INTERNATIONAL JOURNAL OF ADVANCES IN PHARMACY, BIOLOGY AND CHEMISTRY

Research Article

# Compatibility of selected insecticides with fungicide Saaf® against Diamondback moth, *Plutella xylostella* (Plutellidae; Lepidoptera).

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**Abstract**

Among seven insecticides in combination with fungicide Saaf® tested for efficacy, five insecticides (chlorantraniliprole, flubendiamide, novaluron, Proton® and profenophos) showed synergistic effect, whereas two insecticides (indoxcarb and Hamla®) were antagonistic against *P. xylostella* larvae.

**Keywords:** Insecticide, Diamondback moth, Antagonism, Synergism.

## 1. Introduction

Among various insect pests, diamondback moth is the most serious in causing economic loss on cole crops. Though, the moth originated in the Mediterranean area, it has surpassed all the natural barriers and is believed to have become a cosmopolitan pest (Meyriche, 1928). Diamondback moth, *P. xylostella* is one of the most destructive pests of cruciferous vegetables in the world and has been reported from at least 128 countries. In recent years, DBM acquired serious dimension and has become major limiting factor for successful cultivation of cabbage in India (Sexena*et al.*, 1989; Srinivasan and Krishnamoorthy, 1991). Diamondback moth is known to cause yield loss in cabbage from 31 per cent (Abraham and Padmanabhan, 1968) to 100 per cent (Cardleron and Hare, 1986) and the annual cost for managing this pest is estimated to be US $1 billion (Talekar, 1992).

The number of chemicals involved in plant protection is too many and the information on compatibility of individual chemical is scattered in the literature. Common growers find difficulty in ascertaining the compatibility of agro-chemicals. Hence, based on experience Gray (1914) prepared a chart showing compatibility of some insecticides and fungicides. Later several charts were developed or updated by Frear (1979), Gruzdyed *et al.*, (1983) for the chemicals in use with additional information regarding incompatibility under certain crops, season, aging of mixtures and many other factors. Later Baicu (1980) suggested studying compatibility in different stages including determination of chemicals and physical properties, biological activity of compounds, field tests of effectiveness, phytotoxcity and yield after treatment.Several insecticide molecules are available in market, but many of them are not tested for the compatibility or recommended by reputed research institutes. Hence, it is necessary to investigate the compatibility of the most common agro-chemicals with respect to insect pest management in cabbage ecosystem.Therefore, the present research is planned with the following objectives

i. Insecticidal property of fungicide
ii. Influence of fungicide on the bio-efficacy of insecticides

## 2. Material and methods

**2.1** Seven insecticides and one fungicide were selected for the expirements and these are presented in table 1.

### 2.2 Insecticidal action of Saafagainst *P. xylostella*

A study was carried out to know the insecticidal property of selected fungicide. The *P. xylostella* larvae collected from cabbage field around Chikmagalur were reared to first generation on mustard seedlings. The third instar larvae were exposed to different concentrations of fungicide Saaf(carbendizim + mancozeb).

**2.2 Bioassay**

For every insecticide and fungicide mixture and individual insecticide, keeping the company's recommendation or farmer's practice as the base, five concentrations in geometric progression were used for each bioassay experiment. For every concentration, three replications of 30 third instar larvae were maintained and the leaves treated with water served as control. Fresh and uniform sized cabbage leaves were dipped in insecticide dilutions for thirty seconds and dried under room temperature. The cut ends of petioles of treated leaves were provided with wet cotton wads to retain the vigour. The treated cabbage leaves were placed in petridishes. Thirty early third instar larvae of *P. xylostella* were released on treated leaves in each petridish. The treated larvae were maintained in room temperature and the mortality was recorded at 6, 12, 18, 24, 30, 36, 42 and 48 hours after the treatment.

Observed mortality data were converted to percentages and corrected for control mortality according to Abbott(1925). Observed mortality data were converted to percentage and were subjected to probit analysis(Finney, 1971) for obtaining regression equations for dosage mortality response and to determine the $LC_{50}$ and $LT_{50}$ values.

