Journal of
Agriculture and Biology
ISSN: 3007-1755 (Print), 3007-1763 (Online)

Research Article

Jaggery Based Spray as a Potential Tool in Improving Natural Enemies on Maize Against *Spodoptera Frugiperda*

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ABSTRACT

Fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) is a significant pest of maize in Asia and Africa. The excessive use of synthetic insecticides causes concerns of resistance, environmental pollution and reduction of natural enemies. New mechanisms that have potential to be effective include conservation biological control approaches that improve the activity of predators and parasitoids. This research determined the impacts of sugar sprays using jaggery in the abundance of arthropod predators and pests, such as *S. frugiperda*, in maize fields in Pakistan (Multan) across two agricultural seasons (autumn and spring). Four treatments (Prototype treatment) of full-dose of jaggery spray (17 kg ha-1), half-dose of jaggery spray (8.5 kg ha-1), water spray and an untreated control were done in a replicated field setup. Before and after the weekly applications, the predator and pests of arthropods were measured through standardized plant-based sampling and the maize damage against the *S. frugiperda* predator was measured with the use of the Davis leaf damage scale. Plots that had been treated with jaggery had always greater abundances of generalist predators; specifically, ants, spiders, rove beetles, and ladybird beetles than did water-sprayed and untreated plots. These results show that jaggery-based sugar sprays have the capacity to stimulate predator activity in maize agroecosystems but they do not give conclusive results on the efficiency to suppress the population of *S. frugiperda* when applied individually. Sugar sprays can therefore be useful in conservation biological control as an additional technique in integrated pest management initiative, and not as an isolated control mechanism.

Keywords: Conservation, natural enemies, *S. frugiperda*, Integrated Pest Managament.

OPEN ACCESS

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Article History
Received: September 19, 2025
Accepted: December 02, 2025
Published: December 28, 2025

INTRODUCTION

The parasitoids and predators of *S. frugiperda* in the Americas and the Caribbean Basin were found to comprise 151 species in total and these were placed under 14 families; nine families were under Hymenoptera, four families under Diptera and one family under Nematoda (Molina-Ochoa et al., 2003). Ichneumonids and braconids were the most diverse family of Hymenoptera present in the sampled area. Among 55 species, the Tachinidae was identified as a parasitoid family with the highest species richness. When *S. frugiperda* was first reported in India in July 2018, subsequent searches were conducted to find out whether there were any indigenous natural enemies of this pest. Some of the parasitoids and predators of these arthropods were identified as expected. Shylesha et al., 2018 had explained parasitism with egg parasitoids including *Telenomus* sp. Parasitoids such as the egg-larval braconid *Chelonus* spp, the social larval parasitoid Glyptapanteles

