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Efficacy of Nucleopolyhedrovirus (*Sf*NPV) and Insecticides alone and in Combination against fall Armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) Infesting Maize

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ABSTRACT: The experiment was conducted to evaluate the efficacy of *Sf*NPV and insecticides alone and in combination against fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera:Noctuidae) infesting maize under field condition during *Kharif* season of 2021 at Agronomy farm, Anand Agricultural University, Anand (Gujarat, India). With respect to larval population, the treatment of *Sf*NPV 1% AS + spinetoram 11.7 SC (1.99 larvae/10 plants) found superior in reducing larval population. However, *Sf*NPV 1% AS + emamectin benzoate 5 SG (2.43 larvae/10 plants) and *Sf*NPV 1% AS + chlorantraniliprole 18.5 SC (2.70 larvae/10 plants) found mediocre in their effectiveness against fall armyworm. Regarding plant damage the treatment of *Sf*NPV 1% AS + spinetoram 11.7 SC (15.96%) noted as superior in minimizing plant damage. However, *Sf*NPV 1% AS + emamectin benzoate 5 SG (19.60%) and *Sf*NPV 1% AS + chlorantraniliprole 18.5 SC (22.94%) registered as average in their effectiveness against plant damage due to fall armyworm. Based on cob damage, it was inferred that cob damage caused by fall armyworm, *S. frugiperda* reduced by spraying of *Sf*NPV 1% AS + spinetoram 11.7 SC and *Sf*NPV 1% AS + emamectin benzoate 5 SG. The maximum grain and fodder yield were recorded from the plots treated with *Sf*NPV 1% AS + spinetoram 11.7 SC (2555 and 3461 kg/ha) and *Sf*NPV 1% AS + emamectin benzoate 5 SG (2495 and 3377 kg/ha). Increase in yield over control of grain as well as fodder ranged from 14.52 to 89.48 and 9.45 to 85.86 per cent, respectively. This is the first study on *Sf*NPV combination with insecticides on the invasive pest fall armyworm in India. As a result of the present study, it has been determined that insecticides combined with *Sf*NPV are the most suitable for use in Integrated Pest Management programs.

Keywords: Fall armyworm (FAW), bio-efficacy, nucleopolyhedrovirus (NPV), insecticides, maize.

INTRODUCTION

Maize (*Zea mays* L.) originated about 7000 to 10000 years ago from Teosinte in the western hemisphere (Acosta and Crane 1972). As a cereal grain, maize is a member of the Gramineae/Poaceae family and is called as 'Queen of Cereals' since it can be used in multiple ways. It is the world's leading crop and is widely cultivated as a cereal grain. Cultivation of maize is spread throughout the country, over an area of 95.69 million hectares with a production of 287.66 million tonnes and a productivity of 3.06 tonnes per hectare (Anonymous, 2020a). In Gujarat it is cultivated in about 4.38 lakh ha area with a production of 7.93 lakh tonnes and productivity of 1809 kg/ha (Anonymous, 2020b). The major maize growing districts of Gujarat are Panchmahal, Dahod, Mahisagar, Vadodara, Chhotaudepur, Arvalli, Sabarkantha, Banaskantha and Anand. Among different maize growing districts, Dahod occupies first position in area (1.35 lakh ha) and production (2.13 lakh tonnes), while highest productivity (3043 kg/ha) has been recorded in Tapi (Anonymous, 2020b).

