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Insecticidal effect of high concentrations of spreader and adjuvant on cotton aphid *Aphis gossypii* Glover (Homoptera: Aphididae)

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Abstract
The cotton aphid (*Aphis gossypii* Glover) (Homoptera: Aphididae) is an important insect pest worldwide because it infests a wide variety of crops and develops insecticide resistance. Spiracle-blocking insecticides are often effective against aphids that have developed insecticide resistance. In this study, the insecticidal effects of a spreader, Mairino® and an adjuvant, Approach® BI, on *A. gossypii* were investigated to search for new spiracle-blocking insecticides. We used the standard, and concentrations of the products and found highly significantly corrected mortality rates at 10× dilution of the spreader and 10×, and 100× dilutions of the adjuvant. Specifically, the adjuvant had a highly significant effect on the mortality rate of *A. gossypii*, and since it did not show phytotoxicity, it might be practical for use as an insecticide. However, to utilize spreaders and adjuvants as insecticides, it is necessary to study their phytotoxicity in more detail.

Keywords: Spreader, adjuvant, spiracle-blocking insecticide, *Aphis gossypii*

1. Introduction
The cotton aphid (*Aphis gossypii* Glover) (Homoptera: Aphididae) is an important insect pest worldwide because it infests a wide variety of crops and develops insecticide resistance [1-3]. Spiracle-blocking insecticides are often effective against aphids that have developed insecticide resistance [4, 5] and have fewer side effects on natural enemies of pests [6]. It is considered that resistance to spiracle-blocking insecticides is less likely to be developed than to other insecticides [4, 5]. Thus, they are often used in integrated pest management (IPM) programs in Japan [6].
Spiracle-blocking insecticides kill insect pests by suffocation through physically blocking their spiracles with a surfactant or adhesive substance [4-6]. Since many agricultural spreaders and adjuvants exhibit surface-active and adhesive properties, they can be used as spiracle-blocking insecticides; and higher concentrations of the spreader and adjuvant should show greater insecticidal effects. In addition, depending on the concentration, agricultural spreaders and adjuvants are generally not phytotoxic.
To search for new spiracle-blocking insecticides, we investigated the insecticidal effects of a commonly available spreader (Mairino®) and an adjuvant (Approach® BI) on *A. gossypii*, using the standard and higher concentrations of the products. Their phytotoxicity at the various treatment concentrations was also examined.

2. Materials and Methods
2.1 Insect rearing
Following a simple breeding method for small pests [7], an *A. gossypii* population purchased from the Sumika Techno Service Corporation (Hyogo, Japan) was reared on sprouted broad bean (*Vicia faba* L.) as the host plant. The budded broad beans were inoculated with aphids and transferred to round (12 cm diameter × 10 cm high) or rectangular (20 cm long × 15 cm wide × 8 cm high) lidded rearing containers. To ensure optimal air circulation in the containers, there was an 11 cm diameter cutout in the lid of the circular breeding container and a 19 × 14 cm cutout in the lid of the rectangular container. A fine plastic mesh was sandwiched between the lids and the containers. Vermiculite, moistened with water, was placed in the rearing containers to maintain humidity. The rearing was conducted in an incubator at 20° C with 16 h light and 8 h dark periods per day.

2.2 Experimental procedure

In this experiment, Mairino® (Nihon Nohyaku Co., Ltd.) with 27% polyalkylene glycol alkyl ether as the active ingredient was used as the commonly available spreader, and Approach® BI (Maruwa Biochemical Co., Ltd.) with 50% polyoxyethylene hexitane fatty acid ester as the active ingredient, were used as the commonly available adjuvant. The spreader was tested at 3 concentrations: 10×, 100×, and 1000× dilutions. The adjuvant was tested at 4 concentrations: 10×, 100×, 1000×, and 10000× dilutions. Distilled water was used as the control treatment. The cotton aphids were classified into 5 stages of 1st to 4th instar larvae and adult [8]. The aphids were counted, and the sprouting broad bean plants (with the aphids attached) were dipped into the appropriate treatment concentration of the spreader or adjuvant for 5 seconds. The treated sprouting broad beans with the aphids were maintained in circular plastic cases (10 cm diameter × 4 cm high) in an incubator at 20° C with 16 h light and 8 h dark periods per day. The mortality of the cotton aphids was recorded 24 h after treatment. At 24 h, an aphid that did not respond to touch with a fine brush was counted as dead. In addition, the sprouting broad beans were observed to determine the phytotoxicity of each treatment concentration. The corrected mortality rate for each concentration at each developmental stage was calculated using Abbott's formula [9].

