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Compatibility of carbosulfan 25 EC with certain agrochemicals in brinjal ecosystem

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ABSTRACT: The combined use of chemical insecticides with fungicides and fertilizers in a single application is a promising pest-control option to maximise productivity and minimize labour efficiency. Studies were conducted to assess the compatibility of systemic insecticide, carbosulfan 25 EC with a fungicide, micronutrient and insecticide in brinjal ecosystem. The optimum and effective dose of carbosulfan (250 g a.i.ha^{-1}) was compatible with other agro chemicals used in combination *viz.,* copper oxy chloride 50 WP @500 g a.i.ha^{-1}, zinc sulphate 0.5 per cent and dimethoate 30 EC @ 300 g a.i.ha^{-1}, without any creaming matter and/or sediment formation in any of the combinations. The tank mix foliar application of the combination chemicals *viz.,* carbosulfan @ 250 g a.i.ha^{-1} + copper oxy chloride 50 WP @ 500 g a.i.ha^{-1}, carbosulfan @ 250 g a.i.ha^{-1} + zinc sulphate 0.5 per cent and carbosulfan @ 250 g a.i.ha^{-1} + dimethoate @ 300 g a.i.ha^{-1} did not inflict any phytotoxic effect on the treatment imposed plants and a mean grade of '1' (0-10% injury) was awarded to all the treated plants in the brinjal ecosystem. The bioefficacy trials after two rounds of spraying with carbosulfan and combination with fertilizer and fungicides revealed that maximum per cent reduction is noticed in insecticide combination (carbosulfan @ 250 g a.i.ha^{-1} + dimethoate @ 300 g a.i.$ha^{-1)}$ as well as recommended and four times the dose of carbosulfan (250 and 1000 g a.i.ha^{-1}), which similarly effects in managing the shoot and fruit damage caused by the shoot and fruit borer, *Leucinodes orbonalis.* The treatments with fertilizer and fungicides alone marked the least reduction in fruit and shoot damage.The yield of brinjal ranged from 24.1to 28.7 t ha^{-1} in different treatments. Plots treated with carbosulfan @ 250 g a.i.ha^{-1} + dimethoate @ 300 g a.i.ha^{-1} recorded the highest fruit yield (28.7 t ha^{-1}) followed by carbosulfan @ 250 g a.i.ha^{-1} + copper oxy chloride @ 500 g a.i.ha^{-1} (28.3 t ha^{-1}) and carbosulfan @ 250 g a.i.ha^{-1}+ zinc sulphate (27.8 t ha^{-1}). The current findings states that carbosulfan in combination with other agrochemicals have given better results in terms of phytotoxicity, bioefficacy and yield. © 2023 Association for Advancement of Entomology

KEY WORDS: Combination, copper oxy chloride, zinc sulphate, dimethoate

INTRODUCTION

Brinjal, *Solanum melongena* Linnaeus is highly cosmopolitan and popular vegetable grown as known as "King of vegetables" globally (Lalia *et al.,* 2021). It is grown throughout the year under tropical and subtropical conditions and usually finds its place in common men's kitchen (Ajit *et al.,* 2017). It is also popularly known as poor man's crop; serves a meal for poor people's diet. Being a major vegetable crop in India, brinjal is cultivated in about 7.27 lakh hectares with an annual

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production of 123.23 Lakh tonnes during 2016-17 (Borah and Saikia, 2017).

Brinjal is attacked by more than 70 insect pests (Borah and Saikia, 2017) and the pest problems in brinjal are becoming more serious because of favourable conditions which are provided by present methods of cultivation. The monoculture, overlapping of crops, dense cropping, excess use of fertilizers and pesticides, continuous availability of preferred host plants etc., are some of the major reasons for pest outbreak (Misra, 2008; Rao, 2003). Insecticides provide an acceptable solution to overcome these pests, as they are highly effective, rapid in curative action and adoptable to most situations, flexible in meeting changing agronomic conditions and relatively economical. Various insecticides belonging to, organophosphates, carbamates and synthetic pyrethroids are recommended to control these pests (Jagginavar *et al.,* 2009; Anil Kumar *et al.,* 2000). Carbosulfan, (2,3-dihydro-2,2-dimethyl-7-benzo-furnanyl (din-butyl amino) thio methyl carbamate) a relatively new methyl carbamate insecticide is reported to be effective against insect pests of this crop. Carbosulfan is found to be very efficient in reducing the population of the most notorious pest of brinjal, the fruit and shoot borer as well as sucking pests (Sheeba Jasmine, 2002) and hence the chemical is recommended for brinjal pests.