The newly introduced pest *Spodoptera frugiperda* (Lepidoptera: Noctuidae), also known as the fall armyworm (FAW), is a cosmopolitan maize insect (Wiseman *et al*., 1966). It spread to various parts of Africa and after that FAW targets 353 host plant species belonging to 76 plant families, with a major preference for the Poaceae family (Montezano *et al*., 2018). In India, it was first discovered on maize in the Shivamogga district of Karnataka (Kalleshwaraswamy *et al*., 2018), then it spread to Tamil Nadu, Telangana, and West Bengal. In Gujarat it was first recorded from Anklav village in the Anand district (Sisodiya *et al*., 2018). The feeding performed in the whorls of the plant causes rows of perforations in the leaves, which can lead to extensive defoliation and a decrease in the plant's growth potential. Maize production in India was 28.7 million tonnes in 2017 but due to this insect pest, production dropped by 3.2% (Manupriya, 2019). Insecticides are the primary tool for controlling *S. frugiperda* in corn but when used indiscriminately, they pollute the environment. However, biopesticides also known as biological pesticides, are pest control agents or formulations made from naturally occurring biological agents that are non-toxic to environment (Mazid *et al*., 2011). Biopesticides are less harmful to the environment and human health than synthetic pesticides. In 2019, (Raghunandan *et al*., 2019) reported natural occurrence of nucleopolyhedrovirus (NPV) in *S. frugiperda* in Anand district of Gujarat. Insect larvae are the most common source of infection. A lepidopteran larva becomes sluggish, pinkish, and loses its appetite. The body becomes fragile and ruptures to release polyhedra (virus occlusion bodies). Dead larva hangs from top of plant with prolegs attached (tree top disease). The compatibility of bio-agents with chemical pesticides is significant for lowering the risk of resistance to newer chemical insecticides. Since last three years, fall armyworm *S. frugiperda* is becoming a serious pest of maize in Gujarat. The fall armyworm is also infesting the maize grown even for fodder purpose. In this circumstance, one cannot advice the use of insecticides for the control of fall armyworm in fodder crop as well as crop grown for green cobs and grain purpose. One more important factor is that most Indian farmers are small farmers and cannot buy pesticide so when pesticide combined with bioagent such as NPV which is naturally available can reduce the dose required which is affordable by small and marginal farmers. Hence, the present study was carried out to test the compatibility of NPV with chemical insecticides in order to reduce the chemical concentration used to kill insects.

MATERIALS AND METHODS

Owing to the extent of loss caused by fall armyworm in maize, an attempt has been made to curtail its menace by using effective insecticide molecules. Field evaluation of NPV and insecticides alone and in combination (Table 1) were undertaken during late *kharif* 2021 at Agronomy farm, Anand Agricultural University, Anand (Gujarat, India). The experiment was conducted in a randomized block design (RBD) with ten treatments including untreated control with three replications. The flat bed sizes of 4.8 × 6.0 m were prepared and the seeds of maize, were dibbled at 5 cm deep in soil as per recommendation. The recommended dose of fertilizers (150:60:0 NPK kg/ha) was applied by broadcasting method. All cultural practices except plant protection were carried out as per recommendation. Each plot was marked and labeled with pegs. The first spray was applied with the initial appearance of pest using high volume sprayer (knapsack sprayer) with required treatment concentration. Quantity of spray fluid required per plot was calculated by spraying untreated control plot with water. The spray volume used per ha was 500 liters. During spraying, proper care was taken to wash the spray pump with water in the beginning and while switching over from one pesticide to another during spraying. All sprayings were done during morning hours to avoid spray drift due to heavy winds from one treatment plot to other and subsequent two sprays were done at 15 days interval. For recording the observations, 10 plants were randomly selected from each net plot area and total number of larvae as well as healthy and damaged plants were recorded. The observations were recorded one day prior to first spray and subsequently at 3, 7, 10 and 14 days after each spray. Observations on cob damage were made on ten randomly selected plants per plot. Cobs of each plant were observed for the presence or absence of the holes or damage made by the larvae of *S. frugiperda* and per cent cob damage was computed as per the following formula.

$$\text{Per cent cob infestation} = \frac{\text{Total number of damaged cobs}}{\text{Total number of cobs observed}} \times 100$$

Grain and fodder yield. The grain and fodder yield are an important criterion for comparing the efficacy of different treatments. The maize crop was harvested at maturity and grain as well as fodder yield (kg/plot) were recorded from each net plot area under each treatment. Yield recorded from each net plot was converted in to hectare basis for comparison.