**3. Results and discussion**

**3.1 Insecticidal properties of fungicide Saaf**

Certain compounds are marketed as fungicides to be used exclusively against fungal diseases. However, many workers have reported such compounds to possess insecticidal activity also. In this line a study was undertaken to evaluate the insecticidal properties of selected fungicide against third instar larvae of *P. xylostella* in the laboratory at five concentrations. The results revealed that fungicide possess insecticidal properties and the mortality was significantly more at higher concentrations. Among the fungicide, Saaf®(mancozeb + carbendazim) at 1875 ppm caused the highest mortality of 28.91 per cent (Table 2). Though, no similar studies have been reported in the literature. The available literature envisaged that contact fungicides namely mancozeb and carbendazim, are the component of Saaf® included in the present study exhibited varying levels of toxicity to some of the insects. To quote few examples, mancozeb against various insect pests have been reported. Mancozeb nine kg toxicant per hectare was effective in controlling only nymphs of *Psylla pyricola* on pear (Mcmullan and Jong., 1971), *Phyllocoptruta oleivora* on citrus (Hanna and Abdelhafez., 1977). The fungicide is highly effective for the control of *Polyphagotarsonemus latus* on potato crop and the per cent efficacy ranging from 87.63 to 96.23. Similarly, insecticidal activity of carbendazim one of the component of Saaf® has been documented. Carbendazim at 0.07 per cent caused 64 per cent reduction in reproduction of alate *Schizaphis creminium* on wheat (Hendi and Kansouh, 1986) and ovicidal effect on *Scirphophaga incertulus* at 0.01 per cent concentration (Raju and Rao, 1983). Similarly, fungicides namely mancozeb and quintal caused 12.59 and 10.37 per cent larval mortality against *P. xylostella* at 200 ppm (Sreedhar, 2006). Likewise insecticidal properties of chlorothalonil were toxic against *Trichoplusia ni, Pseudoplusia includens* and *H. lea* and the size of the larvae on fungicide treated diet were smaller and slow developmental rates were exhibited when compared to untreated controls (Livingston *et al.*, 1978).

**3.2 Influence of fungicide Saaf on the bio-efficacy of insecticides**

Compatibility of pesticides is the behaviour of combination with reference to active component that is, whether it has maintained, reduced or potentiated its insecticidal activity. The changes in chemical contentsof individual components, their respective characters, formulation, qualities *etc.*, occurring in the mixtures have not been studied deeply for majority of chemicals. If a new chemical discovered then studying its behaviour in the presence of other chemicals is equally important to exploit utilization of more than one chemical at a time in combination. However, only few attempts have been made to study the compatibility problem in the light of increase in number of chemicals. Hence, attempts were made to study the compatibility of insecticides in combination with fungicide under laboratory conditions by using third instar larvae of *P. xylostella* as test insect. The toxicity of insecticides with fungicide and individual insecticides to test insect was quantified by adopting leaf dip bioassay method and the compatibility was assessed based on the median lethal concentrations($LC_{50}$) and median lethal time($LT_{50}$) cumulative per cent larval mortality and relative toxicity values.

The results clearly revealed that in some combinations toxicitywas enhanced while in others the toxicity was lowered. The median lethal concentrations of seven insecticides *viz.*, chlorantraniliprole, flubendiamide, novaluron, indoxacarb, Proton®, Hamla® and profenophos were 7.21, 13.99, 74.25, 95.47, 391.74, 420.72 and 907.68 ppm, respectively (table 4). The median lethal time of seven insecticides at three different concentrations was chlorantraniliprole (27.58, 37.86 and 46.87 h) flubendiamide (30.33, 38.53 and 47.81 h), novaluron(40.82, 51.07 and 61.70 h), indoxacarb(32.35, 37.88 and 49.65 h), Proton®(35.15, 40.33 and 52.81 h), Hamla®(28.21, 34.43 and 58.49 h) and profenophos (36.19, 43.97 and 50.24 h).

Later the extent of loss or gain in toxicity of test insecticides when mixed with fungicides was quantified based on the relative toxicity, median lethal concentrations($LC_{50}$), median lethal time($LT_{50}$) and cumulative per cent larval mortality to ascertain the compatibility, Some combinations were more toxic and some were less toxic to the test insect compared to insecticides alone. As noticed from the earlier trials inherent insecticidal properties possessed by the fungicide contributed to the larval mortality. Thus additive effect of these fungicide and plant growth regulator with insecticides accounted for increase in mortality over insecticides alone and the antagonistic effect may be due to in-sensitization of insecticidal target sites, resulted in decrease in the susceptibility of pest species involved.

