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Efficacy of new insecticide chemistry sulfoxaflor 12% SC on cotton aphids (*Aphis gossypii* Glover) (HOMOPTERA: APHIDIDAE)

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Abstract
Aphis gossypii Glover (Homoptera: Aphididae), a cotton aphid, is a significant pest that has been seriously harming cotton and reducing productivity. Finding a newer insecticide with a distinct mechanism of action is necessary to manage aphids in the cotton environment because some insecticides have developed resistance against Aphis gossypii. The current study aimed to assess Sulfoxaflor 12% SC w/v's phytotoxicity, bio-efficacy, and impact on natural enemies in relation to aphids in cotton crops. The findings indicated that the highest per cent reduction over control at ten days post-treatment was observed with the highest dosage of Sulfoxaflor 12% SC at 250 ml/ha, which recorded 90.73 aphids per leaf, followed by the subsequent dose of Sulfoxaflor 12% SC at 225 ml/ha (85.63%). Similarly, the lowest population of aphids was recorded in the highest dosage of Sulfoxaflor 12% SC @ 250 ml/ha, next treatment was Sulfoxaflor 12% SC @ 225 ml/ha seven days after second spray. The maximum yield of 1252 kg/ha was achieved with Sulfoxaflor 12% SC at a dosage of 250 ml/ha, which was comparable to the yield of 1206 kg/ha obtained with Sulfoxaflor 12% SC at 225 ml/ha. The test chemical Sulfoxaflor 12% SC did not affect the natural enemies like coccinellids and spiders indicated that, Sulfoxaflor 12% SC were safe to natural enemies.

Keywords: Aphids, cotton, efficacy, insecticide, natural enemies, sulfoxaflor

Introduction
Cotton, commonly referred to as "White Gold" in India, is essential to the nation's agricultural landscape since it thrives in a variety of agroclimatic conditions and provides almost two thirds of the raw materials needed by the textile industry. India is the world's largest producer of cotton, but its output is only second behind China's (CCI, 2021). It is cultivated in India on an area of 10.2 million acres, producing 32.5 million bales (Anonymous, 2022) [2]. Insect pest infestations are a major hindrance to cultivation efforts and are primarily responsible for the ongoing problem of low cotton output (Manjunath, 2004) [11]. Due to a variety of factors, such as a lack of appropriate seed and environmental difficulties, cotton production has been poor for a number of years. The most significant of these is the severity of insect pest attacks, which cause 30 40% yield losses from seedling stage to harvest (Tokel *et al.*, 2021) [17].

Cotton production underwent a sea change in 2002 with the introduction of Bollgard technology, which increased yields, decreased bollworm losses, and decreased the need for pesticides (Rao and Dev, 2009) [14]. But this breakthrough unintentionally encouraged the spread of other pest species, presenting cotton farming with fresh financial risks. Notably, sucking pests such as aphids, leafhoppers, whiteflies, and thrips became strong enemies, reducing crop output and causing significant harm at different phases of growth. Although transgenic cotton shows promise in the fight against bollworms (Kulkarni *et al.*, 2003) [10], even the adoption of Bt-cotton, with its inherent advantages, does not shield against yield losses inflicted by sap-feeding pests like leafhoppers, aphids, thrips, whiteflies, and mealybugs throughout the growing season (Biradar and Venilla, 2008) [3]. Managing sucking pests requires the creation of efficient management techniques. Among the sucking insect pests cotton aphids are one among the most serious pests of cotton all over the world (Rummel *et al.*, 1995; Akey and Butler, 1989) [15, 1]. The heavy infestation of nymphs and adults of aphids results in leaf yellowing, wrinkled leaves and leaf distortion. They also secrete honey dew which leads to the growth and development of sooty-mould fungus (*Capnodium* sp.) on leaves. The fungus inhibits the photosynthetic activity of the plants resulting in chlorosis that affects the seed cotton yield. Cotton aphids damage cotton plants by persistently consuming fluids found in the phloem tubes of the plant.