Increase in yield over control. The increase in yield over control was worked out by using following formula.

$$\text{Increase in yield over control (\%)} = \frac{\text{Yield in treatment} - \text{Yield in control}}{\text{Yield in control}} \times 100$$

Experimental data were analyzed as per the ANOVA technique (Steel and Torrie, 1980) after using suitable transformation.

Table 1: Treatment details.

Sr. No.	Treatments	Active ingredient (g a.i. /ha)	Dose (g or ml/ 10 litre of water)
1.	Spinetoram 11.7 SC	58.5	10.0
2.	Chlorantraniliprole 18.5 SC	30.0	3.0
3.	Emamectin benzoate 5 SG	12.50	5.0
4.	Cypermethrin 25 EC	50.0	4.0
5.	*Sf*NPV 1% AS (1×10^9 POBs/ml)	--	30.0
6.	*Sf*NPV 1% AS (1×10^9 POBs/ml) + Spinetoram 11.7 SC	--	15 + 5.0
7.	*Sf*NPV 1% AS (1×10^9 POBs/ml) + Chlorantraniliprole 18.5 SC	--	15 + 1.5
8.	*Sf*NPV 1% AS (1×10^9 POBs/ml) + Emamectin benzoate 5 SG	--	15 + 2.5
9.	*Sf*NPV 1% AS (1×10^9 POBs/ml) + Cypermethrin 25 EC	--	15 + 2.0
10.	Untreated control	--	--

RESULTS AND DISCUSSION

Bio-efficacy based on larval population. The data on pooled over periods and sprays (Table 2 and Fig. 1) clearly indicated that the treatments of spinetoram 11.7 SC (0.50 larva/10 plants) and emamectin benzoate 5 SG (0.88 larva /10 plants) found effective than all the evaluated treatments. Also, chlorantraniliprole 18.5 SC (1.41 larvae /10 plants) and *Sf*NPV 1% AS + spinetoram 11.7 SC (1.99 larvae/10 plants) treated maize plots registered lower incidence of fall armyworm larvae compared to the remaining treatments. However, *Sf*NPV 1% AS + emamectin benzoate 5 SG (2.43 larvae/10 plants) and *Sf*NPV 1% AS + chlorantraniliprole 18.5 SC (2.70 larvae/10 plants) found mediocre in their effectiveness against fall armyworm. Whereas, the plots treated with cypermethrin 25 EC (3.65 larvae/10 plants) recorded the maximum larval population, which was found at par with *Sf*NPV 1% AS (3.38 larvae/10 plants). Of the evaluated treatments, highest larval population was noticed from the plots treated with *Sf*NPV 1% AS + cypermethrin 25 EC (4.37 larvae/10 plants) and was inferior in its efficacy.

The results of the present investigation are in similar line with the findings of Mendez *et al*. (2002) who reported *Sf*MNPV + 3ppm spinosad produced around 90% *S. frugiperda* mortality, which was 12.5 to 32% higher than plots treated with *Sf*MNPV alone. However, results are agreement with Pokharkar and Chaudhary (2001) who concluded that combining *Ha*NPV 250 LE/ha with half the doses of pyrethroids lower larval population, fruit damage and boost production in tomatowhen compared to their recommended doses. The results of the present investigation are in similar line with the findings of Reddy *et al*. (1992) who reported that the treatment of *Ha*NPV 500 LE/ha + Fenvalerate 0.005 per cent found superior in reducing the larval population. The present finding was also supported by Sirvi *et al*. (2013) who concluded that the treatment *viz.*, NPV + fenvalerate (0.005%), NPV + monocrotophos (0.035%) could be employed for pest control. Results could not be compared with best combination of *Sf*NPV 1% AS + spinetoram 11.7 SC and *Sf*NPV 1% AS + emamectin benzoate 18.5 SC for want of literature. However, results are agreement with Pugalenthi *et al*. (2013) who concluded that the combined treatment of NPV 500 LE/ha + cypermethrin 25% EC + quinalphos 25% EC reduced significantly pest population and boll damage than the individual treatments. Above results regarding efficacy of spinetoram 11.7 SC are agreement with Bharadwaj *et al*. (2020) who reported that *S. frugiperda* population was successfully reduced with spinetoram 11.7 SC, followed by emamectin benzoate 5 WG.