(Viereck) (Braconidae), *Trichogramma* spp . from the family *Trichogrammatidae* and, the solitary larval parasitoid *Campoletis chlorideae* Uchida (Ichneumonidae) and an unidentified social/individual larval-pupal Ichneumoninae parasitoid. Larval parasitoid *S. frugiperda* was found by Gupta et al., (2019) in the maize fields of Karnataka, Tamil Nadu, Rajasthan, Uttar Pradesh, Punjab, and Meghalaya Cotesia ruficrus (Haliday). Also mentioned by Gupta et al, (2020) parasitoids isolated from *S. frugiperda* were *Chelonus formosanus* Sonan and *Coccygidium transcaspicum* Kokujev. Compared to *T. remus Trichogramma chilonis Chelonus formosanus Chelonus spp*. This in addition to three parasitoids, *Campoletis chlorideae* Uchida and *Cotesia ruficrus* and Phanerotoma sp. are *S. nitidus* and *Coccygidium transcaspicum* which were established to be related to *S. frugiperda*. In some of the sites that were not sprayed with insecticide, *Forficula* sp. (Dermaptera). The contribution of another family of Mantodea (Forficulidae) was also noticed while feeding on *S. frugiperda*-larvae. In the maize field, there are also a lot of helpful insects, such as parasitoids and predators, which serve as biological control agents. A biological control agent against the autumn armyworm and other insect pests in maize crops is said to have more than 20 predators. *Orius insidiosus*, *Solenopsis spp*., and *Dorus spp*. are examples of predators (Souza et al., 2013). The fall armyworm is also documented to be the target of several parasitoids, including egg 66 larval parasitoids and others that feed on both eggs and larvae. *Telenomus rumus* is an egg parasitoid, *Campoletis sonorensis* is a larval parasitoid, and *Chelonus insularis* is an egg parasitoid (Padilla Cortes et al., 2022). Predators are essential to the natural control of fall armyworm. More than 20 predators have reportedly been observed to be actively pursuing the fall armyworm, according to 30-year old historical data. They include *Orius insidiosus* (Say) (Hemiptera: Anthocoridae), *Solenopsis* spp. (Hymenoptera: Formicidae) (Wyckhuys and O'Neil, 2006), and *Dorus spp.* (Diptera: Forficulidae) (Varella et al., 2015). The majority fall armyworm predators were found in maize crops; however, some were also found in turfgrass.(Braman *et al*.,2004) To test the effectiveness of predator species against fall armyworm, the majority of the tests were carried out in the United States, followed by Brazil and Honduras. Fall armyworm known to be destructive pest in the maize growing countries of the world and giving big threat to maize production as compared to the other pests of maize crop. Synthetic insecticides are being used worldwide to control this destructive pest especially in Pakistan. Very little research has been conducted on the ecofriendly management especially the biological control agents of fall armyworm in Pakistan as compared to other regions. it has been known that ants, which are the natural enemies of stemborers, can be lured into the maize fields using sugar (Hussain, 2022). The objectives of conservation in management by natural enemies are to make conditions favoring survival and reproduction of natural enemies over pests so that subsequent generations of these latter insects are less in number and produce fewer offspring in the future (Van Driesche and Bellows, 1996). One method is the use of artificial solutions on crops to attract the natural enemies in the field (Wade et al., 2004). Exogenous solutions these include: solutions of sucrose and brewer’s yeast in water, honey water solutions and aphid honeydews and honeydew concentrations (Bortolotto 2014). Wright and Devries (2000) and Seagraves et al., 2011 reported that sucrose solution in water attract predator such as adult hover flies Syrphidae ,lady beetles Coccinellidae , big eyed bugs Lygaeidae, lacewings Chrysopidae, minute pirate bugs Anthocoridae, and ants Formicidae (Seagraves et al., 2011, Evans and Swalow,1993) As much as sugar sprays benefits insects like ants which in turn acts as predator to the gypsy moth Lymantria dispar (L.) (Lepidoptera; Lymantriidae), there has been reduction in the population of the gypsy moth due to enhanced activity of ants. By the efforts of an extension program for integrated pest management, `MIP Laderas’ (hillsideIPM), a course in natural control was introduced with understanding among the small-scale farmers (Canas et al, 2013; Hussain, 2022). Use of synthetic insecticides in most of the maize-based systems interferes with the useful arthropods and this may not be cost-effective and environmentally feasible to maintain. The goal of conservation biological control is to make species of naturally occurring predators and parasitoids more effective in agroecosystems. Several natural predators of FAW are also noted, and the activity of these predators can also be used to regulate pests when appropriate habitats and food sources are available. The use of natural enemies however, may be limited by the lack of adult food and field retention. One way suggested to feed beneficial insects is through sugar provisioning which is the supply of easily accessible carbohydrates and may result in both longer residence time and foraging behavior in crop fields. The question that we answered in this work was whether jaggery (unrefined cane sugar) sprays on maize can enhance the abundance of generalist predator groups and whether we can see a corresponding change in pest abundance as well as the FAW-related leaf damage. Our hypotheses were that, with jaggery sprays, (i) predator abundance will be greater than in water-sprays and untreated controls, (ii) predator abundance will be lower than in the presence of pests, and (iii) predator abundance will be lower than in the presence of leaves.