According to Raboudi *et al.* (2002) [12], this feeding may cause foliar changes, plant development delays, fewer fruit sets, decreased fruit retention, and decreased cotton lint weight. To date, numerous kinds of insecticides have been evolved for management of aphids. However, prolonged use or constant application of pesticides for crop protection frequently results in the formation of insect pests that are resistant to different insecticides. Generally, rotation programs that incorporate a few insecticides with various modes of action are advised in order to combat the development of such resistance. It was attempted to identify the best insecticide for managing cotton aphids while keeping these considerations in mind the experiment was executed to know the efficacy of new insecticide on aphids.

Materials and Methods

Evaluation of Sulfoxaflor 12% SC w/v against sap sucking insect's cotton aphid *Aphis gossypii* was undertaken in an experimental block at Agricultural Research Station, Darsi, Prakasam District (Andhra Pradesh) during the year 2021.Three replications of the experiment were set up using a randomized block design (RBD). Three distinct dosages of the test molecule, Sulfoxaflor 12% SC w/v, were tested: 200, 225, and 250 ml/hectare for its effectiveness against the cotton aphid *Aphis gossypii*. This was compared with two standard checks *viz.*, Imidacloprid 17.8% SL and Acetamiprid 20% SP along with an untreated control against cotton aphid Aphis gossypii. Treatments were imposed two times based on pest population build-up (above ETL). Every agronomic practice was carried out in accordance with the ANGRAU prescribed package of practices. To record the aphid population, five randomly chosen plants in each treatment were tagged with *Aphis gossypii*. Each plant in each treatment had five leaves, and the quantity of aphids on each leaf was converted to the population. Following each application, observations were made in five leaves per plant and five plants per replication at DBS, 1 DAS, 3 DAS, 7 DAS, 10 DAS, and 14 DAS. Later, the aphid population was converted into per leaf, and the percentage decrease over control was calculated. Each plot's total seed cotton yield was noted separately at each picking. The total yield was then calculated by aggregating the yields from all pickings and expressed on a per-hectare basis. The yield information gathered from every plot was extrapolated to the hectare level. Observations on natural enemies (Parasites and predators) like coccinellids, Spiders, Chrysopa etc. were recorded on one day before application (Pre-treatment) per plant, and at subsequently at 1, 3, 5, 7 and 10 days after each application.

Results and Discussions

Bioefficacy of Sulfoxaflor 12% SC against cotton aphid, *Aphis gossypii* (First Spray)

During the first spray, among the treatments population of aphids a day before spray ranged in between 17.48 and 18.57 per leaf and were non-significant. A day after spray the lowest aphids population with 10.80 per leaf was recorded in highest dosage of Sulfoxaflor 12% SC @ 250 ml/ha followed by its next dosage treatment of Sulfoxaflor 12% SC @ 225 ml/ha (12.23 aphids/leaf). The treatment Sulfoxaflor 12% SC @ 200 ml/ha, Acetamiprid 20% SP @ 50g/ha and Imidacloprid 17.8% SL @ 125 ml/ha recorded 13.92, 14.24 and 14.38 aphids per leaf and were on par with each other. At three days after spray the treatments Sulfoxaflor 12% SC @ 250 ml/ha and 225 ml/ha recorded 4.72, 5.87 aphids per leaf respectively. The lowest dosage of Sulfoxaflor 12% SC @ 200 ml/ha (7.40 aphids/leaf) was on par with Acetamiprid 20% SP @ 50g/ha and Imidacloprid 17.8% SL @ 125 ml/ha (Table 1).

