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Impact of adjuvants on efficacy of insecticides against aphid infesting cauliflower

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Abstract
A field experiment was conducted at Anand Agricultural University, Anand during *Rabi*, 2024-25 to assess the impact of various adjuvants on the efficacy of insecticides against aphid, *Lipaphis pseudobrassicae* infesting cauliflower. Among the fifteen treatment combinations of insecticides and adjuvants, cyantraniliprole 10.26% OD + sticker 0.1% (I_3A_2) and cyantraniliprole 10.26% OD + guar gum 0.1% (I_3A_5) were found most effective in reducing of aphid incidence in cauliflower. The treatment combinations of cyantraniliprole 10.26% OD + silicone spreader 0.1% (I_3A_3), tolfenpyrad 15 EC + sticker 0.1% (I_1A_2) and tolfenpyrad 15 EC + silicone spreader 0.1% (I_1A_3) emerged out as next best effective combinations against aphid, these were mediocre in their effectiveness. Cyantraniliprole 10.26 OD and tolfenpyrad 15 EC exhibited increased effectiveness when combined with adjuvants compared to sprayed alone, whereas flonicamid 50 WG performed better without adjuvants or with sticker 0.1%. Moreover, the higher curd yield was harvested from the plots treated with cyantraniliprole 10.26 OD + guar gum 0.1% (170.01 q/ha) and cyantraniliprole 10.26 OD + silicone spreader 0.1% (161.52 q/ha).

Keywords: Aphids, adjuvants, efficacy, cauliflower, *Lipaphis pseudobrassicae*

Introduction
Cauliflower (*Brassica oleracea* var. *botrytis* Linnaeus), a member of the Brassicaceae family, is predominantly grown in temperate regions across the world. In India, it ranks among the most significant vegetable crops, with cultivation spanning about 4.94 lakh hectares and an impressive annual yield of 97.3 lakh metric tonnes. Among the Indian states, West Bengal leads in cauliflower cultivation, covering an area of 80.11 thousand hectares and producing approximately 20.57 lakh metric tonnes. In contrast, Gujarat ranks fifth in terms of area under cultivation (34.81 thousand hectares) but moves up to fourth place in production with an output of around 7.70 lakh metric tonnes (Anon., 2025) [1].

Despite its wide cultivation, cauliflower farming faces serious challenges due to insect pests and disease outbreaks. These biological stresses are major limiting factors, often leading to yield losses ranging from 50% to 80%, significantly affecting productivity and farmer income (Dotasara *et al.*, 2017) [7]. Cauliflower is notably vulnerable to pest infestations due to its tender physiological makeup, its preference for cold and humid growing conditions and the prevalence of intensive cultivation practices. This crop is targeted by a wide range of insect pests throughout its growth stages, with up to 24 different species of insect-pest reported to cause significant damage (Devjani and Singh, 2002) [6]. The important pests of cauliflower are aphid., *L. erysimi* Kaltenbach; diamondback moth., *Plutella xylostella*. Linnaeus.; webworm, *Hellua undalis* Fabricius.; cabbage butterflies, *Pieris brassicae* Linnaeus and flea beetles *Chaetocnema basalis* Bally (Chaudhari *et al.*, 2001; Srinivasan and Murthy, 1991) [4, 16]. Among the various insect-pests of cauliflower, aphid is the most destructive and predominant pest reported from all areas. Three aphid species *viz.*, *Brevicoryne brassicae*., *L. erysimi* and *Myzus persicae*. reported on cauliflower crop but *L. erysimi* caused extensive damage up to 54.2 per cent (Srivastava and Gularia, 2003) [17]. Besides, causing direct losses, it is also capable of transmitting more than 50 plant viruses (Blackman and Eastop, 1985) [3].

To combat the substantial losses caused by insect-pests, many farmers use pesticides indiscriminately.

Also, combined with the use of high-yielding crop varieties and chemical fertilizers, pesticides play a major role in boosting agricultural productivity among Indian farmers. However, this approach raises concerns about ecological balance, pest resistance and food safety (Birthal *et al.*, 2000) [2]. Moreover, the effectiveness of any agrochemical is often observed to vary with weather parameters, their physical and chemical properties and crop conditions. The insufficient wetting and deposition performance of pesticides on superhydrophobic crop leaves reduces the utilization rate of pesticides and causes harm to the environment (Liu *et al.*, 2021; Schulzt *et al.*, 2021) [11, 13]. This decreases the effectiveness of the spraying and increases the risk of polluting the environment and harming people living in nearby areas. Temperatures of air and surfaces are important factors in determining the efficacy of pesticides.