In combination with Saaf®, $LC_{50}$ values of indoxacarb and Hamla® comparatively increased to 4699.41 and 6873.47 ppm respectively. Saaf® interacted antagonistically with withindoxacarb and Hamla® where the $LT_{50}$ values of indoxacarb and Hamla® comparatively increased to 43.51, 48.29, 63.02 h and 39.99, 50.29, 66.85 h, respectively. Where as in cumulative larval mortality also indoxacarb(90.00, 83.33, 70.00, 36.67 and 23.33 per cent) and Hamla®(93.33, 86.67, 66.67, 41.11 and 16.67 per cent) interacted antagonistically because the larval mortality was decreased. However in combination with Saaf® per cent cumulative mortality of five insecticides after 48 hours of treatment impose were chlorantraniliprole (100.00, 96.67, 86.67, 50.00 and 33.33 per cent), flubendiamide (100.00, 96.67, 86.67, 53.33 and 40.00 per cent), novaluron (100.00, 83.33, 70.00, 40.00 and 23.33 per cent), Proton®(100.00, 93.33, 86.66, 56.67 and 40.00 per cent) and profenophos(100.00, 93.33, 83.33, 60.00 and 36.67 per cent). These five insecticides when combined with Saaf®, the mortality were increased as compared when insecticides used alone. In combination with Saaf® the $LT_{50}$ values of five insecticides were Chlorantraniliprole (25.71, 34.23 and 44.47 h), flubendiamide(26.00, 33.81 and 44.67 h), novaluron(37.62, 50.71 and 60.77), Proton®(35.54, 40.31 and 47.68 h) and profenophos(35.62, 40.32 and 47.69 h). These five insecticides when combined with Saaf® the $LT_{50}$ values were decreased which shows synergistic nature (table 3, 4 and 5)

No specific studies are available in the literature involving compatibility of above chemical combinations against *P. xylostella* for comparison. However Saaf® is combination of mancozeb + carbendizim. It is evident from the available literature that mancozeb potentiated the toxicity of some insecticides. Indoxacarb and thiodicarb interacted antagonistically with mancozeb 100 ppm in laboratory against *P. xylostella* larvae (Sreedhar, 2006). Aly (1997) in laboratory investigations revealed that mancozeb was more compatible with the insecticide Karate (Lambda-cyhalothrin) and Turadacupral against the adults of *Tribolium confusum*. Similarly Abbaiah(1985) reported synergistic action of mancozeb with monocrotophos against *Drosophila melanogaster.* Dakshinamurthy(1980) observed that acephate 34.00 ppm($LC_{50}$) with all the four concentrations of mancozeb showed no variation in the toxicity against chilli white aphid and therefore, appeared to be compatible. Mancozeb also exhibited synergistic action over carbaryl, phosphomidon and dimethoate (Tripathi*et al.*, 1983), monocrotophos 0.075 per cent against chilli pest compiex (Sitaramaraju and Srinivasrao, 1981), endosulfan against *Aphis gossypii* and *Aspondylia sesame* on sesamum (Abraham *et al.*,1977), dimethoate against *Tribolium castaneum* (Premkumar, 1978), carbaryl in controlling *Heliothis armigera* and *Spodoptera litura* (Dodd, 1979) and fenvalerate 20 EC at the rate of 75 g and monocrotophos 36 SL @ 250 ml with mancozeb 75 WP @1500 g *a.i*., per hectare against leaf hopper *Amrasca bigutulla bigutulla* (Nagia*et al.*, 1993). However, Lakshminarayana and Subbaratnam(2000) in laboratory studies reported that monocrotophos 0.52 ppm ($LC_{50}$) in combination with four test concentrations of mancozeb*viz.*, 500, 1000, 2000 and 3000 ppm showed mortality of nymphs less than 50.0 per cent indicating antagonism between these two pesticides. Tripathi *et al.* (1983) also reported antagonistic effect of monocrotophos and fenvalerate which is due to sedimentation of mancozeb. From the above discussion present investigations on compatibility can be concluded that insecticides tested were compatible with Saaf® except the indoxcarb and Hamla®.