Lowest population of aphids at seven days after treatment was recorded in the highest dosage of Sulfoxaflor 12% SC @ 250 ml/ha which recorded 1.63 aphids per leaf followed by next dosage of Sulfoxaflor 12% SC @ 225 ml/ha which recorded aphids population of 2.33 per leaf. Sulfoxaflor 12% SC @ 200 ml/ha, Acetamiprid 20% SP @ 50 g/ha and Imidacloprid 17.8% SL @ 125 ml/ha were on par with each other which recorded aphids population of 5.51, 5.72 and 5.81 aphids per leaf respectively. Aphids population at ten days after spray increased but the highest dosage of Sulfoxaflor 12% SC @ 250 ml/ha maintained its superiority in reducing the aphids population (2.00 aphids/ leaf) followed by this was Sulfoxaflor 12% SC @ 225 ml/ha. Population of aphids at fourteen days after spray gradually increased in all the treatments (Sulfoxaflor 12% SC treatments at different doses and Imidacloprid 17.8% SL) and untreated control which recorded 19.28 aphids per leaf respectively (Table 1 & 2).

Bioefficacy of Sulfoxaflor 12% SC against cotton aphid, *Aphis gossypii* (Second Spray)

A day after spray the lowest aphids population with 10.16 per leaf was recorded in highest dosage of Sulfoxaflor 12% SC @ 250 ml/ha followed by its next dosage treatment of Sulfoxaflor 12% SC @ 225 ml/ha (11.51 aphids/leaf). Sulfoxaflor 12% SC @ 200 ml/ha, Acetamiprid 20% SP @ 50 g/ha and Imidacloprid 17.8% SL @ 125 ml/ha recorded 13.04, 13.33 and 13.48 aphids per leaf and were on par with each other. At three days after spray the treatments Sulfoxaflor 12% SC @ 250 ml/ha and 225 ml/ha recorded 3.62, 4.87 aphids per leaf respectively. The lowest dosage of Sulfoxaflor 12% SC @ 200 ml/ha (6.33 aphids/leaf) was on par with Acetamiprid 20% SP @ 50 g/ha (6.37 aphids/leaf) and Imidacloprid 17.8% SL @ 125 ml/ha (6.58 aphids/leaf). Untreated control recorded aphids population of 20.18 aphids per leaf (Table 3&4).

At seven days after spray lowest population of aphids was recorded in the highest dosage of Sulfoxaflor 12% SC @ 250 ml/ha which recorded 1.16 aphids per leaf and next dosage of Sulfoxaflor 12% SC @ 225 ml/ha which recorded aphids population of 2.01 per leaf. Sulfoxaflor 12% SC @ 200 ml/ha, Acetamiprid 20% SP @ 50 g/ha and Imidacloprid 17.8% SL @ 125 ml/ha were on par with each other. At ten days after spray aphids population increased but Sulfoxaflor 12% SC @ 250 ml/ha maintained its superiority in reducing the aphids population (2.58 aphids/ leaf) followed by its lower dose treatment of Sulfoxaflor 12% SC @ 225 ml/ha (4.17 aphids/leaf). Population of aphids increased in all the treatments and were on par with each other at fourteen days after spray. Whereas, untreated control which recorded 21.88 aphids per leaf (Table 3 & 4).

Efficacy of Sulfoxaflor 12% SC on predatory population:

Population of coccinellids a day before spray ranged from 1.74 to 1.80 adults per plant during first spray and there was no significant difference among the treatments at three, five and ten days after spray where the population of coccinellids were statistically on par with each other. Similarly, during the second spray population of coccinellids a day before were

statistically non-significant and ranged from 2.16 to 2.21 per plant and after ten days of spray population of coccinellids were statistically on par with each other (1.99 to 2.26/plant) (Table 5).

Similarly the population of spiders a day before first spray among different treatments were non-significant which ranged between 1.06 to 1.12 per plant. At three, five, seven and ten days after first spray the population of spiders were on par with each other and were non-significant. During second spray the population of spiders a day before among different treatments ranged from1.53 to 1.59 per plant and were statistically non-significant. Ten days after spray population of coccinellids were statistically on par with each other (1.33 to 1.59/plant), (Table 6).