In addressing this issue, a viable solution is to incorporate adjuvants into pesticides during field spraying, a strategy known to enhance their physical and chemical characteristics (Horak *et al.*, 2021; Zhang and Xiong, 2021) [10, 20]. This strategy not only improves the overall performance of pesticides but also enhances their effectiveness against insect pests. To support this, utilize a variety of adjuvants substances that aid in the penetration and absorption of pesticides through the plant's foliage. These adjuvants significantly influence the interaction between the crop, the pest and pesticide, thereby increasing treatment efficiency. Commonly used adjuvants include surfactants, compatibility agents, anti-foaming compounds, spray colorants (dyes) and drift control agents (Tu and Randall, 2001) [19]. The adjuvants are usually much cheaper than insecticides and have the potential to reduce the effective pesticide dosage by as much as tenfold, but their efficacy is contingent on factors such as the diverse nature of chemicals, formulations and plant characteristics (Green and Foy, 2003) [9].

Adjuvants, often added to insecticide formulations to enhance effectiveness, can change the chemical properties of active ingredients, affecting both their potency against pests and their stability in the environment.

Materials and Methods

The research work was carried out at the Entomology farm, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat (22.56 ºN and 72.95 ºE) during *Rabi*, 2024-25. The land was ploughed to a fine tilth at a depth of 20-25 cm. Clods, stubbles and weeds are removed mechanically and by manual labours. Local variety of cauliflower was transplanted in the gross plot size of 2.4 × 3.6 m (Net plot: 1.2 × 2.7 m) at a spacing of 60 × 45 cm. The experiment was laid out in Randomized Complete Block Design (Factorial) with three levels of I (Insecticides) like tolfenpyrad 15 EC, flonicamid 50 WG and cyantraniliprole 10.26 OD and five levels of A (Adjuvants) *viz.*, control (no adjuvant), sticker 0.1%, silicone spreader 0.1%, cotton seed oil 0.1% and guar gum 0.1%, which gives out total 15 treatment combinations (I_1A_1, I_1A_2, I_1A_3, I_1A_4, I_1A_5, I_2A_1, I_2A_2, I_2A_3, I_2A_4, I_2A_5, I_3A_1, I_3A_2, I_3A_3, I_3A_4, I_3A_5). The experiment was conducted in three replications with a view to evaluate the impact of adjuvants on the efficacy of insecticides against aphid.

The treatment details for this investigation are as described below in Table 1.

Table 1: Details of treatment combinations

Sr. No.	Symbol	Treatment Combinations	Dose (g or mL/10 litre of water)
1	I_1A_1	Tolfenpyrad 15 EC + No adjuvant	20
2	I_1A_2	Tolfenpyrad 15 EC + Sticker 0.1%	20 + 10
3	I_1A_3	Tolfenpyrad 15 EC + Silicone spreader 0.1%	20 + 10
4	I_1A_4	Tolfenpyrad 15 EC + Cottonseed oil 0.1%	20 + 10
5	I_1A_5	Tolfenpyrad 15 EC + Guar gum 0.1%	20 + 10
6	I_2A_1	Flonicamid 50 WG + No adjuvant	3
7	I_2A_2	Flonicamid 50 WG + Sticker 0.1%	3 + 10
8	I_2A_3	Flonicamid 50 WG + Silicone spreader 0.1%	3 + 10
9	I_2A_4	Flonicamid 50 WG + Cottonseed oil 0.1%	3 + 10
10	I_2A_5	Flonicamid 50 WG + Guar gum 0.1%	3 + 10
11	I_3A_1	Cyantraniliprole 10.26 OD + No adjuvant	12
12	I_3A_2	Cyantraniliprole 10.26 OD + Sticker 0.1%	12 + 10
13	I_3A_3	Cyantraniliprole 10.26 OD + Silicone spreader 0.1%	12 + 10
14	I_3A_4	Cyantraniliprole 10.26 OD + Cottonseed oil 0.1%	12 + 10
15	I_3A_5	Cyantraniliprole 10.26 OD + Guar gum 0.1%	12 + 10