Bio-efficacy based on plant damage. The data on pooled over periods and sprays (Table 2 and Fig. 1) clearly indicated that the treatment of spinetoram 11.7 SC (3.71%) and emamectin benzoate 5 SG (6.83%) found significantly superior than rest of the evaluated treatments. Also, chlorantraniliprole 18.5 SC (12.41%) and *Sf*NPV 1% AS + spinetoram 11.7 SC (15.96%), treated maize plots registered lower plant damage due to fall armyworm larvae compared to the remaining treatments. However, *Sf*NPV 1% AS + emamectin benzoate 5 SG (19.60%) and *Sf*NPV 1% AS + chlorantraniliprole 18.5 SC (22.94%) found mediocre in their effectiveness against plant damage due to fall armyworm. Whereas, the plots treated with cypermethrin 25 EC (29.04%) recorded the maximum plant damage, which remained at par with *Sf*NPV 1% AS (26.31%). Of the evaluated treatments, highest plant damage was noticed in the plots treated with *Sf*NPV 1% AS + cypermethrin 25 EC (33.19%) and was inferior in its efficacy.

Findings of earlier researchers pertaining to evaluation of *Sf*NPV and insecticides alone and its combination evaluated based on plant damage caused by fall armyworm, *S. frugiperda* infesting maize are not available to compare. However, Singh and Kumar (2012) reported that *Ha*NPV@ 250 LEha^{-1} + emamectin benzoate 5 SG @ 200 gha^{-1} found effective in keeping minimum per cent pod damage due to *H. armigera* in pigeon pea. However, results are in agreement with Pokharkar and Chaudhary (2001) who concluded that combining *Ha*NPV 250 LE/ha with half the doses of pyrethroids registered lower larval population, fruit damage and boost production in tomato when compared to their recommended doses. The present finding was also supported by Sirvi *et al*. (2013) who concluded that the treatment *viz.*, NPV + fenvalerate (0.005%), NPV + monocrotophos (0.035%)

could be employed for pest control. Results could not be compared with best combination of *Sf*NPV 1% AS + spinetoram 11.7 SC and *Sf*NPV 1% AS + emamectin benzoate 5 SG for want of literature. However, results are agreement with Pugalenthi *et al*. (2013) who concluded that the combined treatment of NPV 500 LE/ha + cypermethrin 25% EC + quinalphos 25% EC reduced significantly pest population and boll damage than the individual treatments. Above results regarding efficacy of spinetoram 11.7 SC are agreement with Bharadwaj *et al*. (2020) who reported that *S. frugiperda* population and plant damage were successfully reduced with spinetoram 11.7 SC, followed by emamectin benzoate 5 WG. Similar results were also obtained by Mallapur *et al*. (2019) where they documented that spinetoram, emamectin benzoate, and spinosad 45 SC were considerably superior to all other treatments against fall army worm *S. frugiperda*, with reduction in plant damage (96.26 to 98%), respectively.

Table 2: Efficacy of *Sf*NPV and insecticides alone and its combination based on larval population, plant damage and cob damage caused by fall armyworm, *S. frugiperda* infesting maize.