In plant protection schedule very often, it becomes necessary to combine the application of different agrochemicals. At times, the insect pests and diseases occur simultaneously on a crop requiring foliar application of different insecticides as well as fungicides. In addition, foliar spray of fertilizers may also be required at the same time to meet the fertility of the crop (Chandrakumar *et al.,* 2008). Considering the need for application of insecticides, fungicides and fertilizers repeatedly, the combined application *i.e.* tank mix is preferred by the farmers since it could save time, money, energy and wear and tear of equipment. However, the major problem associated with this practice is the possibility of reduction in bioefficacy owing to physical and chemical incompatibility. Pesticides and fertilizers when mixed together tend to react with each other in some cases and in this process compounds may be formed which may produce harmful effects rather benefits to the crop plants. Sometimes toxicity may be increased or decreased (Patial and Mehta, 2008). Carbosulfan was tried in combination with other chemicals in few crops and found compatible. Carbosulfan (5%) was compatible with fungicides like captan, captafol, thiram and do not have any adverse effect on germination of sorghum seeds. The shootfly, *Atherigona soccata* (Rond.) was effectively controlled by five per cent carbosulfan followed by carbosulfan + carbendazim, carbosulfan + captan, carbosulfan + captafol and carbosulfan + thiram. A similar trend was observed in grain yield also (Morale *et al.,* 1991). The information on the above aspect is very much limited with respect to carbosulfan combinations in brinjal ecosystem. In view of above facts, a study of carbosulfan with different combination of agrochemicals was attempted in brinjal crop to evaluate its phytotoxic effects, bioefficacy against the shoot and fruit borer, *Leucinodes orbonalis* and its yield impacts.

MATERIALS AND METHODS

Laboratory studies: Emulsion stability test was conducted to study the compatibility of carbosulfan emulsion alone and in combination as detailed below.

Preparation of standard hard water: Standard hard water was prepared by dissolving 0.302g $CaCl_2$ and 0.139g $MgCl_2$ in one litre of distilled water.

Emulsion stability test: The test was carried out as prescribed by Indian Standard Specification (Anonymous, 1973). 0.2 ml of formulated chemical (carbosulfan 25 EC) was added into 30 ml of standard hard water taken in a beaker at the rate of 25 to 30 ml per minute with the material pouring directly into the beaker and not along the sides. The contents of the beaker was stirred with a glass rod at a rate of 4 revolutions per second during the addition. The diluted emulsion was made up to 100 ml with hard water and it was transferred immediately to a clean dry graduated cylinder. The graduated cylinder with its contents was kept in a thermostat at 30 ±1°C for 1 hour. After the specified time, the volume of the creamed matter at the top and/or the sediment if any at the bottom was observed. For stable emulsion, the creaming matter and/or the sediment if any should not exceed 2.0 ml. To 30 ml of standard hard water taken in a beaker, 0.2 ml of formulated chemical (carbosulfan 25 EC) was added. Similarly, diluted solutions of copper oxy chloride (0.2g), zinc sulphate (0.5 g), dimethoate (0.2 ml) were prepared separately using standard hard water. To 30 ml of the formulated chemical suspension (carbosulfan) prepared, 30 ml of the combination chemical (copper oxy chloride, zinc sulphate and dimethoate) was added and transferred to a clean dry graduated cylinder and the volume was made upto 100 ml with standard hard water, shaken well and was kept in a thermostat at 30 ± 1°C for 1 hour without any disturbance. The volume of the creamed matter at the top or the sediment if any at the bottom was observed. The creaming matter and/or the sediment not exceeding 2.0 ml was considered as criteria for the compatibility.

Field experiment: A replicated and randomized field experiment was conducted to study the compatibility of carbosulfan with other agrochemicals at Urumandampalayam village, Vellakinaru, Coimbatore, with the variety CO-2, during the period of Jan - May, 2013, with ten treatments replicated four times and the plot size was 20m^2.

The treatment details are mentioned in table 3. Three rounds of insecticidal spraying were given in the field trials at the vegetative stage as soon as the pest infestation starts at 14 days interval commencing from 10th day after transplanting with pneumatic knapsack sprayer using 500 litres of spray fluid per hectare. The control plots were water sprayed with pneumatic knapsack sprayer using 500 litres of spray fluid per hectare. All treatments were replicated thrice with a plot size of 20 m^2.

Phytotoxicity assessment: In the field, symptoms like leaf injury, wilting, vein clearing, necrosis, epinasty and hyponasty were observed in each plot from ten randomly tagged plants at 1, 3, 7 and 14 days after spraying as per Central Insecticide Board Registration Committee (CIBRC) protocol.

Leaf injury was assessed on visual rating from 1 - 10 scale such as

Rating	Phytotoxicity (%)
1	0 - 10
2	11 - 20
3	21 - 30
4	31 - 40
5	41 - 50
6	51 - 60
7	61 - 70
8	71 - 80
9	81 - 90
10	91 - 100

The per cent leaf injury was calculated using the formula ,

$$\text{Per cent leaf injury} = \frac{\text{Total grade points}}{\text{Max. grade x no. of leaves observed}} \times 100$$

Bioefficacy: Observation on shoot damage was recorded on five randomly selected and tagged plants from each plot on 7th and 14th day after the spray and expressed as shoot damage per cent. Observation on fruit damage was made by counting total number of fruits and damaged fruits with bore holes from 10 randomly selected plants per plot at each picking and converted into fruit damage per cent.