**4. Compatibility conclusion**

From the results of *in vitro* experiments on the interaction of agro-chemicals, a compatibility chart has been prepared and presented in the Table5. It may said that insecticides namely chlorantraniliprole, flubendiamide, novaluron, Proton®, profenophos in combination with Saaf® were clearly compatible against test insect. However indoxacarb and Hamla®

in combination with Saaf® were clearly incompatible against test insect.

Interestingly, some of the combinations which behaved differently against test insect are to be viewed differently on the basis of desirable action exhibited by the chemicals in the mixture. A mixture of insecticide in combination with fungicide may cause desirable effect on insect or vice- versa. If a mixture intended to suppress insect, failed to accomplish and causes adverse effects, such a combination may be rejected. For example, indoxacarb and Hamla® in combination with Saaf® resulted in lowering of toxicity to test insect. The literature review also highlighted such variations in compatibility of pesticides this may be due to variability in test organism or crop. In most of the studies, where compatibility among agro-chemicals tried were too low to exert desirable effects. Hence further combination is needed regarding compatibility and bio-efficacy and compatibility of various pesticidal mixtures at their recommended doses in the laboratory and under field conditions. These combinations can be evaluated for phytotoxicity in field conditions. Baseline studies can be undertaken for individual insecticides, so that the folds of resistance can be worked out.

**Table 1. Details of agrochemicals selected for the bioassay**

| Sl. No | Common name | Chemical name | Trade name and formulation | Manufacturing company |
|---|---|---|---|---|
| **Insecticides** | | | | |
| 1. | Chlorantraniliprole | 3-bromo-*N*-[4-chloro-2-methyl-6-[(methylamino)carbonyl] phenyl]-1-(3-chloro-2-pyridinyl)-1H-pyrazole-5-carboxamide | Coragen®18.5 SC | E.I. Dupont India Pvt. Ltd., Gurgaon, Haryana |
| 2. | Flubendiamide | 3-iodo-*N'*-(2-mesyl-1,1-dimethylethyl)-*N*-{4-[1,2,2,2-tetrafluoro-1-(trifluoromethyl)ethyl]-*o*-tolyl}phthalamide | Fame®480 SC | Bayer Crop Science India Ltd., Mumbai |
| 3. | Chlorpyriphos + Cypermethrin | *O,O*-diethyl *O*-3,5,6-trichloro-2-pyridyl phosphorothioate + | Hamla®505 EC | Gharda Chemicals Ltd., Mumbai |
| 4. | Proton | Cocktail of botanicals *viz.,* Langdu root extract (*Stellerachamaejasme*L.)- 2.9 %, CGL extract- 1.50 %, *Brassica campestris*L.- 0.5 %, Eugenol- 9.0 %, Siberian cocklour fruit extract-10 %, Trace elements- 10 % (Venkateshalu*et al*.,2009) | Proton® | United Crop Care, Mumbai |
| 5. | Indoxacarb | Methyl(S)-N-[7-choloro-2,3,4a,5-tetrahydro-4a-Hethoxycarbomyl) indeno [1,2-e]-[1,3,4] oxadiazin-2-ylcarbonyl]-4-(triflurometheoxy)carinilat | Avaunt® 14.5 EC | E.I. Dupont India Pvt. Ltd., Gurgaon, Haryana |
| 6. | Novaluron | 1-∂3-Chloro-4-(1, 1,2-trifluro-2-trifluoromethoxyethoxy) Phenyl | Rimon® 10 EC | Indofil Chemical Company, Mumbai |
| 7. | Profenophos | O-(4-Bromo-2-chlorophenyl)-O-ethyl-S-propyl phosphorothioate | Curacron® 50 EC | Syngenta India Ltd., Mumbai |
| **Fungicides** | | | | |
| 1. | Carbendazim 12% + Mancozeb 63% | methyl benzimidazol-2-ylcarbamate + [[1,2-ethanediylbis[carbamodithioato]](2-)]manganese mixture with [[1,2-ethanediylbis [carbamodithioato]](2-)]zinc | Saaf® | United Phosphorus Ltd., Ahmedabad |