Efficacy of Sulfoxaflor 12% SC on yield

All the products tested recorded significantly higher seed yield when compared to untreated control. The highest yield of 1252 kg/ha was recorded with Sulfoxaflor 12% SC @ 250 ml/ha which was on par with Sulfoxaflor 12% SC @ 225 ml/ha (1206 kg/ha). Sulfoxaflor 12% SC @ 200 ml/ha and Imidacloprid 17.8% SL @ 125 ml/ha were on par with each other which recorded yield of 1150 and 1124 kg/ha respectively. The lowest yield (952 kg/ha) was recorded in the untreated control (Table 3).

The findings are similarly consistent with those of Siebert *et al.* (2012) [16], who assessed sulfoxaflor's effectiveness against various plant pests in comparison to acephate, the most commonly used insecticide in cotton. Sulfoxafor administered at ≥ 50 g a.i/ha produced control and yield levels comparable to those seen with acephate across infestation levels (12 locations, 49 trials). Sulfoxaflor's novel method of action and effectiveness can be added to multi-insecticide-based cotton integrated pest management strategies for tarnished plant bugs. Gore *et al.* (2013) [8] who reported that sulfoxaflor is likely going to be used as an alternative to other insecticides in the control of the cotton aphids, i.e., it is going to be widely present in agricultural lands in the coming years.

The effectiveness of sulfoxaflor 12 SC in controlling aphids in the wheat crop in Ludhiana was also assessed by Chandi (2019) [5]. Chinniah *et al* (2019) [6] evaluated combination products spinetoram 10% w/w WG + sulfoxaflor 30% w/w WG against Grapevine thrips, *Rhipiphorothrips cruentatus* in TN. Three rounds of foliar application of spinetoram 10% w/w WG + sulfoxaflor 30% w/w WG @350 ml/ha and spinetoram 10% WG+ sulfoxaflor 30% WG @ 300 ml/ha were superior and effective in reducing the thrips damage on leaves and berries, which also recorded higher fruit yield and Cost-Benefit Ratio. Ram Prasad (2022) [13] reported that sulfoxaflor at 100 g a.i ha^{-1} and flonicamid at 75 g a.i. ha^{-1} have shown good efficacy against sucking pests as well as recorded the highest seed cotton yield compared to other treatments and can be used as an alternative to other insecticides in the control of Cotton sucking pests. Further, Katare *et al* (2022) [9] evaluated efficacy of sulfoxaflor 12%SC for the control of aphids at Haryana. The incidence of aphids was significantly less with sulfoxaflor 12 SC @ 24, 27 and 30 g a.i./ ha with 94.54, 95.27 and 96.03% reduction, respectively, these being at par with each other, followed by thiamethoxam 25WDG @ 12.5 g a.i./ ha and Quinalphos 25EC @ 250 g a.i./ ha. Our results were comparable to the experiment described by Garzon *et al.* (2015) [7] where sulfoxaflor was harmless to the natural enemies.

Table 1: Efficacy of Sulfoxaflor 12% SC against aphids in cotton during 2021-22, *Kharif* season (First Spray)

Sl. No.	Treatments	Formulation (ml/ha)	Dose (g ai/ha)	Aphids/Leaf					
				1DBS	1 DAS	3DAS	7 DAS	10 DAS	14 DAS
1	Sulfoxaflor 12% SC	200	24	18.57	13.92 (3.80)	7.40 (2.81)	5.51 (2.45)	6.98 (2.73)	13.34 (3.72)
2	Sulfoxaflor 12% SC	225	27	18.00	12.23 (3.57)	5.87 (2.52)	2.33 (1.68)	3.10 (1.90)	13.29 (3.71)
3	Sulfoxaflor 12% SC	250	30	17.48	10.80 (3.36)	4.72 (2.28)	1.63 (1.46)	2.00 (1.58)	13.24 (3.71)
4	Imidacloprid 17.8% SL	125	25	17.57	14.38 (3.86)	7.65 (2.85)	5.81 (2.51)	7.24 (2.78)	14.89 (3.92)
5	Acetamiprid 20% SP	50	10	18.38	14.24 (3.84)	7.57 (2.84)	5.72 (2.49)	7.20 (2.77)	13.69 (3.77)
6	Untreated control		--	17.98	19.32 (4.45)	20.88 (4.62)	19.22 (4.44)	21.57 (4.70)	19.28 (4.45)
S.E.M ±				0.48	0.02	0.03	0.04	0.06	0.18
CD at 5 %				NS	0.17	0.10	0.10	0.16	0.57
CV (%)				15.37	11.12	13.26	10.61	12.10	14.05