Tr. No.	Treatments	No. of larva(e)/10 plants after 3 sprays	Plant damage (%) after 3 sprays	Cob damage (%)
T1	Spinetoram 11.7 SC	**1.00a (0.50)***	**11.10a (3.71)****	**6.75a* (1.38)**
T2	Chlorantraniliprole 18.5 SC	**1.38bc (1.41)**	**20.62b (12.41)**	**18.43bc (10.00)**
T3	Emamectin benzoate 5 SG	**1.17ab (0.88)**	**15.15a (6.83)**	**12.59ab (4.75)**
T4	Cypermethrin 25 EC	**2.04fg (3.65)**	**32.60ef (29.04)**	**31.00ef (26.52)**
T5	*Sf*NPV 1% AS (1×10^9 POBs/ml)	**1.97efg (3.38)**	**30.86de (26.31)**	**28.78de (23.18)**
T6	*Sf*NPV 1% AS (1×10^9 POBs/ml) + Spinetoram 11.7 SC	**1.58cd (1.99)**	**23.55bc (15.96)**	**18.43bc (10.00)**
T7	*Sf*NPV 1% AS (1×10^9 POBs/ml) + Chlorantraniliprole 18.5 SC	**1.79def (2.70)**	**28.62cd (22.94)**	**23.86cd (16.36)**
T8	*Sf*NPV 1% AS (1×10^9 POBs/ml) + Emamectin benzoate 5 SG	**1.71de (2.43)**	**26.28cd (19.60)**	**21.14bc (13.01)**
T9	*Sf*NPV 1% AS (1×10^9 POBs/ml) + Cypermethrin 25 EC	**2.21g (4.37)**	**35.18f (33.19)**	**33.21f (30.00)**
T10	Untreated control	**2.96h (8.28)**	**50.67g (59.83)**	**48.85g (56.69)**
S. Em ± Treatment (T)		**0.084**	**1.791**	**2.84**
C. D. at 5 %		**0.249**	**5.318**	**8.40**
C. V. (%)		**11.90**	**15.05**	**20.23**

Note:* Figures in parenthesis are retransformed values and those outside are $\sqrt{x+0.5}$ transformed values

****-** Figures in parenthesis are retransformed values and those outsides are arc sine transformed values

1. Treatment mean(s) with the letter(s) in common are not significant by Duncan's New Multiple Range Test (DNMRT) at 5% level of significance

Bio-efficacy based on cob damage. The plots treated with spinetoram 11.7 SC (1.38%) and emamectin benzoate 5 SG (4.75%) recorded minimum cob damage caused by fall armyworm. While, treatment of chlorantraniliprole 18.5 SC and *Sf*NPV 1% AS + spinetoram 11.7 SC noticed as second-better treatment (10.00%) and it remained at par with *Sf*NPV 1% AS + emamectin benzoate 5 SG (13.01%). The treatment of *Sf*NPV 1% AS + chlorantraniliprole 18.5 SC (16.36%) found mediocre in their effectiveness against cob damage due to fall armyworm. Of the evaluated treatments, the relatively maximum cob damage was observed in the plots treated with *Sf*NPV 1% AS + cypermethrin 25 EC (30.00%), cypermethrin 25 EC (26.52%) and *Sf*NPV 1% AS (23.18%) and found less effective treatments. Overall, it was inferred that maize cob damage caused by fall armyworm, *S. frugiperda* can be reduced by spraying of spinetoram 11.7 SC and emamectin benzoate 5 SG.

The treatment of chlorantraniliprole 18.5 SC, *Sf*NPV 1% AS + spinetoram 11.7 SC, *Sf*NPV 1% AS + emamectin benzoate 5 SG found next better treatments. In contrast to this, *Sf*NPV 1% AS + cypermethrin 25 EC and cypermethrin 25 EC proved unsuccessful to provide satisfactory protection against fall armyworm. From available source of literature, it was found that none of the earlier workers in past have tried/evaluated the efficacy of *Sf*NPV + insecticide, and hence the present results cannot be compared and discussed. However, Singh and Kumar (2012) reported that *Ha*NPV@ 250 LEha^{-1} + emamectin benzoate 5 SG @ 200 gha^{-1} found effective in keeping minimum per cent pod damage due to *H. armigera* in pigeon pea. This is in support to the present findings. Similar findings were obtained by Pokharkar and Chaudhary (2001) who concluded that combining *Ha*NPV 250 LE/ha with half the doses of pyrethroids recorded lower larval population, fruit damage and boost production in tomato when compared to their recommended doses.

