condiments for sauces, soup, meat or fish, ketchup, puree, powder and juice (3). Despite the usefulness of tomato, its production is limited by several factors such as pests and diseases, soil and weather conditions. However, major losses in the quality and quantity of tomato production in Nigeria are due to attack by insect pests such as aphids, thrips, whiteflies, budworms, cutworm, tomato mite, looper caterpillars and red spider mite. *Tomato Fruit Borer -TFB (Helicoverpa armigera)* is potentially the most damaging insect pest of tomato (12). TFB larvae caused yield loss in tomato up to 35-55 % due to their boring activities (19, 5). TFB become a major threat to tomato production in Southwestern Nigeria due to the physiological, ethiological and ecological factors of the area (*1).*

The control of *H. armigera on tomato* mainly depends on the use of insecticides due to its preference for highly-valued tomato fruits (13). However, indiscriminate use of insecticides to control TFB by farmers led to development of resistance to most classes of pesticides (*23*). Hence, there is an inclination of the farmers towards the use of higher doses and frequencies of insecticides than recommended rates for the management of TFB, this has deleterious effects on both target and non-target organisms as well as environmental hazards (20). Tomato farmers therefore, use higher rates and frequencies of insecticides on account of perception that recommended doses are not working very well in fields. Also, a field survey conducted in 2013 and 2017 on major tomato farms in Abeokuta and Ayetoro, Ogun State, Nigeria revealed that 80 % of tomato farmers use cypermethrin either singly or in combination with other insecticides for the management of TFB as often as possible without adhering to recommended rate or frequency due to their perception of insecticide resistance in TFB

Use of higher doses of insecticides, however leads to development of insecticide resistance because insects adapted to higher doses of insecticides become less susceptible to lower doses of insecticides, rendering insecticides ineffective thereby necessitating repeated applications of insecticides (6, 15). According to Zanin *et al.*, (25), reducing the number of spray applications during the cropping period, decreasing the applied dose, which can decrease the level of control and promote the appearance of genetic resistance; and restricting the treated area are three possible ways to reduce the volume of pesticides used in agriculture The development of management strategies for insecticide application can reduce or prevent the build-up of resistance in agricultural insect pests (11). Hence, the rate and frequency of application of insecticides as a means of pest control is becoming an increasingly more important issue.

Cypermethrin was reported to be among many insecticides used by farmers to control TFB on tomato in Southwestern Nigeria, (17). There is therefore, the need to investigate the minimum rate and frequency of application of the commonly used insecticide for TFB in the study area. The research was aim to reduced indiscriminate use of Cypermethrin in order to prevent population build-up of the pest and development of resistance to Cypermethrin thereby, reducing the cost of production and improve tomato fruits as yield integrated pest management (IPM) strategy for the control of TFB in Abeokuta. Therefore, the objectives of the study were to;

(1.) establish the minimal effective rate and frequency of application of Cypermethrin using two tomato varieties
(2.) investigate the influence of frequency and rate of application of Cypermethrin on *H. armigera* population density, fruit damage and yield of tomato
(3.) analyze the cost benefit of using Cypermethrin in tomato production.