The first foliar application of treatments was carried out at the initiation of aphid and subsequent spray was given after fifteen days of the first application. For recording observations, five plants were randomly selected from each net plot area. From each selected plant, a total of 3 leaves were observed and the aphid population was recorded from 25 cm² leaf area from each selected leaf. The observations were made before the first spray as well as 1, 3, 7 and 14 days after each spray. Further, the population of aphids reduced after each spray was computed with the following formula.

$$\text{Population reduction (\%)} = \frac{C-T}{C} X\ 100$$

Where,

C = Population of aphids in the control plot

T = Population of aphids in treatment plot

Experimental data recorded on aphids were analysed as per the ANOVA technique (Steel and Torrie, 1980) after using square root transformation. Cauliflower curd were harvested at different intervals and weighted treatment wise from each net plot area. The cauliflower curds were weighted in kg and converted on hectare basis.

Results and Discussion

The pooled results of first and second sprays as well as pooled over sprays of individual and their interaction effect

on aphid infesting cauliflower were presented in table 2 and 3, respectively.

Effect of Insecticides (I)

The pooled results of insecticides (Table 2) revealed that the aphid population was homogeneous across treatments before spray as the treatments difference was statistically non-significant in the cauliflower crop. However, plots treated with insecticides showed notable variations in aphid population after each spray as well as in the pooled over sprays.

In pooled over periods of first spray (Table 2), the significantly lowest aphid population (3.54/25 cm^2 area/leaf) was recorded in the plots treated with cyantraniliprole 10.26 OD followed by tolfenpyard 15 EC (4.47 aphid/25 cm^2 area/leaf) and flonicamid 50 WG (6.26 aphid/25 cm^2 area/leaf). The same trend was also noticed in pooled of second spray (Table 2). In which, plots of cauliflower treated with cyantraniliprole 10.26 OD was showed with lowest aphid population (2.42/25 cm^2 area/leaf) than rest of the insecticidal treatments. Whereas, flonicamid 50 WG treated plots was recorded significantly higher aphid population (4.88/25 cm^2 area/leaf) followed by tolfenpyard 15 EC (2.00 aphid/25 cm^2 area/leaf). The pooled results of both sprays illustrate that insecticides significantly affect the aphid population in cauliflower (Table 2). The cauliflower plots protected with cyantraniliprole 10.26 OD (2.96 aphid/25 cm^2 area/leaf) had the lowest number of aphid followed tolfenpyard 15 EC (4.12 aphid/25 cm^2 area/leaf) and flonicamid 50 WG (5.55 aphid/25 cm^2 area/leaf).

Effect of Adjuvants (A)

The population of aphid was uniform before spray in all the treatments as treatment difference was non-significant (Table 2) in cauliflower crop. However, the aphid population significantly affected by adjuvants after first and second spray as well as in pooled over sprays.

The first spray pooled data (Table 2) indicated that the lowest aphid population was recorded in sticker 0.1% *i.e.* 3.70 aphid/25 cm^2 area/leaf, which was followed by guar gum 0.1% (4.47 aphid/25 cm^2 area/leaf). Silicone spreader 0.1% and plots without adjuvant were recorded 4.88 and 5.26 aphid/25 cm^2 area/leaf, respectively. while, plots treated with cottonseed oil 0.1% exhibited highest aphid population (5.57 aphid/25 cm^2 area/leaf).

Similarly, pooled over periods data of second spray (Table 2) indicate that the lowest aphid population was observed in treatment sticker 0.1% (2.49 aphid/25 cm^2 area/leaf) succussed by guar gum 0.1% (3.30 aphid/25 cm^2 area/leaf). Plots with silicone spreader 0.1% and without adjuvant recorded 3.50 and 4.12 aphid/25 cm^2 area/leaf, respectively. Among the various adjuvants, insecticides sprayed with cottonseed oil 0.1% was recorded the highest aphid population (4.47 aphid/25 cm^2/leaf).