Yield. The data on grain and fodder yield of maize crop were recorded from the various treatments during *kharif*, 2021 and presented in Table 3. During *kharif*, 2021 (Table 3) the plots treated with spinetoram 11.7 SC (2937 kg/ha) and emamectin benzoate 5 SG (2791 kg/ha) registered significantly higher grain yield over rest of the other treatments, which were followed by treatment of chlorantraniliprole 18.5 SC (2726 kg/ha), *Sf*NPV 1% AS (1×10^9 POBs/ml) + spinetoram 11.7 SC (2555 kg/ha) and *Sf*NPV 1% AS + chlorantraniliprole 18.5 SC (2452 kg/ha). Whereas, the plots treated with *Sf*NPV 1% AS (2181 kg/ha), cypermethrin 25 EC (1896 kg/ha) and *Sf*NPV 1% AS (1×10^9 POBs/ml) + cypermethrin 25 EC (1775 kg/ha) recorded comparatively minimum grain yield.

The data on fodder yield recorded in plots treated with various treatments revealed that the plots treated with spinetoram 11.7 SC (4062 kg/ha), emamectin benzoate 5 SG (3778 kg/ha) and chlorantraniliprole 18.5 SC (3693 kg/ha) recorded significantly higher fodder yield. Subsequently, next better yield was registered from plots treated with *Sf*NPV 1% AS (1×10^9 POBs/ml) + spinetoram 11.7 SC (3461 kg/ha), *Sf*NPV 1% AS (1×10^9 POBs/ml) + emamectin benzoate 5 SG (3377 kg/ha) and *Sf*NPV 1% AS (1×10^9 POBs/ml) + chlorantraniliprole 18.5 SC (3320 kg/ha). Whereas, plots treated with *Sf*NPV 1% AS (2954 kg/ha), cypermethrin 25 EC (2566 kg/ha) and *Sf*NPV 1% AS (1×10^9 POBs/ml) + cypermethrin 25 EC (2392 kg/ha) observed with comparatively lower fodder yield. From available source of literature, it was found that none of the earlier workers in past have tried/evaluated the efficacy of *Sf*NPV + insecticide, and hence the present results cannot be compared and discussed. However, Omprakash (2021) recorded the highest grain yield in treatment of spinetoram 11.7 SC (56.12q/ha), followed by chlorantraniliprole 18.5 SC (54.16q/ha). This is in support to the present findings. Despite the fact that present findings are somewhat differ with those of above researchers regarding the treatment against fall armyworm, there may be differences based on the variety, season, environmental conditions and study location.

Table 3: Effect of *Sf*NPV and insecticides evaluated alone and in combination on yield against fall armyworm, *S. frugiperda* infesting maize.

Tr. No.	Treatments	Yield (kg/ha)		Increase in yieldover control (%)	
		Grain	Fodder	Grain	Fodder
1.	Spinetoram 11.7 SC	2937a	4062a	89.48	85.86
2.	Chlorantraniliprole 18.5 SC	2726ab	3693ab	75.87	68.98
3.	Emamectin benzoate 5 SG	2791ab	3778ab	80.06	72.87
4.	Cypermethrin 25 EC	1896de	2566de	22.32	16.95
5.	*Sf*NPV 1% AS (1×10^9 POBs/ml)	2181cd	2954cd	40.71	35.16
6.	*Sf*NPV 1% AS (1×10^9 POBs/ml) + Spinetoram 11.7 SC	2555abc	3461abc	64.84	58.36
7.	*Sf*NPV 1% AS (1×10^9 POBs/ml) + Chlorantraniliprole 18.5 SC	2452bc	3320bc	58.19	51.91
8.	*Sf*NPV 1% AS (1×10^9 POBs/ml) + Emamectin benzoate 5 SG	2495bc	3377bc	60.97	54.52
9.	*Sf*NPV 1% AS (1×10^9 POBs/ml) + Cypermethrin 25 EC	1775de	2392de	14.52	9.45
10.	Untreated control	1550e	2031e	0.00	0.00
S. Em. ±		131.50	194.14	-	-
C. D. at 5 %		Sig.	Sig.	-	-
C. V. (%)		9.75	10.63	-	-

Note: 1. Treatment mean(s) with the letter(s) in common are not significant by Duncan's New Multiple Range Test (DNMRT) at 5% level of significance; 2. Significant parameter: T 3. Sig. = Significant