Yield Assessment: Brinjal fruits were harvested as replicated plot wise at an interval of 3 days and pooled to arrive the total yield from the first harvest which commenced 15 days after third spraying.

Statistical analysis

Laboratory studies: The data related to safety tests were transformed to $\sqrt{x+0.5}$ and analysed by completely randomized design. The treatment mean values of the experiment were compared using Duncan's Multiple Range Test (DMRT). The corrected per cent mortality for lab studies was worked out by using Abbott's (1925) correction.

$$\text{Corrected percent mortality} = \frac{P_o - P_c}{(100 - P_c)} \times 100$$

Where,

Po - Observed mortality in treatment

Pc - Observed mortality in untreated check

The values of the corrected per cent mortality were transformed using arc sine transformation for normalisation of data (Snedecor and cochran, 1967)

Field studies: The yield data in the field experiment were transformed to $\sqrt{x+0.5}$ and analysis of variance was carried out by randomized block design (Panse and Sukhatme,1958) and means were separated by Duncan's Multiple Range Test. The corrected per cent reduction in field population was worked out by using the formula of Henderson and Tilton (1955).

$$\text{Corrected per cent reduction} = 1 - \frac{(T_a X C_b)}{(T_b X C_a)} \times 100$$

Where,

Ta - Number of insects in the treatment after spraying

Tb - Number of insects in the treatment before spraying

Ca - Number of insects in the untreated check after spraying

Cb - Number of insects in the untreated check before spraying

RESULTS

Evaluation of compatibility of carbosulfan 25 EC by emulsion stability test: The emulsion stability test conducted to assess the compatibility of carbosulfan 25 EC with copper oxy chloride 50 WP, zinc sulphate (0.5%) and dimethoate 30 EC revealed that no creaming matter and/or sediment formation was observed in any of the combinations *viz.*, carbosulfan 25 EC @ 250 g a.i.ha^{-1} + copper oxy chloride 50 WP @ 500 g a.i.ha^{-1}, carbosulfan 25 EC @ 250 g a.i.ha^{-1} + zinc sulphate 0.5 per cent, carbosulfan 25 EC @ 250 g a.i.ha^{-1} + dimethoate 30 EC @ 300 g a.i.ha^{-1}. The results indicated that carbosulfan at the optimum and effective dose was compatible with other agrochemicals used in the present study.

Evaluation of carbosulfan 25 EC for phytotoxicity on brinjal in the compatibility study: The results of the investigation on the compatibility of carbosulfan 25 EC with copper oxy chloride 50 WP, zinc sulphate (0.5%) and dimethoate 30 EC as tank mix foliar application on brinjal were furnished in the table 2. The observations showed that none of the combination treatments *ie.* carbosulfan 25 EC @ 250 g a.i.ha^{-1} + copper oxy chloride 50 WP @ 500 g a.i.ha^{-1}, carbosulfan 25 EC @ 250 g a.i.ha^{-1} + zinc sulphate (0.5 %), carbosulfan 25 EC @ 250 g a.i.ha^{-1} + dimethoate 30 EC @ 300 g a.i.ha^{-1} caused any phytotoxic effect and were not differed symptomatically from control. During the entire period of observations the mean grade of '1' (0-10% injury) was awarded for all the treatment imposed plants. Hence it was concluded that the combination of carbosulfan with other fungicide, micronutrient and insecticide did not inflict any phytotoxic effect on brinjal.

Evaluation of carbosulfan 25 EC in combination with other chemicals on the bioefficacy of brinjal against shoot and fruit borer, on shoot damage: Two sprays of carbosulfan with its recommended, double and triple the dose (250, 500 and 1000 g a.i.ha^{-1}) and the combinations were given and the shoot and shoot damage percent was worked out. The results of the evaluation of carbosulfan 25 EC in combination with other chemicals on the bioefficacy of brinjal against shoot and fruit borer, *L. orbonalis* on shoot damage after first spray revealed that a maximum of 81.58 per cent reduction in shoot damage was noticed in

Table 1. Effect of carbosulfan 25 EC in combination with other chemicals on shoot damage by shoot and fruit borer, *Leucinodes orbonalis* in brinjal ecosystem (Mean of three replications)