MATERIALS AND METHODS

Field experiments were conducted at Agricultural Farm (30.148353, 71.445772) of MNS University of Agriculture Multan during two maize seasons of maize crop: in two growing seasons of maize: Autumn 2022 (August-September 2022) and Spring 2023 (February-May 2023). A deep cultivator was used to plough the fields. Additionally, a rotavator was utilized to prepare the difficult terrain before seed was sown on the ridges with the aid of a planter. All of the locations had local kinds of maize seed planted. Each of the maize cultivars used in the study was an open-pollinated landrace that local farmers had chosen and enhanced. One 48,400 square feet area was selected for study. Plots of 55 feet length and 50 feet width were made. Four treatments T1(Full Dose=430g), T2(Half Dose=215g), (T3=water effect), (T4=control). Each treatment was replicated thrice. Maize variety was P4040. Crop was hand-planted and harvested and was periodically weeded. Although herbicides were used occasionally, no insecticides were used. Each plot measured 55 ft x 50 ft (255 m^2). According to this area, the doses of field equation were 430 g jaggery per plot (T_1) and 215 g per plot (T_2) per slot. Jaggery was diluted in water (90 g L^{-1}) and sprayed with the Solo backpack sprayer with a TG-2 nozzle. The volume of spray used was adjusted in such a way that the cumulative amount of jaggery applied in each plot was proportional to the target hectare per rate. The applications were carried out five weeks in a row with a weekly basis (Hussain 2022). Previous studies have used concentrations of sucrose ranging from 38 g to 700 g per liter of water. (Wade et al., 2004, Seagraves et al., 2011, Ulhaq et al. 2006). It was applied three weeks after plant emergence for five times in the V3 to V12 stage of plant development. 30 August 2023 to 26 September 2023, and the experiment terminated at around V12 development of the maize plant. All applications were conducted between 1100 and 1200 h Mean pest and natural enemy populations were determined by two sets of direct observations. The first observation, before the jaggery solution spray and then the observations after the applications. For each plot, the density and species of natural enemies of 10 plants at five random sites were determined. One week and two hours after each application, a second observation was made to see if sugar-treated plots would have more natural enemies. The relative abundance of pests and natural enemies in jaggery dosages and the water effect and control were then compared. Frequency and percentage of natural enemies and pest population per plant found half an hour after applications as well as 1 week after applications ANOVA in a factorial design (Montgomery, 2017). Data collected during the first week of study were excluded from statistical analysis since there was no prior usage of sugar. The analysis was first conducted for three factors: The analysis of variance by study field, treatment and year and the analysis of variance by study field and treatment within the year were carried out (PROC GLM; SAS Institute, 1985). The study was carried out in Autumn, 2022 and Spring, 2023 growing seasons and the maize fields were sampled at weekly intervals at different phenophases. Fifty randomly selected plants were evaluated for growth condition at each visit using the "leaf collar method (Wyckhuys and O'Neil 2006, Nielsen 2004).