**Table 2. Per cent mortality of *P. xylostella* larvae against Saaf® and Energy® formulations**

| Chemicals | Concentration (ppm) | Per cent larval mortality at different hours after treatment | |
|---|---|---|---|
| | | 24 (h) | 48 (h) |
| Saaf® (Carbendazim + Mancozeb) | 1875 | 18.89 (25.72) | 28.89 (32.49) |
| | 1500 | 13.33 (21.39) | 22.22 (28.09) |
| | 1125 | 6.67 (14.89) | 14.44 (22.27) |
| | 750 | 3.33 (10.47) | 10.00 (18.44) |
| | 375 | 3.33 (10.47) | 5.56 (13.42) |
| Energy® | 385 | 6.67 (14.89) | 8.89 (17.26) |
| | 330 | 3.33 (10.47) | 6.67 (14.89) |
| | 275 | 0.00 (0.00) | 3.33 (10.47) |
| | 220 | 0.00 (0.00) | 0.00 (0.00) |
| | 165 | 0.00 (0.00) | 0.00 (0.00) |
| Control | 0.00 | 0.00 (0.00) | 0.00 (0.00) |
| S Em ± | | 0.25 | 0.70 |
| C D 1% | | 1.01 | 2.81 |

Figures in parenthesis are arc sine transformed values

**Table 3: Cumulative per cent larval mortality of *P. xylostella* against selected insecticides in combination with Saaf®**

| Treatments (ppm) | Cumulative per cent larval mortality at different hours after treatment | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 6 h | 12 h | 18 h | 24 h | 30 h | 36 h | 42 h | 48 h |
| Chlorantraniliprole + Saaf® @ 1898.13 | 3.33 (10.47) | 16.67 (24.04) | 36.67 (37.23) | 63.33 (52.71) | 90.00 (71.56) | 96.67 (79.37) | 100.00 (90.00) | 100.00 (90.00) |
| Chlorantraniliprole + Saaf® @ 1518.5 | 1.11 (3.49) | 3.33 (10.47) | 13.33 (21.39) | 40.00 (39.23) | 70.00 (56.79) | 86.67 (68.53) | 93.33 (75.00) | 96.67 (79.37) |
| Chlorantraniliprole+ Saaf® @ 1138.75 | 0.00 (0.00) | 0.00 (0.00) | 3.33 (10.47) | 16.67 (24.04) | 33.33 (35.24) | 60.00 (50.77) | 80.00 (63.44) | 86.67 (68.53) |
| Chlorantraniliprole+ Saaf® @ 759.25 | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 8.89 (17.26) | 16.67 (24.04) | 33.33 (35.24) | 43.33 (41.15) | 50.00 (45.00) |
| Chlorantraniliprole+ Saaf® @ 379.65 | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 3.33 (10.47) | 10.00 (18.44) | 18.89 (25.72) | 28.89 (32.49) | 33.33 (35.24) |
| Flubendiamide+ Saaf® @ 1924.2 | 3.33 (10.47) | 18.89 (25.72) | 40.00 (39.23) | 66.67 (54.70) | 86.67 (68.53) | 96.67 (79.37) | 100.00 (90.00) | 100.00 (90.00) |
| Flubendiamide+ Saaf® @ 1539.4 | 0.00 (0.00) | 3.33 (10.47) | 13.33 (21.39) | 40.00 (39.23) | 66.67 (54.70) | 86.67 (68.53) | 93.33 (75.00) | 96.67 (79.37) |