MATERIALS AND METHODS

Experimental Site

The study was carried out at the Teaching and Research Farm of the Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State (7° 15' N, 3°25' E, and 159 m above sea level) in the rainforest transition Zone of South-Western Nigeria. The study was conducted in the early season (April– June) of 2017 and repeated in the late season (September – November) of 2021. A susceptible tomato genotype, "Kerewa" and a resistant genotype, "Roma VF" sourced from FUNAAB/ KNUST/ DfiD/ British Council DelPHE 5 Research Project and Cypermethrin (Avesthrin 10 % EC, Eastsun Chemical Co. Ltd) a reputable agrochemical shop were used for the experiment. Seeds of "Kerewa" and Roma VF were sown in separate nursery pots, under shed and watered at every 24 hours. Seedlings from the nursery were transplanted to the permanent field at 3 weeks after sowing (3 WAS) spacing 0.5 m by 0.5 m at the rate of one seedling per stand. The experiment was laid out in a split-split plot design with three replications. In both seasons, each of the two main plots were 81 x 13 m (1053 $m^{2)}$ and it consisted of two (2) genotypes of tomato, "Kerewa" and Roma VF; each of the four (4) sub-plots was 18 x 13 m (234 m^2) and it comprised four spray-frequencies of Cypermethrin: (a) once-a-week (b) twice-a-week (c) once-a-month and (d) twice-a-month. The five sub-sub plots, measured 2 x 3 m (6 m^2), representing five different rates of Cypermethrin application: (i) 20 % (ii) 40 % (iii) 60 % (iv) 80 % and (v) 100 % of manufacturer's recommendation for Cypermethrin (2.4 litres/ha). A 3 m border was maintained between main plots, sub- plots and blocks while 2 m border was also maintained between sub-sub plots to minimize pesticide drift and pests' movement across adjacent plots. Manual hoe weeding was carried out once every 2 weeks. No fertilizer application was done throughout the experiment. Application of Cypermethrin commenced 2 weeks after transplanting (WAT) to fruit maturity using Knapsack sprayer.

Assessment of H. armigera population and yield assessment

Larval population of *H. armigera* commenced from (2 WATS) to fruit maturity, (9WAP) using visual counting on ten randomly selected tomato plants from the middle row of each plot at weekly intervals between 0700 hours and 009 hours. Observations were based on the number of *H. armigera* larvae found on the leaves, stems, flowers, fruits and exit holes on fruits.

Fruits were harvested at 9 to 12 WAT from 5 randomly selected plants per genotype and later sorted into damaged and undamaged fruits. Yield and damage evaluations were based on the weight of undamaged and damaged fruits respectively.

Determination of cost benefit ratio of Cypermethrin

Cost incurred in the production of tomato using different rates and frequencies of Cypermethrin and revenues were recorded. The cost benefit analyses for each of the treatments were calculated using (Dormon *et a*l., 2007).

$$\text{Cost Benefit ratio} = \frac{\text{Additional Income}}{\text{Additional cost}} \times 100$$

Additional income (AI) = Additional revenue (AR) – Additional cost (AC)

Additional revenue (AR) = Additional yield (kg) x price/kg:

where Additional yield = Yt – Yc; Yt = Yield of treatment; Yc = Yield of control.

Additional cost (AC) = Cost of insecticide + Cost of renting spraying equipment + Cost of spraying.

Data analyses

Data collected were subjected to analysis of variance (ANOVA) tests at ($P < 0.05$). Data on insect count were square root transformed, while data on percentage damage were arcsine ($\sin^{-1}$) transformed before ANOVA tests were carried out. Least significant difference (LSD) was used to separate significant means.

RESULTS

Effects of Cypermethrin on population of Helicoverpa armigera larvae, fruits damage and yield of tomato

The population of *H. armigera* larvae was not significantly influenced by tomato genotype and its various interactions with rate and frequency of Cypermethrin application in both 2017 and 2021. The population of *H. armigera* larvae however, varied significantly ($P \leq 0.05$) with frequency and rate of Cypermethrin application, and the interaction between genotype and frequency of Cypermethrin application in 2017 (Table 1).

Population of *H. armigera* larvae was significantly higher when Cypermethrin was sprayed once a month compared to once a week, twice a week, and twice a month, while the lowest populations were recorded from plots sprayed once and twice a week, regardless of the genotype. Significantly lower number of *H. armigera* larvae ($P \leq 0.05$) was observed at 80 % and 100 %, while the highest number of *H. armigera* larvae was obtained at 20 % rate of application (Table 1

Fruit damage induced by *H. armigera* larvae on tomato fruits was significantly influenced by the frequency and rate of Cypermethrin application, interaction between frequency and genotype, genotype and rate of application and as well as frequency and rate of application as shown in (Table 2). The percentage damaged was significantly ($P \leq 0.05$) lower once and twice a-week and was observed to be higher once month in both experiments irrespective of the genotype. However, *H. armigera* larvae significant ($P \leq 0.05$) reduction in fruit damaged was observed at 60 %, 80 % and 100 % compared with 20 % and 40 % rate of Cypermethrin application.