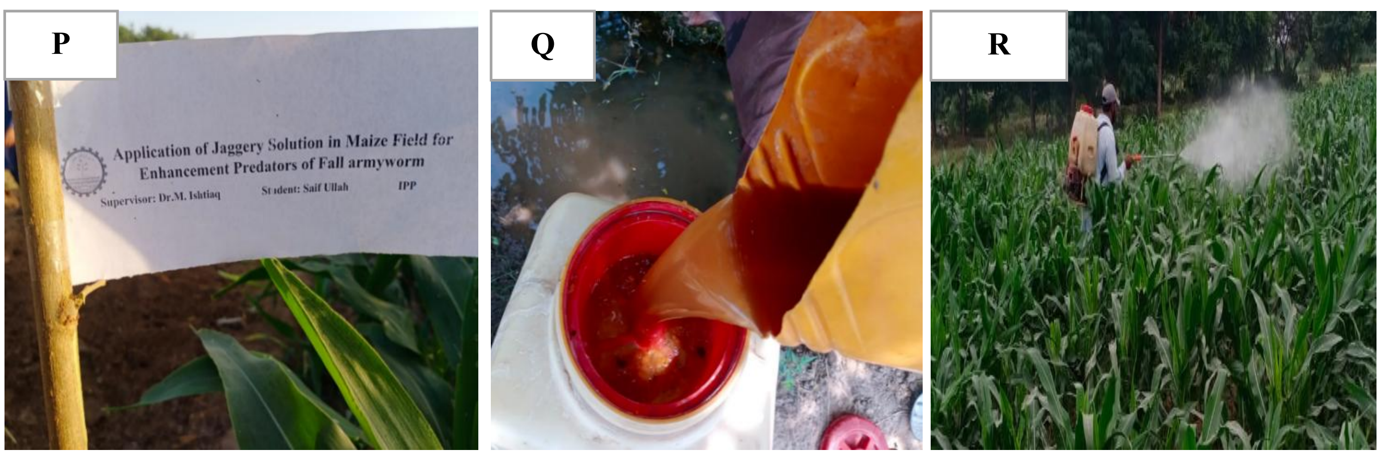

Figure 1. Field Selection(P), Jaggery Solution Preparation(Q), Spray in Field(R).

Sampling and Data Analysis of Natural Enemies There were field trip every week. In each of the field visits, we randomly chose five transects of ten plants and then determined the number of arthropod predators on the particular plant. Due to edge effects, all the transects were laid within the field. Effectiveness of Jaggery solution spray on damage induced by fall armyworm. The impact of Jaggery applications was determined by evaluating fall armyworm damage on the leaf area and percentage whorl infestation. The extent of leaf area attacked by the fall armyworm suggested that the smallsized larvae were active. Detection of whorls suggested that big fall armyworm larvae were active. During the second observation, the extent of attack by Fall armyworm on Maize leaves was determined by means of the Davis rating scale which starts from 0 to 9. Ten plants were sampled from each Jaggery spray treatment while each treatment had three replications. Damage at T 1 varied from 0 to 3. In T1 it was 1 to 3 In T2 it was 3 to 5 In T3 it was 5 to 7 In T4 it was 7 to 9 scale and average of all treatments was taken which is shown in following graph Statistics 8. 1 software used for data analysis Anova Table shows significant result**.**

Data was recorded from two seasons (Summer and Autumn) of pests and predators before and after the spray of jaggery solution, in all four treatmentsusing the Davis leaf damage rating scale (0-9) of *S. frugiperda.*

Data Analysis

Data was analyzed with statistical software 8.1. Analysis of variance and Tukey HSD All-Pairwise Comparisons Test was performed to check comparisons.

RESULTS

In Autumn Season on an average, the number of biocontrol agents e.g. Ants abundance after application of Jaggery solution T1=17kg/hectare(average number of insect /plant 2.72±0.17 S.E) increased 45% and at T2=8.5kg/hectare (average number of insect /plant 2.40±0.16 S.E) increased 40% and at T3,T4= (average number of insect /plant 2.13±0.15 S.E., 2.01±0.14 S.E.) gave almost 34% increase rate, Spider on T1 increased 67% (average number of insect /plant 0.67±0.04 S.E) and on T2 (average number of insect /plant 0.65±0.04 S.E) 52% increased and T3,T4= (average number of insect /plant 0.58±0.04.) gave almost 41% increase rate, Rove Beetle on T1 increased 48.5% (average number of insect /plant 0.62±0.04 S.E) and on T2 (average number of insect /plant 0.57±0.04 S.E) 45.5% increased and T3,T4= (average number of insect /plant 0.37±0.04.) gave almost 40% increase rate, Lady Bird Beetle on T1 increased 49% (average number of insect /plant 0.66±0.04 S.E) and on T2 (average number of insect /plant 0.51±0.04 S.E) 46% increased and T3,T4= (average number of insect /plant 0.51±0.03.) gave almost 42% increase rate.