Cont…

| **Treatments (ppm)** | **Cumulative per cent larval mortality at different hours after treatment** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **6 h** | **12 h** | **18 h** | **24 h** | **30 h** | **36 h** | **42 h** | **48 h** |
| Flubendiamide+ Saaf® @ 1154.5 | 0.00 (0.00) | 0.00 (0.00) | 3.33 (10.47) | 13.33 (21.39) | 33.33 (35.24) | 60.00 (50.77) | 76.67 (61.07) | 86.67 (68.53) |
| Flubendiamide+ Saaf® @ 769.68 | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 3.33 (10.47) | 14.44 (22.27) | 31.11 (33.89) | 43.33 (41.15) | 53.33 (46.89) |
| Flubendiamide+ Saaf® @ 384.84 | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 3.33 (10.47) | 11.11 (19.42) | 24.44 (29.59) | 40.00 (39.23) |
| Novaluron+ Saaf®@ 1975 | 0.00 (0.00) | 6.67 (14.89) | 16.67 (24.04) | 30.00 (33.21) | 50.00 (45.00) | 73.33 (58.89) | 93.33 (75.00) | 100.00 (90.00) |
| Novaluron+ Saaf®@ 1590 | 0.00 (0.00) | 3.33 (10.47) | 6.67 (14.89) | 20.00 (26.56) | 43.33 (41.15) | 66.67 (54.70) | 80.00 (63.44) | 83.33 (65.88) |
| Novaluron+ Saaf®@1205 | 0.00 (0.00) | 0.00 (0.00) | 3.33 (10.47) | 10.00 (18.44) | 21.11 (27.33) | 34.44 (35.90) | 54.44 (47.52) | 70.00 (56.79) |
| Novaluron+ Saaf®@ 820 | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 3.33 (10.47) | 6.67 (14.89) | 15.56 (23.16) | 25.56 (30.32) | 40.00 (39.23) |
| Novaluron+ Saaf®@ 435 | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 3.33 (10.47) | 6.67 (14.89) | 13.33 (21.39) | 23.33 (28.86) |
| Indoxacarb+ Saaf®@2092.5 | 0.00 (0.00) | 3.33 (10.47) | 14.44 (22.27) | 31.11 (33.89) | 56.67 (48.79) | 76.67 (61.07) | 86.67 (68.53) | 90.00 (71.56) |
| Indoxacarb+ Saaf®@1681.5 | 0.00 (0.00) | 0.00 (0.00) | 6.67 (14.89) | 30.00 (33.21) | 56.67 (48.79) | 73.33 (58.89) | 80.00 (63.44) | 83.33 (65.88) |
| Indoxacarb+ Saaf®@1270 | 0.00 (0.00) | 0.00 (0.00) | 3.33 (10.47) | 13.33 (21.39) | 30.00 (33.21) | 50.00 (45.00) | 66.67 (54.70) | 70.00 (56.79) |
| Indoxacarb+ Saaf®@858.75 | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 8.89 (17.26) | 15.56 (23.16) | 23.33 (28.86) | 33.33 (35.24) | 36.67 (37.23) |
| Indoxacarb+ Saaf®@447.5 | 0.00 (0.00) | 0.00 (0.00) | 3.33 (10.47) | 6.67 (14.89) | 13.33 (21.39) | 16.67 (24.04) | 20.00 (26.56) | 23.33 (28.86) |
| Proton®+ Saaf®@2767.5 | 0.00 (0.00) | 6.67 (14.89) | 20.00 (26.56) | 40.00 (39.23) | 60.00 (50.77) | 80.00 (63.44) | 93.33 (75.00) | 100.00 (90.00) |
| Proton®+ Saaf® @2243.75 | 0.00 (0.00) | 0.00 (0.00) | 10.00 (18.44) | 30.00 (33.21) | 50.00 (45.00) | 70.00 (56.79) | 86.67 (68.53) | 93.33 (75.00) |
| Proton®+ Saaf® @1720 | 0.00 (0.00) | 0.00 (0.00) | 10.00 (18.44) | 30.00 (33.21) | 50.00 (45.00) | 66.67 (54.70) | 80.00 (63.44) | 86.67 (68.53) |
| Proton®+ Saaf® @1196.25 | 0.00 (0.00) | 0.00 (0.00) | 3.33 (10.47) | 8.89 (17.26) | 20.00 (26.56) | 36.67 (37.23) | 50.00 (45.00) | 56.67 (48.79) |
| Proton®+ Saaf® @672.5 | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 3.33 (10.47) | 10.00 (18.44) | 18.89 (25.72) | 33.33 (35.24) | 40.00 (39.23) |
| Hamla®+ Saaf® @2700 | 0.00 (0.00) | 10.00 (18.44) | 26.67 (31.05) | 53.33 (46.89) | 73.33 (58.89) | 83.33 (65.88) | 90.00 (71.56) | 93.33 (75.00) |
| Hamla®+ Saaf®@2187.5 | 0.00 (0.00) | 3.33 (10.47) | 10.00 (18.44) | 26.67 (31.05) | 45.56 (42.42) | 65.56 (54.04) | 78.89 (62.65) | 86.67 (68.53) |
| Hamla®+ Saaf®@1675 | 0.00 (0.00) | 0.00 (0.00) | 3.33 (10.47) | 10.00 (18.44) | 26.67 (31.05) | 46.67 (43.05) | 60.00 (50.77) | 66.67 (54.70) |
| Hamla®+ Saaf®@1162 | 0.00 (0.00) | 0.00 (0.00) | 3.33 (10.47) | 8.89 (17.26) | 15.56 (23.16) | 24.44 (29.59) | 30.00 (33.21) | 41.11 (39.87) |
| Hamla®+ Saaf®@650 | 0.00 (0.00) | 0.00 (0.00) | 3.33 (10.47) | 6.67 (14.89) | 6.67 (14.89) | 10.00 (18.44) | 13.33 (21.39) | 16.67 (24.04) |
| Profenophos+ Saaf®@3625 | 0.00 (0.00) | 6.67 (14.89) | 16.67 (24.04) | 32.22 (34.56) | 57.78 (49.45) | 80.00 (63.44) | 93.33 (75.00) | 100.00 (90.00) |
| Profenophos+ Saaf®@3000 | 0.00 (0.00) | 3.33 (10.47) | 10.00 (18.44) | 26.67 (31.05) | 46.67 (43.05) | 73.33 (58.89) | 90.00 (71.56) | 93.33 (75.00) |
| Profenophos+ Saaf® @2375 | 0.00 (0.00) | 0.00 (0.00) | 3.33 (10.47) | 16.67 (24.04) | 33.33 (35.24) | 56.67 (48.79) | 76.67 (61.07) | 83.33 (65.88) |
| Profenophos+ Saaf®@ 1750 | 0.00 (0.00) | 0.00 (0.00) | 3.33 (10.47) | 13.33 (21.39) | 26.67 (31.05) | 43.33 (41.15) | 53.33 (46.89) | 60.00 (50.77) |
| Profenophos+ Saaf®@ 1125 | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 3.33 (10.47) | 10.00 (18.44) | 23.33 (28.86) | 30.00 (33.21) | 36.67 (37.23) |
| Control | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| **S Em ±** | 0.59 | 0.14 | 0.15 | 0.43 | 0.33 | 0.38 | 0.27 | 0.11 |
| **C D 1%** | 2.21 | 0.53 | 0.56 | 1.62 | 0.93 | 1.07 | 1.02 | 0.41 |
| **Cv 1%** | - | 4.89 | 1.94 | 3.03 | 1.59 | 1.43 | 0.87 | 0.31 |