Tomato genotype and the interaction between genotype and rate of Cypermethrin application were not significantly influenced by fruit yield of tomato but the rate and frequency of applications (Tables 4 and 5). At 60 %, 80 % and 100%, highest tomato fruit yield (kg/ha) were recorded once, twice week and twice-a-month. However, the lowest yield was recorded at 20 % rate of Cypermethrin application (Tables 3). Highest profit however, was observed at 100 % and 80 % Cypermethrin application once a week, followed by 60 % once a week, 60 % twice a week and 100 % twice a week, while the lowest profit was recorded at 20 % once a month in 2017. The result in 2021 showed that the highest economic return was observed when tomato was fruit sprayed with 80 % once-a-week and the lowest was recorded at 20 % once-a-month.

DISCUSSION

The observed reduced populations of *H. armigera* larvae at 60 and 80 % Cypermethrin applications rate showed that *H. armigera* larvae were susceptible to Cypermethrin at these rates. It also implied that cypermethrin applications at 60 and 80 % were effective in controlling *H. armigera* larvae. The level of *H. armigera* control achieved at 60 and 80 % Cypermethrin applications was also comparable to 100 % rate. This therefore, means that higher rate of Cypermethrin application such as 100 % may not be necessarily required for the control of *H. armigera* on tomato to prevent wastage of insecticide and reduce cost of production. These results are in line with the findings of Ashok (4) who reported the effectiveness of Endosulfan, Cypermethrin, Fenvalerate and Spinosad, against *H.*

Table 1: Effect of Cypermethrin sprayed at different rate and frequency on the population of *Helicoverpa armigera* larvae in 2017 and 2021 seasons

Variable	Variety	Frequency	Rate of application (%) 20	40	60	80	100	Mean
Number of *H. armigera* larvae (2017)	Kerewa	Once a week	2.1	2.25	0.0	0.7	0.55	1.12
		Twice a week	0.0	0.0	0.0	0.0	0.0	0.0
		Once a month	7.9	3.65	6.35	5.2	6.65	5.95
		Twice a month	5.1	4.4	2.85	2.15	2.5	3.4
	Roma VF	Once a week	1.05	0.75	0.6	0.7	0.7	0.76
		Twice a week	0.55	0.75	0.0	0.0	0.0	0.26
		Once a month	4.0	3.05	2.7	1.75	1.7	2.64
		Twice a month	2.35	2.35	0.8	1.35	0.6	1.49
		Mean	2.88	2.15	1.66	1.48	1.59	
		LSD (0.05)	v= (ns): f=1.21; r=0.72; v*f=4; v*r= (ns); f*r= (ns); v*f*r = (ns)					
Number of *H. armigera* larvae (2021)	Kerewa	Once a week	3.7	4.0	2.15	0.7	0.0	2.11
		Twice a week	1.5	1.3	0.75	0.0	0.0	0.71
		Once a month	7.4	7.25	6.0	5.7	4.15	6.1
		Twice a month	5.6	5.1	3.65	2.15	1.15	3.53
	Roma VF	Once a week	2.85	2.65	1.45	0.5	1.15	1.72
		Twice a week	1.7	1.5	0.0	0.0	0.0	0.64
		Once a month	4.85	4.35	3.85	3.45	3.15	3.93
		Twice a month	4.2	3.90	2.95	2.90	2.00	3.19
		Mean	3.98	3.78	2.60	1.93	1.45	
		LSD (0.05)	v= (ns): f = 2.05; r = 0.57; v*f = 3.0;v*r = 4.54; f*r = 1.49; v*f*r =ns					

Table 2: Effect of Cypermethrin sprayed at different rates and frequencies on *Helicoverpa armigera* damage in 2017 and 2021 seasons