3. Results and Discussion

Higher corrected mortality rates at all developmental stages of *A. gossypii* was observed at higher concentrations of the spreader, Mairino® (Table 1). At the standard concentration of 1000× dilution, the corrected mortality rate ranged between 0% to 2.3%. Even at 100× dilution, the corrected mortality rate was only 0% to 7.5%; therefore, these concentrations were considered to have no significant lethal effect on *A. gossypii*. Whereas, at 10× dilution, the corrected mortality rate ranged from 13.0% to 63% depending on the developmental stage, confirming a lethal effect; however, the high corrected mortality rate of 63% was observed only in the first instar larvae. Therefore, multiple sprays might be needed to suppress this aphid. Other studies have also reported the need for multiple sprays of spiracle-blocking insecticides [10].

Higher corrected mortality rates at all developmental stages of *A. gossypii* were also observed at higher concentrations of the adjuvant, Approach® BI (Table 1). The corrected mortality rate was 0% at 10000× dilution that is the standard dilution for this adjuvant; at 1000× dilution, it was 0% to 14.3%; therefore, these 2 concentrations did not have a significantly lethal effect, however, at 100× dilution, the corrected mortality rate was 83.8% to 98.0%, and at 10× dilution, it was 100% in all developmental stages. Therefore, the 100× and 10× dilutions were considered to have a significant insecticidal effect on *A. gossypii*. Using the adjuvant at higher concentrations may be costly; therefore, it might be more economical to apply multiple sprays at 100× dilution.

The phytotoxicity of the spreader at each concentration was observed. We found that at 10× and 100× dilution of the spreader, the tips of the broad bean buds were blackened. Phytotoxicity was not observed with the adjuvant, but has been observed with other spiracle-blocking insecticides and may vary depending on species, growth stage, and climatic conditions [10].

Table 1: Corrected mortality of cotton aphid (*Aphis gossypii*) at different concentrations of spreader Mairino® and adjuvant Approach BI®

Treatment	Concentration (dilution)	Corrected mortality (%) at each developmental stage*				
		Larval instar stage				Adult
		First	Second	Third	Fourth	
Mairino®	10	63.3(38)	22.2(144)	26.6(104)	13.0(46)	18.1(72)
	100	7.5(44)	1.5(43)	0(51)	2.6(20)	3.2(31)
	1000	0(34)	0(30)	0(35)	0(23)	2.3(44)
Approach BI®	10	100(43)	100(91)	100(148)	100(44)	100(46)
	100	96.7(32)	97.0(68)	98.0(51)	87.9(17)	83.8(37)
	1000	14.3(35)	10.2(64)	9.1(75)	0(27)	6.1(33)
	10000	0(62)	0(53)	0(32)	0(21)	0(48)
Control	-	6.7(30)	0.9(116)	1.7(58)	2.5(40)	0(53)

*Numbers in parenthesis indicate number of aphid tested in different treatments of concentrations and developmental stages.

4. Conclusion

In this study, we investigated the insecticidal effect of the spreader, Mairino® and the adjuvant, Approach® BI, on *A. gossypii*. We found high corrected mortality rates at 10× dilution of the spreader and at 10× and 100× dilution of the adjuvant. Specifically, the adjuvant had a highly significant lethal effect on the mortality rate of *A. gossypii*, and no phytotoxicity was observed; therefore, it may be practical for use as an insecticide against *A. gossypii*. However, phytotoxicity was observed with the spreader at 10× dilution. Although no phytotoxicity was observed with the adjuvant in this study, it may occur, depending on the species, growth stage and climatic conditions. Therefore, to utilize the spreader and adjuvant as insecticides against *A. gossypii*, it is necessary to investigate their phytotoxicity to a wide range of crops.

5. References

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