The data on pooled over sprays showed that all treatments significantly differed from each other (Table 2). The plots treated with insecticides by adding adjuvant sticker 0.1% showed significantly lowest (3.07/25 cm^2 area/leaf) aphid population and followed by guar gum 0.1% (3.87 aphid/25 cm^2 area/leaf). The adjuvant silicone spreader 0.1% and without adjuvant plots recorded 4.17 and 4.70 aphid per leaf, respectively. The highest aphid population was observed in plots sprayed with cottonseed oil 0.1% *i.e.*, 5.12 aphid per 25 cm^2 area per leaf.

Table 2: Effect of insecticides and adjuvants on aphid infesting cauliflower

Treatments	No. of aphid/25 cm^2 area/leaf							
	Before spray		First spray		Second spray		Pooled over sprays	
Insecticide (I)								
I_1: Tolfenpyrad 15 EC	5.35 (28.12)		2.29 (4.74)		2.00 (3.50)		2.15 (4.12)	
I_2: Flonicamid 50 WG	5.31 (27.70)		2.60 (6.26)		2.32 (4.88)		2.46 (5.55)	
I_3: Cyantraniliprole 10.26 OD	5.43 (28.98)		2.01 (3.54)		1.71 (2.42)		1.86 (2.96)	
	S. Em. ±	C. D. at 5%	S. Em. ±	C. D. at 5%	S. Em. ±	C. D. at 5%	S. Em. ±	C. D. at 5%
Insecticide (I)	0.12	NS	0.03	0.08	0.03	0.07	0.02	0.05
Period (P)	-	-	0.03	0.09	0.03	0.08	0.02	0.06
Spray (S)	-	-	-	-	-	-	0.01	0.04
I × P	-	-	0.06	NS	0.05	NS	0.04	NS
I × S	-	-	-	-	-	-	0.03	NS
P × S	-	-	-	-	-	-	0.03	NS
I × P × S	-	-	-	-	-	-	0.05	NS
Adjuvant (A)								
A_1: No Adjuvant	5.44 (29.09)		2.40 (5.26)		2.15 (4.12)		2.28 (4.70)	
A_2: Sticker 0.1%	5.49 (29.64)		2.05 (3.70)		1.73 (2.49)		1.89 (3.07)	
A_3: Silicone spreader 0.1%	5.33 (27.91)		2.32 (4.88)		2.00 (3.50)		2.16 (4.17)	
A_4: Cottonseed oil 0.1%	5.31 (27.70)		2.50 (5.57)		2.23 (4.47)		2.37 (5.12)	
A_5: Guar gum 0.1%	5.25 (27.06)		2.23 (4.47)		1.95 (3.30)		2.09 (3.87)	
	S. Em. ±	C. D. at 5%	S. Em. ±	C. D. at 5%	S. Em. ±	C. D. at 5%	S. Em. ±	C. D. at 5%
Adjuvant (A)	0.16	NS	0.04	0.10	0.03	0.09	0.02	0.07
Period (P)	-	-	0.03	0.09	0.03	0.08	0.02	0.06
Spray (S)	-	-	-	-	-	-	0.01	0.04
A × P	-	-	0.07	NS	0.06	NS	0.05	NS
A × S	-	-	-	-	-	-	0.04	NS
P × S	-	-	-	-	-	-	0.03	NS
A × P × S	-	-	-	-	-	-	0.07	NS
C. V. (%)	8.86		9.38		9.86		9.63	

Notes: 1. Figures in parentheses are retransformed values and those outsides are $\sqrt{x + 0.5}$ transformed values
2. NS: Non-significant

Interaction Effect of Insecticides with Adjuvants (I × A)

The data on aphid populations in different combinations of insecticides and adjuvants, both before spray and pooled over period of each spray as well as pooled over sprays are presented in Table 3. Before spray, the aphid population had remained homogenous in all plots as observed no significant differences among treatments.