	Variety		Rate of application (%) 20	40	60	80	100	Mean
Damage (kg/ha) (2017)	Kerewa	Once a week	360.0	350.0	110.0	136.0	88.0	108.80
		Twice a week	152.0	120.0	0.0	0.0	0.0	84.40
		Once a month	584.0	552.0	504.0	526.0	466.0	372.40
		Twice a month	364.0	322.0	202.0	204.0	172.0	252.80
	Roma	Once a week	170.0	154.0	52.0	50.0	32.0	91.60
		Twice a week	36.0	30.0	0.0	0.0	0.0	13.20
		Once a month	202.0	200.0	154.0	134.0	48.0	317.60
		Twice a month	142.0	154.0	102.0	88.0	82.0	193.60
		Mean	251.2	235.2	140.5	142.2	111.0	
		LSD (0.05)	v= (ns): f= 88.29; r = 32.74; v*f =165.06; v*r=248.08; f*r=98.0; v*f*r = (ns)					
Damage (kg/ha) (2021)	Kerewa	Once a week	294	274	186	146	116	203.2
		Twice a week	158	156	108	82	66	114
		Once a month	570	520	394	408	412	460.8
		Twice a month	416	386	232	216	212	292.4
	Roma	Once a week	202	196	112	52	46	121.6
		Twice a week	66	62	48	30	24	46
		Once a month	284	292	228	260	222	257.2
		Twice a month	214	184	108	92	86	136.8
		Mean	275.5	258.8	177.0	160.8	148.0	
		LSD (0.05)	v= (ns): f=81.97; r = 25.76; v*f = *r= 888.62; f*r=87.89; v*f*r = (ns)					

Table 3: Fruit yield of tomato treated with different rate and frequency of Cypermethrin in 2017 and 2021 seasons

			Rates of application (%)					
	Variety	Frequency	20	40	60	80	100 (Check)	Mean
Yield (kg/ha) (2017)	Kerewa	Once a week	1014	1219	1704	1968	2074	1596
		Twice a week	1242	1374	1816	1722	1900	1611
		Once a month	796	1084	986	1028	1072	993
		Twice a month	1036	1038	1388	1348	1284	1219
	Roma VF	Once a week	1088	1142	1920	1822	1886	1572
		Twice a week	1456	1502	2048	1928	1772	1741
		Once a month	1058	952	1234	1252	1270	1153
		Twice a month	1010	1228	1630	1554	1792	1443
		Mean	1088	1192	1591	1578	1631	-
		LSD (0.05)	v = (ns); f =243.20; r =94.30; v*f = (ns); v*r= (ns); f*r =274.60;v*f*r=583.3					
Yield (kg/ha) (2021)	Kerewa	Once a week	1238.0	1510.0	2189.0	2510.0	2458.0	1981.0
		Twice a week	1526.0	1604.0	2318.0	2400.0	2442.0	2058.0
		Once a month	770.0	866.0	1048.0	1288.0	1312.0	1057.0
		Twice a month	976.0	1012.0	1428.0	1544.0	1634.0	1319
	Roma VF	Once a week	1064.0	1200.0	2200.0	2266.0	2370.0	1820.0
		Twice a week	1356.0	1422.0	2028.0	2306.0	2132.0	1849.0
		Once a month	954.0	882.0	1234.0	1152.0	1274.0	1099.0
		Twice a month	930.0	1174.0	1496.0	1490.0	1740.0	1366.0
		Mean	1102.0	1209.0	1743.0	1870.0	1920.0	-
		LSD (0.05)	v =(ns); f=252.3; r=143.9; v*f= (ns), v*r = 847.0; f*r=335.0; v*f*r= (ns)					

LSDs are for the following comparisons; v, variety; f, frequency of Cypermethrin application; r, rate of Cypermethrin application, v*r = combination of variety and rate; v*F = combination of variety and frequency; V*r*f = combination of variety and frequency and rate of Cypermethrin

Table 4: Partial budgeting of tomato fruit yield sprayed with different rate and frequency of Cypermethrin for t he control of tomato fruit borer in 2017