Treatments	Per cent Shoot Damage														
	Days after first application								Days after second application						
	PTC	1	3	7	10	14	Mean	% Redn	1	3	7	10	14	Mean	% Redn
Carbosulfan 25 EC @ 250 g a.i.ha^{-1}	6.33	0.83^{a} (1.15)	0.57^{a} (1.03)	1.27^{ab} (1.31)	$1.87a^{b}$ (1.52)	2.37^{ab} (1.68)	1.38	81.47	0.60^{a} (1.05)	0.47^{a} (0.98)	0.50^{a} (1.00)	0.93^{a} (1.19)	1.23^{a} (1.31)	2.53	91.46
Carbosulfan 25 EC @ 250 g a.i.ha^{-1} + Copper oxy chloride @ 500 g a.i ha^{-1}	6.13	1.47^{b} (1.40)	1.43^{c} (1.39)	1.57^{bc} (1.44)	1.90^{d} (1.55)	2.17^{a} (1.63)	1.71	77.10	1.30^{b} (1.34)	1.23^{b} (1.31)	1.50^{ab} (1.39)	1.97^{c} (1.51)	2.20^{c} (1.59)	0.79	81.24
Carbosulfan 25 EC @ 250 g a.i.ha^{-1} + Zinc sulphate - 0.5%	5.80	1.83^{c} (1.49)	1.60^{c} (1.37)	2.23^{c} (1.57)	2.77^{c} (1.80)	2.93^{b} (1.81)	2.05	72.49	1.97^{c} (1.56)	1.83^{b} (1.51)	2.13^{c} (1.61)	2.73^{d} (1.79)	3.03^{d} (1.87)	2.43	73.25
Carbosulfan 25 EC @ 250 g a.i.ha^{-1} + Dimethoate 30 EC @ 300 g a.i.ha^{-1}	7.27	0.80^{a} (1.14)	0.47^{a} (0.97)	$1.23^{a}b$ (1.28)	1.90^{ab} (1.55)	2.47^{b} (1.68)	1.37	81.58	0.70^{a} (1.07)	0.47^{a} (0.98)	0.79^{a} (1.09)	0.93^{a} (1.18)	1.10^{a} (1.25)	0.80	90.87
Copper oxy chloride @ 500 g a.i ha^{-1}	6.60	5.03^{e} (2.35)	4.77^{e} (2.29)	5.23^{d} (2.39)	5.40^{d} (2.43)	6.27^{d} (2.60)	2.78	62.72	1.90^{d} (1.55)	2.10^{d} (1.61)	2.60^{c} (1.76)	2.90^{e} (1.84)	3.13^{d} (1.91)	2.34	71.10
Zinc sulphate- 0.5%	7.40	2.20^{d} (1.64)	2.00^{d} (1.58)	2.50^{c} (1.73)	2.90^{c} (1.84)	3.37^{c} (1.97)	2.59	65.28	1.97^{d} (1.49)	1.90^{c} (1.46)	2.27^{d} (1.60)	2.70^{e} (1.74)	3.33^{d} (1.92)	2.43	72.15
Dimethoate EC @ 300 g a.i.ha^{-1}	7.07	1.43^{b} (1.39)	1.33^{c} (1.35)	1.53^{b} (1.43)	1.90^{ab} (1.55)	2.07^{a} (1.60)	1.65	77.86	1.57^{c} (1.44)	1.23^{b} (1.30)	1.33^{b} (1.34)	1.37^{b} (1.35)	1.63^{b} (1.43)	1.43	83.68
Carbosulfan 25 EC @ 500 g a.i.ha^{-1}	7.38	1.10^{ab} (1.25)	1.03^{b} (1.22)	1.27^{ab} (1.30)	1.90^{ab} (1.55)	1.93^{a} (1.50)	1.43	81.15	1.03^{ab} (1.24)	0.87^{b} (1.17)	1.27^{b} (1.32)	1.53^{b} (1.42)	1.87^{b} (1.53)	1.314	84.97
Carbosulfan 25 EC @ 1000 g a.i.ha^{-1}	7.53	0.97^{ab} (1.21)	0.87^{b} (1.15)	1.10^{a} (1.25)	1.70^{a} (1.41)	2.10^{a} (1.61)	1.52	81.39	0.77^{a} (1.12)	0.53^{a} (1.01)	0.63^{a} (1.06)	0.93^{a} (1.19)	1.10^{a} (1.26)	0.79	90.94
Untreated control	6.80	6.97^{f} (2.72)	7.20^{f} (2.77)	7.63^{e} (2.84)	7.43^{e} (2.81)	8.07^{e} (2.92)	7.46		8.20^{e} (2.94)	8.43^{e} (2.98)	8.80^{e} (3.04)	9.17^{f} (3.10)	9.10^{e} (3.09)	8.74	-