The pooled over periods data of first spray indicating interaction effect of insecticides and adjuvants are presented in Table 3. The results highlight significant differences in efficacy among the various insecticides and adjuvants combinations. Among the different combinations, plots treated with cyantraniliprole 10.26 OD + sticker 0.1% and cyantraniliprole 10.26 OD + guar gum 0.1% were observed lower aphid population *i.e.,* 2.32 and 2.56 aphid/25 cm^2 area/leaf, respectively and emerged out as best effective combination for aphid management in cauliflower. The plots treated with cyantraniliprole 10.26 OD + silicone spreader 0.1% (3.34 aphid/25 cm^2 area/leaf), tolfenpyard 15 EC + sticker 0.1% (3.62 aphid/25 cm^2 area/leaf) and tolfenpyard 15 EC + silicone spreader (3.95 aphid/25 cm^2 area/leaf) were at par with each other and found as next best combination in management of aphid in cauliflower. The plots treated with cyantraniliprole 10.26 OD without adjuvant was recorded 4.52 aphid per 25 cm^2 area per leaf in cauliflower and it was at par with tolfenpyard 15 EC + guar gum 0.1% (5.21 aphid/25 cm^2 area/leaf) and cyantraniliprole 10.26 OD + cotton seed oil 0.1% (5.31 aphid/25 cm^2 area/leaf) in their chronological order. These three treatments emerged as mediocre in their efficacy against aphid in cauliflower. The highest number of aphid were recorded from plots treated with flonicamid 50 WG + silicone spreader 0.1% (7.74 aphid/25 cm^2 area/leaf) and flonicamid 50 WG + cotton seed oil 0.1% (6.31 aphid/25 cm^2 area/leaf) followed by flonicamid 50 WG + guar gum 0.1% (6.00 aphid/25 cm^2 area/leaf), flonicamid 50 WG + no adjuvant (5.95 aphid/25 cm^2 area/leaf), tolfenpyard 15 EC + cotton seed oil 0.1% (5.70 aphid/25 cm^2 area/leaf), flonicamid 50 WG + sticker 0.1% (5.50 aphid/25 cm^2 area/leaf) and tolfenpyard 15 EC + no adjuvant (5.40 aphid/25 cm^2 area/leaf) were found at par with each other.

The second spray pooled over periods data (Table 3) on aphid revealed that the combination of cyantraniliprole 10.26 OD + sticker 0.1% (1.14 aphid/25 cm^2 area/leaf) and cyantraniliprole 10.26 OD + guar gum 0.1% (1.63 aphid/25 cm^2 area/leaf) were significantly superior than remaining combinations and emerged out as the most effective treatments against aphid infesting cauliflower. Cyantraniliprole 10.26 OD + silicone spreader 0.1% (2.26 aphid/25 cm^2 area/leaf), tolfenpyrad 15 EC + sticker 0.1% (2.39 aphid/25 cm^2 area/leaf) and tolfenpyrad 15 EC + silicone spreader 0.1% (2.70 aphid/25 cm^2 area/leaf) were found next effective combination group and at par with each other followed by cyantraniliprole 10.26 OD + no adjuvant, tolfenpyrad 15 EC + guar gum 0.1% (3.99 aphid/25 cm^2 area/leaf) and cyantraniliprole 10.26 OD + cottonseed oil 0.1% (4.12 aphid/25 cm^2 area/leaf). The cauliflower plots sprayed with the combination of tolfenpyrad 15 EC + no adjuvant (4.30 aphid/25 cm^2 area/leaf), flonicamid 50 WG + sticker 0.1% (4.34 aphid/25 cm^2 area/leaf), tolfenpyrad 15 EC + cottonseed oil 0.1% (4.38 aphid/25 cm^2 area/leaf) and flonicamid 50 WG + no adjuvant (4.47 aphid/25 cm^2 area/leaf) were found mediocre in management of aphid in cauliflower. The higher population of aphid was noticed from flonicamid 50 WG + guar gum 0.1% (7.34 aphid/25 cm^2 area/leaf) followed by flonicamid 50 WG + silicone spreader 0.1% (5.95 aphid/25 cm^2 area/leaf) and flonicamid 50 WG + cottonseed oil 0.1% (4.93 aphid/25 cm^2 area/leaf).