Frequency	Rate (%)	Cost of Insecticide (₦)	Cost of renting sprayer (₦)	Labour cost (₦)	TFC (₦)	Total cost (TC) (₦)	Revenue (₦)	Profit (₦)
Once a week	20	4,608	4,000	20,000	60,000	88,608	202,800	114,192ef
	40	9,216	4,000	20,000	60,000	93,216	243,800	150,584de
	60	13,824	4,000	20,000	60,000	97,284	340,800	243,516b
	80	18, 432	4,000	20,000	60,000	102,432	393,600	291,168a
	100 (check)	23,040	4,000	20,000	60,000	107,040	414,800	307,760a
Twice a week	20	9216	4,000	40,000	60,000	133,216	248,400	115,184ef
	40	18,342	4,000	40,000	60,000	122,342	274,800	152,458de
	60	27,648	4,000	40,000	60,000	131,648	363,200	231,552b
	80	36,864	4,000	40,000	60,000	140,864	344,400	203,536bcd
	100 (check)	46,080	4,000	40,000	60,000	150,080	380,800	229,920b
Once a month	20	1152	4,000	5.000	60,000	130,152	159,200	29,048g
	40	2304	4,000	5.000	60,000	131,304	216,800	85,496f
	60	3456	4,000	5.000	60,000	72,456	197,200	124,744ef
	80	4608	4,000	5.000	60,000	73,608	205,600	131,992ef
	100 (check)	5760	4,000	5.000	60,000	74,760	214,400	131,992ef
Twice a month	20	2304	4,000	10,000	60,000	76,304	207,200	130.896ef
	40	4608	4,000	10,000	60,000	78,608	207,600	128,992ef
	60	6912	4,000	10,000	60,000	80,912	277,600	196,688bcd
	80	9216	4,000	10,000	60,000	83,216	296,600	213,384bc
	100(Check)	11,520	4,000	10,000	60,000	85,520	256,800	171,280cde

Cost of insecticide + Cost of renting sprayer + Labour cost = TVC; TC= TFC +TVC; Profit = Re venue - TC

Table 5: Partial budgeting of tomato fruit yield sprayed with different rate and frequency of Cypermethrin for the contro l of tomato fruit borer in 2021

Frequency	Rate (%)	Cost of Insecticide (₦)	Cost of renting sprayer (₦)	Labour cost (₦)	Total fixed cost (TFC)	Total Cost (₦)	Revenue (₦)	Profit (₦)
Once a week	20	4,608	4,000	20,000	60,00	88,608	247,600	158,992def
	40	9,216	4,000	20,000	60,000	93,216	302,200	208,984cde
	60	13,824	4,000	20,000	60,000	97,284	437,800	340,516b
	80	18, 432	4,000	20,000	60,000	102,432	502,000	399,56a
	100 (check)	23,040	4,000	20,000	60,000	107,040	491,600	384,560ab
Twice a week	20	9216	4,000	40,000	60,000	133,216	305,200	171,984cdef
	40	18,342	4,000	40,000	60,000	122,340	320,800	198,458cde
	60	27,648	4,000	40,000	60,000	131,648	463,600	331,952ab
	80	36,864	4,000	40,000	60,000	140,864	480,000	339,136ab
	100 (check)	46,080	4,000	40,000	60,00	150,080	488,400	338,320ab
Once a month	20	1152	4,000	5.000	60,000	130,152.00	154,200	24,048g
	40	2304	4,000	5.000	60,000	131,304	173,200	41,896g
	60	3456	4,000	5.000	60,000	72,456	209,600	137,144ef
	80	4608	4,000	5.000	60,000	73,608	257,600	183,99cdef
	100 (check)	5760	4,000	5.000	60,000	74,760	262,400	187,640cdef
Twice a month	20	2,304	4,000	10,000	60,000	76,304	195,200	118,896f
	40	4,608	4,000	10,000	60,000	78,608	202,400	123,792f
	60	6,912	4,000	10,000	60,000	80,912	285,600	204,688cde
	80	9,216	4,000	10,000	60,000	83,216	308,800	225,584cdc
	100 (check)	11,520	4,000	10,000	60,000	85,520	326,800	241,280c