PTC – Pre - treatment count; Figures in parentheses are $\sqrt{x + 0.5}$ transformed values; In a column, means followed by a common letter(s) are not significantly different by DMRT (p=0.05)

carbosulfan 25 EC @ 250 g a.i.ha^{-1} and dimethoate 30 EC @ 300 g a.i.ha^{-1} combination, followed by recommended, four times and double the dosage of carbosulfan recording 81.47, 81.39 and 81.15 per cent damage, which are on par. The treatments without insecticides *ie.* fertilizers and fungicides alone marked the lowest percent damage of 65.28 and 62.72 per cent damage. After the second spray, the highest per cent reduction was noticed for the recommended dose of carbosulfan 25 EC @ 250 g a.i.ha^{-1} displaying 91.46 per cent followed by four times the dose of carbosulfan (1000 g a.i.ha^{-1}) and the insecticides combination (carbosulfan 25 EC @ 250 g a.i.ha^{-1} and dimethoate 30 EC @ 300 g a.i.ha^{-1}) portraying 90.94 and 90.87 per cent reduction (Table 1). Two times the dose of carbosulfan (500 g a.i.ha^{-1}), the insecticide, dimethoate EC @ 300 g a.i.ha^{-1} and the combination of carbosulfan and fungicide (carbosulfan 25 EC @ 250 g a.i.ha^{-1} + copper oxy chloride @ 500 g a.i ha^{-1}) offered 84.97, 83.68 and 81.24 per cent reduction in shoot damage and were

Table 2. Effect of carbosulfan 25 EC in combination with other chemicals on fruit damage by shoot and fruit borer *Leucinodes orbonalis* in brinjal ecosystem (Mean of three replications)

Treatments	Per cent Fruit Damage															
	Days after first application								Days after second application							
	PTC	1	3	7	10	14	Mean	% Redn	PTC	1	3	7	10	14	Mean	% Redn
Carbosulfan 25 EC @ 250 g a.i.ha-1	16.33	1.37^{a} (1.37)	1.30^{a} (1.34)	1.50^{a} (1.41)	1.73^{ab} (1.49)	1.97^{a} (1.57)	1.57	77.18	4.70	1.30^{b} (1.34)	1.17^{b} (1.29)	1.40^{b} (1.38)	1.60^{a} (1.45)	1.97^{ab} (1.57)	1.49	90.96
Carbosulfan 25 EC @ 250 g a.i.ha-1 + Copper oxy chloride @ 500 g a.i ha-1	17.27	2.10^{c} (1.56)	2.03^{c} (1.54)	2.47^{b} (1.68)	2.93^{c} (1.82)	3.20^{c} (1.89)	2.55	63.09	6.07	2.73^{c} (1.80)	2.57^{c} (1.75)	2.97^{c} (1.86)	3.73^{c} (2.06)	3.97^{d} (2.11)	3.19	64.06
Carbosulfan 25 EC @ 250 g a.i.ha-1 + Zinc sulphate - 0.5%	16.83	2.03^{c} (1.59)	1.97^{c} (1.57)	2.23^{c} (1.65)	2.90^{c} (1.84)	3.03^{c} (1.88)	2.43	64.74	4.67	2.67^{c} (1.78)	2.37^{c} (1.67)	2.43^{c} (1.71)	2.77^{bc} (1.79)	2.90^{c} (1.84)	2.63	61.87
Carbosulfan 25 EC @ 250 g a.i.ha-1 + Dimethoate 30 EC @ 300 g a.i.ha-1	17.07	1.43^{ab} (1.39)	1.33^{a} (1.35)	1.53^{a} (1.43)	1.90^{b} (1.55)	2.07^{b} (1.60)	1.65	76.05	7.73	0.70^{a} (1.09)	0.57^{a} (1.03)	0.63^{a} (1.06)	1.60^{a} (1.44)	1.83^{ab} (1.53)	1.07	88.00
Copper oxy chloride @ 500 g a.i ha-1	16.07	2.73^{c} (1.80)	2.57^{d} (1.75)	2.97^{c} (1.86)	3.73^{d} (2.06)	3.97^{c} (2.11)	3.19	53.75	8.07	4.07^{d} (2.13)	3.87^{d} (2.09)	3.93^{c} (2.10)	4.60^{d} (2.26)	6.60^{f} (2.66)	4.61	48.08
Zinc sulphate- 0.5%	17.97	2.20^{d} (1.64)	2.23^{d} (1.65)	3.63^{d} (2.03)	4.87^{d} (2.32)	5.40^{d} (2.43)	3.67	46.85	6.37	4.27^{d} (2.18)	4.17^{d} (2.16)	5.10^{d} (1.37)	6.80^{e} (2.70)	9.23^{e} (3.12)	5.91	33.45
Dimethoate EC @ 300 g a.i.ha-1	16.78	1.73^{b} (1.48)	1.57^{bc} (1.43)	2.03^{ab} (1.51)	2.57^{c} (1.70)	2.93^{b} (1.81)	2.17	68.60	8.33	2.03^{b} (1.58)	1.90^{b} (1.54)	1.97^{b} (1.57)	2.27^{b} (1.65)	2.83^{c} (1.82)	2.20	75.24
Carbosulfan 25 EC @ 500 g a.i.ha-1	16.73	1.47^{ab} (1.40)	1.43^{bc} (1.39)	1.57^{b} (1.44)	1.90^{b} (1.55)	2.17^{b} (1.63)	1.71	75.24	4.93	1.30^{b} (1.34)	1.23^{b} (1.32)	1.47^{b} (1.40)	1.73^{ab} (1.49)	2.03^{b} (1.59)	1.55	82.53
Carbosulfan 25 EC @ 1000 g a.i.ha-1	15.42	1.17^{a} (1.28)	1.26^{a} (1.32)	1.37^{a} (1.34)	1.60^{a} (1.43)	1.87^{a} (1.53)	1.45	78.92	3.57	0.80^{a} (1.14)	0.67^{a} (1.08)	0.93^{a} (1.20)	1.03^{a} (1.24)	1.37^{a} (1.36)	0.96	89.20
Untreated control	16.43^{d} (2.63)	6.70^{e} (2.68)	6.87^{e} (2.71)	7.07^{e} (2.75)	7.03^{e} (2.74)	6.82^{e}	6.90		7.87	8.43^{e} (2.99)	8.67^{e} (3.03)	8.73^{e} (3.04)	9.10^{f} (3.10)	9.50^{g} (3.16)	8.89	