The results of pooled over sprays (Table 3) showed that plots applied with combination of cyantraniliprole 10.26 OD + sticker 0.1% (1.69 aphid/25 cm^2 area/leaf), and cyantraniliprole 10.26 OD + guar gum 0.1% (2.09 aphid/25 cm^2 area/leaf) were exhibited least numbers of aphid and emerged out as best effective combination against aphid infesting cauliflower. Cyantraniliprole 10.26 OD + silicone spreader 0.1% (2.78 aphid/25 cm^2 area/leaf), tolfenpyrad 15 EC + sticker 0.1% (3.00 aphid/25 cm^2 area/leaf) found at par with each other and found next best effective group against aphid infesting cauliflower followed by tolfenpyrad 15 EC + silicone spreader 0.1% (3.30 aphid/25 cm^2 area/leaf). Cyantraniliprole 10.26 OD + no adjuvant (4.04 aphid/25 cm^2 area/leaf) and tolfenpyrad 15 EC + guar gum 0.1% (4.56 aphid/25 cm^2 area/leaf) equally reduce aphid population. Whereas, combination of tolfenpyrad 15 EC alone (4.84 aphid/25 cm^2 area/leaf), flonicamid 50 WG + sticker 0.1% (4.93 aphid/25 cm^2 area/leaf), tolfenpyrad 15 EC + cottonseed oil 0.1% (5.02 aphid/25 cm^2 area/leaf) were noted as mediocre group and at par with each other followed by flonicamid 50 WG + no adjuvant (5.21 aphid/25 cm^2 area/leaf), flonicamid + guar gum 0.1% (5.31 aphid/25 cm^2 area/leaf) and flonicamid 50 WG + cottonseed oil 0.1% (5.50 aphid/25 cm^2 area/leaf). However, cyantraniliprole 10.26 OD + cottonseed oil 0.1% (7.45 aphid/25 cm^2 area/leaf) treated cauliflower plots was recorded significantly higher aphid population than rest of the combinations except flonicamid 50 WG + silicone spreader 0.1% (6.84 aphid/25 cm^2 area/leaf) where it was at par with each other. These both treatment combinations were found less effective in management of cauliflower aphid.

The data of per cent reduction over control of pooled over sprays (Table 3) revealed that adjuvants like sticker, guar gum and silicon spreader were increased the effectiveness of cyantraniliprole 10.26 OD and tolfenpyrad 15 EC against aphid infesting cauliflower whereas, adjuvants decreased the efficacy of flonicamid 50 WG as compared to spray alone. Among the different interaction cyantraniliprole 10.26 OD + sticker 0.1% (58.17%), cyantraniliprole 10.26 OD + guar gum 0.1% (48.27%), tolfenpyrad 15 EC + sticker 0.1% (38.02%), tolfenpyrad 15 EC + silicone spreader 0.1% (31.82%) and cyantraniliprole 10.26 OD + silicone spreader 0.1% (31.19%) greatly reduced aphid population. While, tolfenpyrad 15 EC + guar gum 0.1% (5.79%) and flonicamid 50 WG + sticker 0.1% (5.37%) were least effective as reduce 5.79 and 5.37 per cent aphid population in cauliflower as compared to spray alone. The treatment combinations flonicamid 50 WG + guar gum 0.1%, tolfenpyrad 15 EC + cottonseed oil 0.1%, flonicamid 50 WG + cottonseed oil 0.1%, flonicamid 50 WG + silicone spreader 0.1% and cyantraniliprole 10.26 OD + cottonseed oil 0.1% were not able to increase the effectiveness as compared to spray insecticides alone.

The above results indicated that adjuvants like sticker, guar gum and silicon spreader were increased the effectiveness of insecticides cyantraniliprole 10.26 OD and tolfenpyrad 15 EC based on aphid population observed in cauliflower. Whereas, flonicamid 50 WG sprayed with adjuvants were reduced the efficacy against aphid in cauliflower as

compared to plots treated with flonicamid 50 WG alone.

There literature available on this study are very scanty. However, Shalaby *et al.* (2022) [14] observed that silicone surfactant caused 90.76, 74.70 and 66.27 per cent mortality with malathion, diazinon and acetamiprid against *A. gossypii*. Deepak (2024) [5] indicated that adjuvant like, sticker and silicone spreader @ 0.1% with combination of thiamethoxam 25 WG and diafenthiuron 50 WP managed aphid population effectively as compared to sprayed alone. Slabbert and van der Berg (2009) [15] investigated that silicone spreader 0.1% (Break-thru S240) enhanced lambda-cyhalothrin efficacy as compared to spray alone against the maize stem borer. El-Hafez *et al.* (2013) [8] reported cottonseed oil to be the most effective adjuvant in combination with spinosad against cotton leaf worm. Muraro *et al.* (2020) [12] reported that the efficacy of Thiamethoxam 25 WG increased by 12% when added in combination with silicone spreader 0.1% as compared to being sprayed alone. These findings were partially in line with present study. Comparing results of present finding with their findings, it is evident that the use of adjuvants significantly enhanced the efficacy of insecticides.