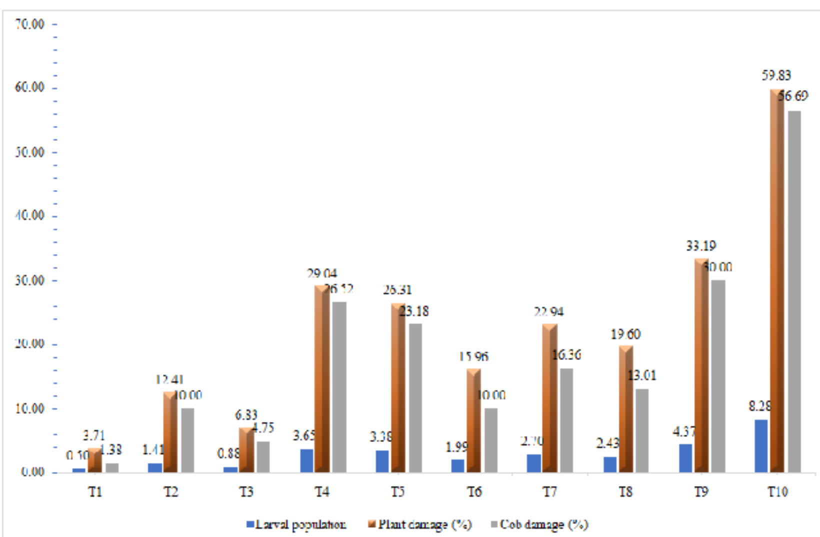

Fig. 1. Effect of *Sf*NPV and insecticides alone and its combination on larval population plant and cob damage evaluated against fall armyworm, *S. frugiperda* infesting maize.

CONCLUSION

This is the first study on *Sf*NPV combination with insecticides on the invasive pest fall armyworm in India. From the results it can be concluded that the spinetoram 11.7 SC and emamectin benzoate 5 SG found most effective in reducing larval population of fall armyworm infesting *kharif* maize. But chemical pesticides, can destroy population of natural enemies of crop pests and cause other issues such as secondary pest epidemics, pest resurgence and pesticide resistance in target pests due to extensive use of pesticides. As observed from above results, *Sf*NPV 1% AS + spinetoram 11.7 SC and *Sf*NPV 1% AS + emamectin benzoate 5 SG also found effective in reducing larval population of fall armyworm *S. frugiperda*, so it can be concluded that combination of insecticides along with NPV can be recommended for pest management. Microbial insecticides in combination with chemicals insecticides not only reduce the use of sole chemical insecticides to an extent but also increase the effectiveness of pesticides. Besides, both in combination would be economically viable reducing cost and risk by improving B:C ratio. Compatibility of bio-gents with chemical pesticides is very important to reduce the chances of development of resistances to newer chemical insecticides.

REFERENCES

Acosta, A. E. and Crane, P. L. (1972). Further Selection for Lower Ear Height in Maize 1. *Crop Science*, *12*(2), 165-167.

Anonymous (2020a). Retrieved from: https://www.indiastatagri.com/ table/agriculture/ selected-state-wise-area-production-productivity-m/1409263 Retrieved on: 28th June, 2021.

Anonymous (2020b). Retrieved from: https://www.indiastatagri.com/table/ agriculture/selected-state-wise-area-production-productivity-m/1409263 Retrieved on: 28th June, 2021.

Bharadwaj, G. S., Mutkule, D. S., Thakre, B. A. and Jadhav, A. S. (2020). Bio-efficacy of different insecticides against fall armyworm, *Spodoptera frugiperda* (JE Smith) on Maize. *Journal of pharmacognosy and phytochemistry*, *9*(5), 603-607.

Kalleshwaraswamy, C. M., Asokan, R., Swamy, H. M., Maruthi, M. S., Pavithra, H. B., Hegbe, K. and Goergen, G. E. (2018). First report of the fall armyworm, *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae), an alien invasive pest on maize in India.