DBS: Day before spray, DAS: Day after spray

*Figures in parentheses are square root transformed values

Table 2: Efficacy of Sulfoxaflor 12% SC against aphids in cotton during 2021-22, *Kharif* season (First Spray) (Per cent reduction over control)

SL. No.	Treatments	Formulation (ml/ha)	Dose (g ai/ha)	Aphids (% Reduction over control)				
				1 DAS	3DAS	7 DAS	10 DAS	14 DAS
1	Sulfoxaflor 12% SC	200	24	27.95	64.56	71.33	67.64	30.81
2	Sulfoxaflor 12% SC	225	27	36.70	71.89	87.88	85.63	31.07
3	Sulfoxaflor 12% SC	250	30	44.10	77.39	91.52	90.73	31.33
4	Imidacloprid 17.8% SL	125	25	25.57	63.36	69.77	66.43	22.77
5	Acetamiprid 20% SP	50	10	26.29	63.75	70.24	66.62	28.99
6	Untreated control	--	--	0.00	0.00	0.00	0.00	0.00

Table 3: Efficacy of Sulfoxaflor 12% SC against aphids in cotton during 2021-22, *Kharif* season (Second Spray)

SL. No.	Treatments	Formulation (ml/ha)	Dose (g ai/ha)	Aphids/ leaf						Yield (kg/ha)
				1DBS	1 DAS	3 DAS	7 DAS	10 DAS	14 DAS	
1	Sulfoxaflor 12% SC	200	24	13.34 (3.72)	13.04 (3.68)	6.33 (2.61)	5.18 (2.38)	7.88 (2.89)	16.91 (4.17)	1150
2	Sulfoxaflor 12% SC	225	27	13.29 (3.71)	11.51 (3.47)	4.87 (2.32)	2.01 (1.58)	4.17 (2.16)	16.86 (4.17)	1206
3	Sulfoxaflor 12% SC	250	30	13.24 (3.71)	10.16 (3.26)	3.62 (2.03)	1.16 (1.29)	2.58 (1.75)	16.81 (4.16)	1252
4	Imidacloprid 17.8% SL	125	25	14.89 (3.92)	13.48 (3.74)	6.58 (2.66)	5.43 (2.44)	8.17 (2.94)	18.46 (4.35)	1124
5	Acetamiprid 20% SP	50	10	13.69 (3.77)	13.33 (3.72)	6.37 (2.62)	5.27 (5.40)	8.08 (2.93)	17.26 (4.21)	1136
6	Untreated control		--	19.28 (4.45)	19.48 (4.47)	20.18 (4.55)	21.57 (4.70)	22.18 (4.76)	21.88 (4.73)	952
S.E.M ±				0.18	0.04	0.03	0.05	0.06	0.18	12
CD at 5 %				0.57	0.12	0.10	0.14	0.18	0.57	38
CV (%)				14.05	11.36	13.84	10.88	12.14	14.05	11.56

DBS: Day before spray, DAS: Day after spray
*Figures in parentheses are square root transformed values

Table 4: Efficacy of Sulfoxaflor 12% SC against aphids in cotton during 2021-22, *Kharif* season (Second Spray) (Per cent reduction over control)