**Table 4. The dosage-mortality response of *P. xylostella* larvae to selected insecticides in combination with Saaf®**

| Treatments | $\chi^2$ | Regression equation Y= a ± bx | $LC_{50}$ (ppm) | Fiducial limits at 95% (ppm) | $LC_{99}$ (ppm) |
|---|---|---|---|---|---|
| Chlorantraniliprole | 5.09 | 2.98±3.47x | 7.21 | 5.71-8.55 | 33.69 |
| Chlorantraniliprole + Saaf® | 4.94 | 10.24±3.71x | 569.53 | 454.47-671.75 | 2406.79 |
| Flubendiamide | 5.36 | 3.59±3.14x | 13.99 | 4.18-20.69 | 77.06 |
| Flubendiamide + Saaf® | 5.09 | 9.23±3.39x | 529.30 | 402.90-636.81 | 2568.22 |
| Novaluron | 1.33 | 22.13±11.83x | 74.25 | 70.51-77.29 | 89.55 |
| Novaluron + Saaf® | 5.46 | 10.66±3.36x | 808.13 | 438.44-1129.50 | 3482.57 |
| Indoxacarb | 3.44 | 10.54±5.32x | 95.47 | 82.13-106.66 | 261.00 |
| Indoxacarb + Saaf® | 2.76 | 9.32±3.17x | 869.26 | 705.48-1024.31 | 4699.41 |
| Proton® | 3.45 | 13.82±5.33x | 391.74 | 337.02-437.63 | 1070.27 |
| Proton® + Saaf® | 3.75 | 10.97±3.72x | 882.89 | 688.34-1042.27 | 3719.39 |
| Hamla® | 2.82 | 17.12±6.52x | 420.72 | 378.84-460.18 | 956.20 |
| Hamla® + Saaf® | 7.80 | 8.95±2.93x | 1111.03 | 218.54-1650.53 | 6873.47 |
| Profenophos | 1.65 | 19.17±6.48x | 907.68 | 798.81-993.35 | 2074.43 |
| Profenophos + Saaf® | 6.18 | 13.95±4.40x | 1474.85 | 454.80-1991.45 | 4977.90 |