Table 3: Impact of adjuvants on the efficacy of insecticides against aphid infesting cauliflower (Interaction: I × A)

Insecticides with adjuvants		No. of aphid/25 cm^2 area/leaf				
		Before spray	**First spray**	**Second spray**	**Pooled over sprays**	**ROC (%)**
I_1A_1: Tolfenpyrad 15 EC + No adjuvant		5.47 (29.42)	2.43 (5.40)	2.19 (4.30)	2.31 (4.84)	-
I1A2: Tolfenpyrad 15 EC + Sticker 0.1%		5.32 (27.80)	2.03 (3.62)	1.70 (2.39)	1.87 (3.00)	38.02
I_1A_3: Tolfenpyrad 15 EC + Silicone spreader 0.1%		5.37 (28.34)	2.11 (3.95)	1.79 (2.70)	1.95 (3.30)	31.82
I_1A_4: Tolfenpyrad 15 EC + Cotton seed oil 0.1%		5.22 (26.75)	2.49 (5.70)	2.21 (4.38)	2.35 (5.02)	-3.72
I_1A_5: Tolfenpyrad 15 EC + Guar gum 0.1%		5.37 (28.34)	2.39 (5.21)	2.12 (3.99)	2.25 (4.56)	5.79
I_2A_1: Flonicamid 50 WG + No adjuvant		5.32 (27.80)	2.54 (5.95)	2.23 (4.47)	2.39 (5.21)	-
I_2A_2: Flonicamid 50 WG + Sticker 0.1%		5.59 (30.75)	2.45 (5.50)	2.20 (4.34)	2.33 (4.93)	5.37
I_2A_3: Flonicamid 50 WG + Silicone spreader 0.1%		5.15 (26.02)	2.87 (7.74)	2.54 (5.95)	2.71 (6.84)	-31.29
I_2A_4: Flonicamid 50 WG + Cottonseed oil 0.1%		5.28 (27.38)	2.61 (6.31)	2.33 (4.93)	2.45 (5.50)	-5.57
I_2A_5: Flonicamid 50 WG + Guar gum 0.1%		5.22 (26.75)	2.55 (6.00)	2.80 (7.34)	2.41 (5.31)	-1.92
I_3A_1: Cyantraniliprole 10.26 OD + No adjuvant		5.54 (30.19)	2.24 (4.52)	2.02 (3.58)	2.13 (4.04)	-
I_3A_2: Cyantraniliprole 10.26 OD + Sticker 0.1%		5.57 (30.52)	1.68 (2.32)	1.28 (1.14)	1.48 (1.69)	58.17
I_3A_3: Cyantraniliprole 10.26 OD + Silicone spreader 0.1%		5.48 (29.53)	1.96 (3.34)	1.66 (2.26)	1.81 (2.78)	31.19
I_3A_4: Cyantraniliprole 10.26 OD + Cottonseed oil 0.1%		5.41 (28.77)	2.41 (5.31)	2.15 (4.12)	2.82 (7.45)	-84.40
I_3A_5: Cyantraniliprole 10.26 OD + Guar gum 0.1%		5.16 (26.13)	1.75 (2.56)	1.46 (1.63)	1.61 (2.09)	48.27
S. Em. ±	I × A	0.27	0.06	0.06	0.04	-
	I × A × P	-	0.13	0.12	0.09	-
	I × A × S	-	-	-	0.06	-
	I × A × P × S	-	-	-	0.12	-
C. D. at 5%	I × A	NS	0.18	0.16	0.12	-
	I × A × P	-	NS	NS	NS	-
	I × A × S	-	-	-	NS	-
	I × A × P × S	-	-	-	NS	-
C. V. (%)		8.86	9.38	9.86	9.63	-

Notes: 1. Figures in parentheses are retransformed values and those outsides are $\sqrt{x+0.5}$ transformed values
2. NS: Non-significant
3. ROC: Reduction Over Control

Impact on yield of cauliflower curd

Insecticides (I)

Data on the impact of insecticides on curd yield of cauliflower are presented in Table 4. It revealed that the highest fruit yield was recorded from cyantraniliprole 10.26 OD (157.61 q/ha) followed by tolfenpyrad 15 EC (144.24 q/ha) and flonicamid 50 WG (119.24 q/ha).