The number of pest e.g. Aphid abundance after application of Jaggery solution T1=17kg/hectare(average number of insect /plant 0.44±0.04 S.E) decreased 37% and at T2=8.5kg/hectare (average number of insect /plant 0.40±0.03 S.E) decreased 35% and at T3 (average number of insect /plant 0.56±0.04S.E.) decreased 33% and at T4 gave almost 29% decrease rate, *S. frugiperda* on T1 decreased 45% (average number of insect /plant 0.16±0.01 S.E) and on T2 (average number of insect /plant 0.21±0.02 S.E) 42% decreased and at T2=8.5kg/hectare (average number of insect /plant 2.40±0.16 S.E) increased 40% and at T3,T4= (average number of insect /plant 0.23±0.02 S.E., 0.24±0.02 S.E.) gave almost 39% decrease rate, Field cricket on T1 decreased 67% (average number of insect /plant 0.20±0.01 S.E) and on T2 (average number of insect /plant 0.21±0.01 S.E) 61% decreased and T3,T4= (average number of insect /plant 0.24±0.02, 0.29±0.02) gave almost 55% decrease rate, Shoot Fly on T1 decreased 57% (average number of insect /plant 0.10±0.01S.E) and on T2 (average number of insect /plant 0.12±0.01 S.E) 53% decreased and T3,T4= (average number of insect /plant 0.17±0.01,0.21±0.01) gave almost 48% decrease rate. Stem Borer on T1 decreased 46% (average number of insect /plant 0.19±0.01 S.E) and on T2 (average number of insect /plant 0.20±0.01 S.E) 43% decreased and T3,T4= (average number of insect /plant 0.25±0.02,0.26±0.02) gave almost 40% decrease rate. Stink Bug on T1 decreased 86% (average number of insect /plant 0.53±0.03 S.E) and on T2 (average number of insect /plant 0.49±0.03 S.E) 81% decreased and T3,T4= (average number of insect /plant 0.33±0.03,0.32±0.03) gave almost 61% decrease rate.

In Spring season on an average, the number of natural enemies e.g. Ants abundance after application of Jaggery solution T1=17kg/hectare(average number of insect /plant 2.91±0.18 S.E) increased 34% and at T2=8.5kg/hectare (average number of insect /plant 2.40±0.16 S.E) increased 27% and at T3,T4= (average number of insect /plant 2.20±0.15 S.E., 2.40±0.15 S.E.) gave almost 25% increase rate, Spider on T1 increased 54% (average number of insect /plant 0.69±0.04S.E) and on T2 (average number of insect /plant 0.64±0.04 S.E) 48% increased and T3,T4= (average number of insect /plant 0.59±0.04, 0.61±0.04) gave almost 43% increase rate, Rove Beetle on T1 increased 42% (average number of insect /plant 0.69±0.04 S.E) and on T2 (average number of insect /plant 0.59±0.04 S.E) 40% increased and T3,T4= (average number of insect /plant 0.51±0.03, 0.52±0.03.) gave almost 38% increase rate, Lady Bird Beetle on T1 increased 49% (average number of insect /plant 0.69±0.04S.E) and on T2 (average number of insect /plant 0.51±0.04 S.E) 48% increased and T3,T4= (average number of insect /plant 0.43±0.03, 0.43±0.03) gave almost 45% increase rate. The number of pest e.g. Aphid abundance after application of Jaggery solution T1=17kg/hectare(average number of insect /plant 0.48±0.03 S.E) decreased 42% and at T2=8.5kg/hectare (average number of insect /plant 0.55±0.04 S.E) decreased 40% and at T3 (average number of insect /plant 0.53±0.04 S.E.) decreased 38% and at T4 (0.53±0.04) gave almost 37% decrease rate, *S. frugiperda* on T1 decreased 48% (average number of insect /plant 0.16±0.01 S.E) and on at T2=8.5kg/hectare (average number of insect /plant 0.23±0.02 S.E) increased 44% and at T3,T4= (average number of insect /plant 0.28±0.02 S.E., 0.27±0.02 S.E.) gave almost 41% decrease rate, Field cricket on T1 decreased 67% (average number of insect /plant 0.20±0.01 S.E) and on T2 (average number of insect /plant 0.21±0.01 S.E) 61% decreased and T3,T4= (average number of insect /plant 0.24±0.02, 0.29±0.02) gave almost 55% decrease rate, Shoot Fly on T1 decreased 35% (average number of insect /plant 0.34±0.01S.E) and on T2 (average number of insect /plant 0.14±0.01 S.E) 32% decreased and T3,T4= (average number of insect /plant 0.17±0.01,0.23±0.01) gave almost 28% decrease rate. Stem Borer on T1 decreased 43% (average number of insect /plant 0.17±0.01SE) and on T2 (average number of insect /plant 0.18±0.01 S.E) 39% decreased and T3,T4= (average number of insect /plant 0.19±0.02,0.23±0.02) gave almost 33% decrease rate. Stink Bug on T1 decreased 70% (average number of insect /plant 0.43±0.03 S.E) and on T2 (average number of insect /plant 0.35±0.03S.E) 65% decreased and T3,T4= (average number of insect /plant 0.31±0.03,0.30±0.03) gave almost 59% decrease rate.