SL. No.	Treatments	Formulation (ml/ha)	Dose (g ai/ha)	Aphids (% Reduction over control)				
				1 DAS	3 DAS	7 DAS	10 DAS	14 DAS
1	Sulfoxaflor 12% SC	200	24	33.06	68.63	75.99	64.47	22.71
2	Sulfoxaflor 12% SC	225	27	40.91	75.87	90.68	81.20	22.94
3	Sulfoxaflor 12% SC	250	30	47.84	82.06	94.62	88.37	23.17
4	Imidacloprid 17.8% SL	125	25	30.80	67.39	74.83	63.17	15.63
5	Acetamiprid 20% SP	50	10	31.57	68.43	89.48	63.57	21.12
6	Untreated control		--	0.00	0.00	0.00	0.00	0.00

Table 5: Bioefficacy of Sulfoxaflor 12% SC against natural enemies in cotton *Kharif*, 2021-22

Sl. No	Treatments	Formulation (ml/ha)	Dose (g ai/ha)	Coccinellids (Adults/Plant)									
				First spray					Second spray				
				1 DBS	3 DAS	5 DAS	7 DAS	10 DAS	1 DBS	3 DAS	5 DAS	7 DAS	10 DAS
1	Sulfoxaflor 12% SC	200	24	1.74	1.49	1.55	1.59	1.68	2.21	1.94	2.00	2.02	2.05
2	Sulfoxaflor 12% SC	225	27	1.80	1.53	1.56	1.56	1.63	2.19	1.98	2.06	1.99	2.03
3	Sulfoxaflor 12% SC	250	30	1.75	1.50	1.53	1.59	1.60	2.16	1.90	1.98	2.02	2.00
4	Imidacloprid 17.8% SL	125	25	1.78	1.47	1.47	1.55	1.59	2.17	1.93	1.97	1.98	1.99
5	Acetamiprid 20% SP	50	10	1.74	1.53	1.51	1.61	1.60	2.15	1.98	2.01	2.04	2.00
6	Untreated control		--	1.78	1.87	1.98	1.83	1.78	2.18	2.17	2.22	2.28	2.26
S.E.M ±				0.18	0.24	0.15	0.29	0.21	0.33	0.25	0.13	0.20	0.16
CD (P=0.05)				NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 6: Bioefficacy of Sulfoxaflor 12% SC against natural enemies in cotton *Kharif*, 2021-22

SL. No	Treatments	Formulation (ml/ha)	Dose (g ai/ha)	Spiders (Adults/Plant)									
				First spray					Second spray				
				1 DBS	3 DAS	5 DAS	7 DAS	10 DAS	1 DBS	3 DAS	5 DAS	7 DAS	10 DAS
1	Sulfoxaflor 12% SC	200	24	1.06	0.91	0.88	1.00	1.20	1.55	1.39	1.16	1.24	1.37
2	Sulfoxaflor 12% SC	225	27	1.10	0.95	0.89	1.00	1.18	1.59	1.41	1.14	1.21	1.34
3	Sulfoxaflor 12% SC	250	30	1.07	0.92	0.86	0.97	1.15	1.54	1.38	1.11	1.22	1.35
4	Imidacloprid 17.8% SL	125	25	1.10	0.89	0.82	0.97	1.17	1.53	1.35	1.07	1.14	1.27
5	Acetamiprid 20% SP	50	10	1.07	0.95	0.84	0.95	1.13	1.54	1.40	1.13	1.20	1.33
6	Untreated control		--	1.12	1.18	1.08	1.15	1.28	1.57	1.63	1.45	1.52	1.59
S.E.M ±				0.17	0.29	0.12	0.22	0.14	0.16	0.10	0.16	0.18	0.21
CD (P=0.05)				NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

DBS: Day before spray, **DAS:** Day after spray

Conclusion

Sulfoxaflor 12% SC at 250 ml/ha (30 g ai/ha) treatment was found to be optimum and effective in reducing aphids population with higher yield in cotton. The predatory population (coccinellids and spiders) didn't show any significant difference among treatments indicating that, all the dosages of Sulfoxaflor 12% SC were safe to natural enemies.

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