Cost of insecticide + Cost of renting sprayer + Labour cost = TVC; TC= TFC +TVC; Profit = Revenue - TC *armigera.*

The lower infestation of *H. armigera* observed at 60 %, and 80 % rate is in conformity with the report of Ogunwolu (16) that Cypermethrin suppressed *Heliothis armigera* damage on tomato. The lower populations of *H. armigera* larvae at 100 % compared to 20 and 40 % rates depicted the effectiveness of Cypermethrin in controlling *H. armigera* using the manufacturer's recommended rate. The report of Gressel (9) that application of insecticide using recommended rate could effectively control target species of insect pests agrees with the findings of this study.

The present study also, showed that application of Cypermethrin, once- and twice-a-week reduced infestation of TFB and fruit damage than once and twice-a-month frequencies of application. This may be due to the short intervals of Cypermethrin application that provided long-time protection against *H. armigera* before another application (14). However, according to Grewal *et al.,* (10) effectiveness of insecticides depends on the rates, frequency and application intervals. This was evident from this study as Cypermethrin applied at 60, 80 and 100 % rates were effective in mitigating *H. armigera* populations only at once-and twice-a-week and not at once- and twice-a-month frequencies of Cypermethrin application.

The result of this study was in line with the report of Velini (24) who reported that target insect pests can be effectively managed by applying rates less than the recommended rate in order to reduce cost and environmental impact. Also, Helps *et al.*, (11) has reported that application of insecticide using a rate below the recommended level (i.e. 50% of its full dose) would not lead to loss of its effectiveness.

Furthermore, the effective and better control of *H. armigera* obtained at 60 and 80 % rates of Cypermethrin application coupled with higher yield and reduced fruit damage implied that the rate of Cypermethrin application for the control of *H. armigera* could be reduced to a minimal level without any necessary implication on the yield and pest control irrespective of the variety of tomato used. The agrees with the report of Helps *et al.,* (11) who recommended that insecticide dose should be reduced below the maximum permitted, without prejudicing effective control. This would eradicate indiscriminate use of insecticides to control *H. armigera* which led to development of resistance to insecticides as reported by Torres-Vila, *et al.* (21, 22). Hence, application of insecticides at 60 %, and 80 % rate once or twice-a-week frequency can be integrated as part of the management strategies to slow down the build-up of *H. armigera* population on tomato. According to Glover-Amengor and Tetteh (8), lower rates of pesticide application i. e. lambda-cyhalothrin suppressed pest populations in tomato, garden egg and okra fields, reduced cost of pesticides and pesticide burden on the environment. He also opined that tomato garden egg and okra yields were higher at the lower rates of pesticide application.

The results of the present study further showed that farmers may require only a single round of spray application of cypermethrin in a week to protect their tomato crop to effectively mitigate TFB damage and maximize profits irrespective of the variety used. When adopted by farmers, this reduction in insecticide use might also mitigate the negative consequences of insecticides on human health and the environment.

In the present study, application of

Cypermethrin at 60 and 80 % of the recommended rate once-a-week for the management of *H. armigera* lowered the mean number of *H. armigera*, suppressed fruit damage and increased fruit yield of tomato. The present findings also, revealed that it was more cost effective using Cypermethrin at 60 and 80 % once in a week than 20, 40 and 100 % rates at twice-a-week, once-a-month and twice-a-month frequencies of Cypermethrin applications due to the higher economic returns.

CONCLUSION

The study revealed Cypermethrin application at 60 and 80 % rate once-a-week as the minimal dosage rate at which to achieve a considerable level of control of *H. armigera* infestation and damage. Also, the highest and the positive cost-benefit/profit obtained at 60 and 80% rate once-a week further confirmed the cost effectiveness of using cypermethrin at 60 % rate once a week as the best for the management of *H. armigera*. It can be concluded from this study that spraying of cypermethrin at 60 % of recommended rate once-a-week was the minimal rate and frequency required to achieve adequate control of *H. armigera* on tomato with higher economic returns.

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