Table 1. Autumn Season: Abundance of pest and predator in maize field before and after spray of jaggery solution.

Sr. No.	**Insect Name**	**Time**	**Treatment**			
			T1	**T2**	**T3**	**T4**
			Mean±SE	**Mean±SE**	**Mean±SE**	**Mean±SE**
1	Ants	Before Spray	1.21±0.11	0.97±0.09	0.87±0.09	0.77±0.07
		After Spray	2.72±0.17	2.40±0.16	2.13±0.15	2.01±0.14
2	Aphid	Before Spray	1.16±0.06	1.20±0.06	1.56±0.06	2.01±0.14
		After Spray	0.44±0.04	0.40±0.03	0.56±0.04	0.75±0.05
3	*S. frugiperda*	Before Spray	0.38±0.04	0.48±0.03	0.55±0.03	0.57±0.03
		After Spray	0.16±0.01	0.21±0.02	0.23±0.02	0.26±0.02
4	Field Cricket	Before Spray	0.30±0.02	0.34±0.02	0.42±0.02	0.48±0.02
		After Spray	0.20±0.01	0.21±0.01	0.24±0.02	0.29±0.02
5	Lady Bird Beetle	Before Spray	0.32±0.03	0.24±0.03	0.16±0.02	0.17±0.02
		After Spray	0.66±0.04	0.51±0.04	0.36±0.03	0.37±0.03
6	Rove Beetle	Before Spray	0.30±0.02	0.24±0.02	0.21±0.02	0.21±0.02
		After Spray	0.62±0.04	0.57±0.04	0.51±0.03	0.49±0.03
7	Shoot Fly	Before Spray	0.18±0.01	0.24±0.01	0.31±0.02	0.36±0.02
		After Spray	0.10±0.01	0.12±0.01	0.17±0.01	0.25±0.01
8	Spider	Before Spray	0.45±0.03	0.34±0.03	0.25±0.02	0.30±0.03
		After Spray	0.67±0.04	0.65±0.04	0.58±0.04	0.58±0.04
9	Stem Borer	Before Spray	0.42±0.02	0.49±0.03	0.60±0.03	0.62±0.03
		After Spray	0.19±0.01	0.20±0.01	0.25±0.02	0.26±0.02
10	Stink Bug	Before Spray	0.61±0.03	0.59±0.03	0.53±0.03	0.52±0.03
		After Spray	0.53±0.03	0.49±0.03	0.33±0.03	0.32±0.03
	F,df		52.99,9	80.51,9	47.76,9	59.11,9
	P		<0.001	<0.001	<0.001	<0.001