PTC – Pre treatment count; Figures in parentheses are $\sqrt{x+0.5}$ transformed values; In a column, means followed by a common letter(s) are not significantly different by DMRT (p=0.05)

on par. The lowest per cent reduction in shoot damage was noticed in fungicide and fertilizer treatments (71.10 and 72.15%).

Evaluation of carbosulfan 25 EC in combination with other chemicals on the bioefficacy of brinjal against shoot and fruit borer, on fruit damage: Two rounds of sprays of carbosulfan with its recommended, double and triple the dose (250, 500 and 1000 g a.i.ha^{-1}) and the combinations were given and the shoot and fruit damage percent was worked out. The results of the evaluation of carbosulfan 25 EC in combination with other chemicals on the bioefficacy of brinjal against shoot and fruit borer on fruit damage after first spray revealed that a maximum of 78.92 per cent reduction is noticed in four times the dose of carbosulfan (1000 g a.i.ha^{-1}), followed by the recommended dose of carbosulfan (250 g a.i.ha^{-1}) portraying 77.18 per cent, insecticides combination

Table 3. Effect of carbosulfan 25 EC in combination with other chemicals on the yield of brinjal

No	Treatments	kg plot^{-1}			Mean kg plot^{-1}	Mean t ha^{-1}
		I harvest	II harvest	III harvest		
T_1	Carbosulfan 25 EC @ 250 g a.i.ha^{-1}	52.2^{c}(7.26)	56.6^{a}(7.54)	54.0^{bc}(7.38)	54.2^{c}(7.39)	27.1
T_2	Carbosulfan 25 EC @ 250 g a.i.ha^{-1} + Copper oxy chloride @ 500 g a.i ha^{-1}	57.2^{ab}(7.59)	56.0^{a}(7.51)	56.6^{ab}(7.57)	56.6^{ab}(7.55)	28.3
T_3	Carbosulfan 25 EC @ 250 g a.i.ha^{-1} + Zinc sulphate - 0.5%	54.5^{abc}(7.41)	57.0^{a}(7.58)	55.2^{ab}(7.46)	55.6^{abc}(7.49)	27.8
T_4	Carbosulfan 25 EC @ 250 g a.i.ha^{-1} + Dimethoate 30 EC @ 300 g a.i.ha^{-1}	57.5^{a}(7.61)	56.8^{a}(7.57)	58.0^{a}(7.64)	57.4^{a}(7.61)	28.7
T_5	Copper oxy chloride @ 500 g a.i ha^{-1}	47.3^{d}(6.91)	48.3^{b}(6.98)	49.0^{d}(7.03)	48.2^{e}(6.98)	24.1
T_6	Zinc sulphate- 0.5%	48.5^{d}(6.99)	49.0^{b}(7.03)	48.0^{d}(6.96)	48.5^{e}(6.99)	24.2
T_7	Dimethoate 30 EC @ 300 g a.i.ha^{-1}	51.5^{c}(7.21)	50.0^{b}(7.10)	52.0^{c}(7.24)	51.2^{d}(7.18)	25.6
T_8	Carbosulfan 25 EC @ 500 g a.i.ha^{1}	54.3^{bc}(7.41)	55.5^{a}(7.48)	56.0^{ab}(7.51)	55.2^{bc}(7.46)	27.6
T_9	Carbosulfan 25 EC @ 1000 g a.i.ha^{-1}	53.6^{c}(7.40)	55.2^{a}(7.46)	54.8^{abc}(7.43)	54.5^{c}(7.47)	27.3
T_{10}	Untreated control	32.0^{e}(5.70)	31.5^{c}(5.65)	33.0^{e}(5.78)	32.1^{f}(5.71)	16.05

Values are mean of four observations; In a column means followed by a common letter are not significantly different by DMRT ($p = 0.05$); Values in the parentheses are transformed values