Mallapur, C. P., Naik, A. K., Hagari, S., Praveen, T. and Naik, M. (2019). Laboratory and field evaluation of new insecticide molecules against fall armyworm, *Spodoptera frugiperda* (JE Smith) on maize. *Journal of Entomology and Zoology Studies*, *7*, 869-875.

Manupriya (2019). *Fall armyworm, destroyer of maize farms, causes concern in India*. Published in Mongaway series on 2 September 2019. https://india.mongabay.com/2019/09/fall-armyworm-destroyer-of-maize-farms-causes-concern-in-India.

Mazid, S., Kalita, J. C. and Rajkhowa, R. C. (2011). A review on the use of biopesticides in insect pest management. *Int. J. Sci. Adv. Technol.*, *1*(7), 169-178.

Méndez, W. A., Valle, J., Ibarra, J. E., Cisneros, J., Penagos, D. I. and Williams, T. (2002). Spinosad and nucleopolyhedrovirus mixtures for control of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in maize. *Biological control*, *25*(2), 195-206.

Montezano, D. G., Sosa-Gómez, D. R., Specht, A., Roque-Specht, V. F., Sousa-Silva, J. C., Paula-Moraes, S. D. and Hunt, T. E. (2018). Host plants of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in the Americas. *African entomology*, *26*(2), 286-300.

Omprakash, S. (2021). Field Efficacy of Some Insecticides Against Fall Army Worm *Spodoptera frugiperda* in Maize.

Pokharkar, D. S. and Chaudhary, S. D. (2001). Combined efficacy of nuclear polyhedrosis virus and synthetic insecticides against *Helicoverpa armigera* (Hubner) on tomato. *Journal of Maharashtra Agricultural Universities (India).*

Pugalenthi, P., Dhanasekaran, S., Elumali, K. and Krishnappa, K. (2013). Bio-efficacy of nuclear polyhedrosis virus (NPV) tested against American bollworm *Helicoverpa armigera* (hub.)(Lepidoptera: Noctuidae) and protection of cotton boll damage. *International Journal of Renewable and Environmental Sciences*, *1*(3), 22-26.

Raghunandan, B. L., Patel, N. M., Dave, H. J. and Mehta, D. M. (2019). Natural occurrence of nucleopolyhedrovirus infecting fall armyworm, *Spodoptera frugiperda* (JE Smith)(Lepidoptera: Noctuidae) in Gujarat, India. *Journal of entomology and zoology studies*, *7*(2), 1040-1043.

Reddy, P. D., Padmavathamma, K. and S. K. Reddy (1992). Efficacy of virus along with insecticides in the control of *Helicoverpa armigera* on pigeon pea. *The Andhra Agricultural Journal*, *39*, 31-34.

Singh, S. K. and Kumar, J. E. E. W. E. S. H. (2012). Management of pod borers in pigeon pea (*Cajanus cajan* L.) through bio and novel insecticides. *Trends in Biosciences*, *5*(2), 154-6.

Sirvi, S. L., Jat, A. L., Choudhary, H. R., Jat, N., Tiwari, V. K. and Singh, N. (2013). Compatibility of bio-agents with chemical pesticides: an innovative approach in insect-pest management. *Popular Kheti*, *1*(1), 62-67.

Sisodiya, D. B., Raghunandan, B. L., Bhatt, N. A., Verma, H. S., Shewale, C. P., Timbadiya, B. G. and Borad, P. K. (2018). The fall armyworm, *Spodoptera frugiperda* (JE Smith)(Lepidoptera: Noctuidae); first report of new invasive pest in maize fields of Gujarat, India. *Journal of Entomology and Zoology Studies*, *6*(5), 2089-2091.

Steel, R. G. D. and Torrie, J. H. (1980). *Principles and Procedures of Statistics*. Publication of McGraw hill book company, New York, pp. 137-151.

Wiseman, B. R., Painter, R. H. and Wassom, C. E. (1966). Detecting corn seedling differences in the greenhouse by visual classification of damage by the fall armyworm. *Journal of Economic Entomology*, *59*(5), 1211-1214.

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