**Table 5. The time-mortality response of *P. xylostella* larvae to selected insecticides in combination with Saaf® at different concentrations**

| Treatments (ppm) | $\chi^2$ | Regression equation Y= a ± bx | $LT_{50}$ (h) | Fiducial limits at 95% (ppm) | $LT_{99}$ (h) |
|---|---|---|---|---|---|
| Chlorantraniliprole + Saaf® @ 1898.13 | 6.54 | 4.64±3.29x | 25.71 | 22.67-30.54 | 130.77 |
| Chlorantraniliprole + Saaf® @ 1518.5 | 10.02 | 5.84±3.81x | 34.23 | 28.86-46.42 | 139.67 |
| Chlorantraniliprole+ Saaf® @1138.75 | 6.17 | 7.36±4.47x | 44.47 | 39.94-52.27 | 147.35 |
| Flubendiamide+ Saaf® @ 1924.2 | 2.74 | 4.34±3.06x | 26.00 | 22.70-31.40 | 148.91 |
| Flubendiamide+ Saaf® @ 1539.4 | 4.62 | 6.26±4.09x | 33.81 | 30.46-39.14 | 125.04 |
| Flubendiamide+ Saaf® @ 1154.5 | 3.31 | 7.55±4.57x | 44.67 | 40.24-52.27 | 144.00 |
| Novaluron+ Saaf®@ 1975 | 11.85 | 5.95±3.77x | 37.62 | 30.90-56.22 | 155.35 |
| Novaluron+ Saaf®@ 1590 | 12.21 | 5.44±3.19x | 50.71 | 38.87-101.45 | 271.75 |
| Novaluron+ Saaf®@1205 | 1.40 | 6.67±3.74x | 60.77 | 51.53-80.82 | 254.50 |
| Indoxacarb+ Saaf®@2092.5 | 7.08 | 5.17±3.16x | 43.51 | 37.35-55.16 | 237.02 |
| Indoxacarb+ Saaf®@1681.5 | 12.19 | 5.26±3.12x | 48.29 | 34.60-207.55 | 268.30 |
| Indoxacarb+ Saaf®@1270 | 12.49 | 5.67±3.15x | 63.02 | 45.99-175.31 | 344.83 |
| Proton® + Saaf®@2767.5 | 5.37 | 5.56±3.59x | 35.54 | 31.55-42.10 | 157.98 |
| Proton® + Saaf® @2243.75 | 3.87 | 6.40±3.99x | 40.31 | 35.99-47.61 | 154.31 |
| Proton® + Saaf® @1720 | 7.05 | 5.42±3.23x | 47.68 | 40.78-61.16 | 250.22 |
| Hamla®+ Saaf® @2700 | 7.94 | 4.09±2.55x | 39.99 | 33.25-53.49 | 325.49 |
| Hamla®+ Saaf®@2187.5 | 2.18 | 5.17±3.04x | 50.29 | 42.45-66.04 | 292.86 |
| Hamla®+ Saaf®@1675 | 9.11 | 5.73±3.14x | 66.85 | 54.04-98.86 | 367.72 |
| Profenophos+ Saaf®@3625 | 8.15 | 6.00±3.87x | 35.62 | 31.90-41.58 | 142.21 |
| Profenophos+ Saaf®@3000 | 6.64 | 6.22±3.87x | 40.32 | 35.86-47.90 | 160.70 |
| Profenophos+ Saaf® @2375 | 6.36 | 6.85±4.08x | 47.69 | 42.12-57.93 | 177.09 |

**Table 6: Compatibility chart for agro-chemicals tested against *P. xylostella*larvae**

| Agro-chemicals | Saaf® (Mancozeb + Carbendizim) |
|---|---|
| Chlorantraniliprole | + |
| Flubendiamide | + |
| Novaluron | + |
| Indoxacarb | - |
| Proton® | + |
| Hamla® | - |
| Profenophos | + |

+ = Compatible
- = Incompitable

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