(carbosulfan 25 EC @ 250 g a.i.ha^{-1} + dimethoate 30 EC @ 300 g a.i.ha^{-1}) displayimg 76.05 per cent and double the dose of carbosulfan (500 g a.i.ha^{-1}) with 75.24 per cent reduction in fruit damage. The treatments with fertilizer and fungicides alone represented the highest damage with 46.85 and 53.75 per cent reduction. After the second spray the highest per cent reduction was noticed for the recommended dose of carbosulfan 25 EC @ 250 g a.i.ha^{-1} displaying 90.96 per cent followed by four times the dose of carbosulfan (1000 g a.i.ha^{-1}) with 89.2 per cent reduction and the insecticides combination (carbosulfan 25 EC @ 250 g a.i.ha^{-1} and dimethoate 30 EC @ 300 g a.i.ha^{-1}) portraying 88 per cent reduction in fruit damage. Two times the dose of carbosulfan (500 g a.i.ha^{-1}), the insecticide and dimethoate EC @ 300 g a.i.ha^{-1} offered 82.53 and 75.24 per cent reduction in shoot damage and were on par. The combination of carbosulfan and fungicide (carbosulfan 25 EC @ 250 g a.i.ha^{-1} + copper oxy chloride @ 500 g a.i ha$^{-1)}$ and combination of carbosulfan and fertilizer posed (carbosulfan 25 EC @ 250 g a.i.ha^{-1} + zinc sulphate - 0.5%) 64.06 and 61.87 per cent reduction in fruit damage respectively (Table 2). The lowest per cent reduction in fruit damage was noticed in zn sulphate and copper oxy chloride treatments (33.45 and 48.08 % respectively) (Table 2).

Evaluation of carbosulfan 25 EC in combination with other chemicals on the yield of brinjal: The field experiment conducted to assess the yield of brinjal by tank mix application of carbosulfan 25 EC with copper oxy chloride 50 WP, zinc sulphate (0.5%) and endosulfan 35 EC showed that all the combination treatments registered higher yields than these chemicals when used alone. The yield of brinjal ranged from 24.1 to 28.7 t ha^{-1} in different treatments (Table 3). Carbosulfan 25 EC @ 250 g a.i.ha^{-1} + dimethoate 30 EC @ 300 g a.i.ha^{-1} recorded maximum yield of 28.7 t ha^{-1} followed by carbosulfan 25 EC @ 250 g a.i.ha^{-1} + copper oxy chloride 50 WP @ 500 g a.i.ha^{-1} (28.3 t ha^{-1}) followed by carbosulfan 25 EC @ 250 g a.i.ha^{-1} + zinc sulphate 0.5 per cent (27.8 t ha^{-1}) which were on par with each other. The different doses of carbosulfan 25 EC alone *ie*. 250, 500, 1000 g a.i.ha^{-1} registered 27.1, 27.6 and 27.3 t ha^{-1} which were on par with each other, of which carbosulfan 25 EC @ 500 g a.i.ha^{-1} was on par with the combination treatments (Table 3).

DISCUSSION

The results of the physical compatibility test showed that the carbosulfan in combination with other agro chemicals like copper oxy chloride, zinc sulphate, dimethoate in standard hard water did not produce any sediment and/or creamy matter which showed that the chemical is compatible with other agrochemicals tested. Concordant results were obtained by Judge and Natti (1972) that carbofuran + captan were compatible and not showed any adverse effect on each other, which was again supported by Padmanaban (1980) who obtained concordant results that no creaming matter at the top when carbaryl, endosulfan or monocrotphos was mixed with urea. Similar findings were also reported by Morale *et al.* (1991) that five per cent carbosulfan was compatible with fungicides like captan, captafol and thiram. This was again in agreement with the findings of Paul Mohan Roy (1988) who stated that the addition of mancozeb and/or urea did not produce any creaming or sedimentation with fenvalerate, cypermethrin, deltamethrin and methyl-o-demeton. In the field, the combination treatments did not cause any phytotoxic effects on brinjal and awarded with grade '1' (0-10% injury). This result was in accordance with Morale *et al.* (1991) who reported that five per cent carbosulfan with fungicides like captan, captafal and thiram as seed treatment did not have any adverse effect on the germination of sorghum seeds. Similarly, Poe and Jones (1972) also arrived the same results that carbaryl, methomyl, parathion and dimethoate in combination was compatible and did not produce any adverse effect on tomato crop. Similar reports were also reported by Judge and Natti (1972) in carbofuran + captan combination. In another study by Maduri *et al.* (2021) the physical compatibility of 18 combinations involving 6 insecticides (clothianidin 50 WDG @ 0.1g/l, acetamiprid 20 SP@ 0.2 g/l, flonicamid 50WG@0.2 g/l, buprofezin 25SC @1.5 ml/l, novaluron 10EC @1ml/l and dimethoate 30EC@1.7 ml/l) and 3 fungicides (propiconazole 25EC @ 1ml/l, carbendizm 50 WP @1g/l and carbendizm 12% + mancozeb 63% WP @2G/l) were evaluated. All 18 combinations of insecticides and fungicides tested were physically compatible. The combinations (*viz.,* novaluron + carbendazim, acetamiprid + carbendazim, acetamiprid + carbendazim 12% + mancozeb 63% andbuprofezin + carbendazim 12% + mancozeb 63%) showed phytotoxic symptoms like vein clearing and scorching onleaves, remaining all other treatment combinations were compatible.