Adjuvant (A)

Cauliflower curd harvested from the plots of different adjuvants (Table 4) indicated that the maximum curd yield of cauliflower was harvested from sticker 0.1% (148.83 q/ha) and it was at par with guar gum 0.1% (147.55 q/ha), silicone spreader 0.1% (141.80 q/ha) and without adjuvant (135.54 q/ha). The cauliflower plots sprayed with cottonseed oil 0.1% was picked up significantly lower curd yield (128.09 q/ha) and it was at par with insecticides applied without adjuvant as well as silicone spreader.

Insecticides with Adjuvants (I × A)

The impact of insecticides with adjuvants on cauliflower curd yield is presented in Table 4. The results were obtained indicated that there was non-significant difference among the various combinations. However, higher cauliflower curd yield was obtained from plots treated with cyantraniliprole 10.26 OD + guar gum 0.1% (170.01 q/ha) followed by cyantraniliprole 10.26 OD + silicone spreader 0.1% (161.52 q/ha), cyantraniliprole 10.26 OD + sticker 0.1% (158.95 q/ha), tolfenpyrad 15 EC + silicone spreader 0.1% (158.44 q/ha) and tolfenpyrad 15 EC + sticker 0.1% (151.24 q/ha). However, plots treated with flonicamid 50 WG + guar gum 0.1%, tolfenpyrad 15 EC + cottonseed oil 0.1%, flonicamid 50 WG + sticker 0.1%, tolfenpyrad 15 EC + no adjuvant, tolfenpyrad 15 EC + guar gum 0.1%, cyantraniliprole 10.26 OD + cottonseed oil 0.1% and cyantraniliprole 10.26 OD + no adjuvant noticed cauliflower curd yield between 126.03 to 150.46 quintal per hectare. Among the various combinations, curd yield of cauliflower was harvested lower in plots treated with flonicamid 50 WG + silicone spreader 0.1% (105.45 q/ha) followed by flonicamid 50 WG + cottonseed oil 0.1% (109.57 q/ha) and flonicamid 50 WG + no adjuvant (118.82 q/ha).

Table 4: Impact of insecticides with adjuvants on curd yield of cauliflower

Adjuvants (A)\ Insecticides (I)		Curd yield (q/ha)			
		I_1: Tolfenpyrad 15 EC	**I_2: Flonicamid 50 WG**	**I_3: Cyantraniliprole 10.26 OD**	**Mean (A)**
A_1: No Adjuvant		137.35	118.82	150.46	135.54
A_2: Sticker 0.1%		151.24	136.32	158.95	148.83
A_3: Silicone spreader 0.1%		158.44	105.45	161.52	141.80
A_4: Cottonseed oil 0.1%		127.57	109.57	147.12	128.09
A_5: Guar gum 0.1%		146.61	126.03	170.01	147.55
Mean (I)		144.24	119.24	157.61	
S. Em. ±	Insecticide (I)	4.00			
	Adjuvant (A)	5.17			
	I × A	9.95			
C. D. at 5%	I	11.59			
	A	14.96			
	I × A	NS			
C. V. (%)		11.04			

Conclusion

From the foregoing results it can be concluded that among all insecticidal and adjuvant combinations evaluated, cyantraniliprole 10.26% OD + sticker 0.1% (I_3A_2) and cyantraniliprole 10.26% OD + guar gum 0.1% (I_3A_5) were found most effective in reducing of aphid incidence in cauliflower. The treatment combinations of cyantraniliprole 10.26% OD + silicone spreader 0.1% (I_3A_3), tolfenpyrad 15 EC + sticker 0.1% (I_1A_2) and tolfenpyrad 15 EC + silicone spreader 0.1% (I_1A_3) emerged out as next best effective combinations against aphid. However, the higher curd yield was harvested from the plots treated with cyantraniliprole 10.26 OD + guar gum 0.1% (170.01 q/ha) and cyantraniliprole 10.26 OD + silicone spreader 0.1% (161.52 q/ha).

Conflict of Interest: The authors declare that they have no conflict of interest.

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