The bioefficacy studies revealed that carbosulfan treatments alone and in combinations significantly reduced the shoot and fruit damage caused by shoot and fruit borer, *L. orbonalis*. The per cent reduction in shoot and fruit damage was maximum for the recommended and four times the dose of carbosulfan (250 and 1000 g a.i.ha^{-1})and combination treatment of insecticides (carbosulfan 25 EC at 250 g a.i.ha^{-1} + dimethoate 30 EC at 300 g a.i.ha^{-1}). Two times the dose of carbosulfan (carbosulfan at 500 g a.i.ha^{-1}) and the insecticide (dimethoate 30 EC at 300 g a.i.ha^{-1}) trails its efficacy in managingthe shoot and fruit damage by shoot and fruit borer of brinjal. The results are in conformity with Mahla *et al.* (2017) who stated that carbosulfan 25 EC @1500 ml/ha, followed by 1250 ml/ha, reduced the damage of shoot and fruit borer considerably with high marketable yield, without any phytotoxic effects on brinjal crop. The results are in agreement with Misra (2008) that carbosulfan 25 EC @ 500 g a.i.ha^{-1} led to 84.73 and 71.93 per cent reduction in shoot damage and 76.94 and 77.31 per cent fruit damage. The present results fall in line with Roy *et al.* (2016) who observed a reduced infestation of shoot and fruit borer after application of carbosulfan 25 EC@375g. ai/ha yielding 9.23 q/ha. Much studies are not conducted in combination of chemicals, especially with carbosulfan to compare the current results.

The harvest of healthy brinjal fruits was found to be maximum from the combination treatments than the treatment with individual chemicals, which ranged from 27.8 to 28.7 t ha^{-1}. Such an observation has been reported by Morale *et al*. (1991) that the combination of carbosulfan with fungicides like captan, captafal and thiram recorded maximum grain yield of sorghum. Concordant results were also reported by Srinivasan *et al.* (1986) that the carbamate insecticide BPMC (0.025%) or carbaryl (0.075%) applied with chitin inhibitor SIR 8514 (0.0325%) recorded a higher yield of brinjal fruit of 19.97 t ha^{-1} and 18.5 t ha^{-1} respectively which coincides with the findings of Sathyanarayana Moorthy *et al*. (1988) when insecticides like monocrotophos, quinalphos, chlorpyriphos and carbaryl were combined with neem oil in rice crop. Similar results were also obtained by Peter *et al.* (1989), Rao *et al.* (1995), Singh and Tripathi (1996) and Pawar and Mali (1997).

Carbosulfan at 250 g a.i.ha^{-1} was found to be compatible with the recommended doses of copper oxy chloride 50 WP, zinc sulphate (0.5%) and dimethoate 30 EC in the emulsion stability test, as there was no creaming up at the top layer and/or sediments at the bottom. Carbosulfan at 250 g a.i.ha^{-1} when sprayed as tank mix to brinjal crop, in combination with copper oxy chloride 50 WP, zinc sulphate (0.5%) and dimethoate 30 EC did not exhibit any phytotoxic symptoms in the field. The bioefficacy of carbosulfan with its combinations against the shoot and fruit damage of brinjal shoot and fruit borer revealed a positive effect with carbosulfan at recommended, double and four times the dosage performing the best efficacy. The bioefficacy of combinations revealed that, the insecticides combination (carbosulfan + dimethoate) portrayed a similar better performance, but combination of carbosulfan with fungicide and fertilizer, showed a neutral effect. The treatments with fungicides and fertilizer alone, displayed a very minimal effect in managing the damage due to shoot and fruit borer. The combination of carbosulfan 25 EC at 250 g a.i.ha^{-1} + dimethoate 30 EC at 300 g a.i.ha^{-1} recorded maximum yield of 28.7 t ha^{-1} followed by carbosulfan 25 EC at 250 g a.i.ha^{-1} + copper oxy chloride 50 WP at 500 g a.i.ha^{-1} (28.3 t ha^{-1}) and carbosulfan 25 EC at 250 g a.i.ha^{-1} + zinc sulphate (27.8 t ha^{-1}). All the combinations (carbosulfan + dimethoate, carbosulfan + copper oxy chloride, carbosulfan + zinc sulphate) at the recommended doses exhibited additive effect.

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