Table 1 shows abundance of pest (Fall armyworm, shoot fly, stink bug, stem borer, field cricket and aphid) and predators (ladybird beetle, rove beetle, spider and Ants) observed in maize in Autumn season from V3 –V12 stage after and before spray of jaggery solution on maize on four treatments T1=17kg/hectare jaggery solution, T2= 8.5 kg/hectare jaggery solution T3 =Water spray and T4 =Control. In case of predators Ants (2.72,2.40,2.13,2.01 per plant on T1 to T4 respectively) shows high population after spray application followed by spider(0.67, 0.65, 0.58,0.58 per plant), lady bird beetle (0.61,0.56,0.36, 0.37 per plant), and rove beetle(0.62,0.57,0.51,0.49 per plant) and from pests Stink bug shows high abundance (0.53,0.49,0.33,0.32 per plant from T1 to T4) then Aphid shows (0.44,0.40,0.56,0.65 per plant) followed by fall armyworm (0.16,0.21,0.23,0.26 per plant), stem borer (0.19,0.20,0.25,0.26 per plant), field cricket (0.20,0.21 ,0.24,0.29 per plant) and shoot fly(0.10 ,0.12,0.17,0.25 per plant), after spray application.

Table 2. Spring Season: Abundance of pest and predator in maize field before and after spray of jaggery solution.

Sr. No.	Insect name	Time	Treatmen			
			T1	T2	T3	T4
			Mean±SE	**Mean±SE**	**Mean±SE**	**Mean±SE**
1	Ants	Before Spray	0.99±0.07	0.70±0.07	0.59±0.07	0.63±0.07
		After Spray	2.91±0.18	2.57±0.17	2.50±0.15	2.40±0.14
2	Aphid	Before Spray	1.13±0.06	1.53±0.06	1.52±0.06	1.53±0.06
		After Spray	0.48±0.03	0.55±0.04	0.53±0.04	0.51±0.04
3	*S. frugiperda*	Before Spray	0.36±0.02	0.49±0.03	0.57±0.03	0.59±0.03
		After Spray	0.16±0.01	0.23±0.02	0.28±0.02	0.27±0.02
4	Field Cricket	Before Spray	0.26±0.02	0.31±0.02	0.35±0.02	0.46±0.02
		After Spray	0.12±0.01	0.17±0.01	0.25±0.02	0.27±0.02
5	Lady Bird Beetle	Before Spray	0.34±0.02	0.23±0.03	0.19±0.02	0.17±0.02
		After Spray	0.69±0.04	0.51±0.04	0.43±0.03	0.37±0.03
6	Rove Beetle	Before Spray	0.29±0.02	0.24±0.02	0.20±0.02	0.20±0.02
		After Spray	0.69±0.04	0.59±0.04	0.51±0.03	0.33±0.03
7	Shoot Fly	Before Spray	0.10±0.01	0.23±0.01	0.31±0.02	0.31±0.02
		After Spray	0.34±0.03	0.14±0.01	0.17±0.01	0.23±0.01
8	Spider	Before Spray	0.34±0.03	0.29±0.03	0.26±0.02	0.27±0.03
		After Spray	0.70±0.04	0.64±0.04	0.59±0.04	0.60±0.04
9	Stem Borer	Before Spray	0.43±0.02	0.49±0.03	0.58±0.03	0.69±0.03
		After Spray	0.17±0.01	0.18±0.01	0.19±0.02	0.23±0.02
10	Stink Bug	Before Spray	0.61±0.03	0.53±0.03	0.51±0.03	0.50±0.03
		After Spray	0.43±0.03	0.35±0.03	0.31±0.03	0.30±0.03
	F,df		77.95,9	101.53,9	81.10,9	69.34,9
	P		<0.001	<0.001	<0.001	<0.001

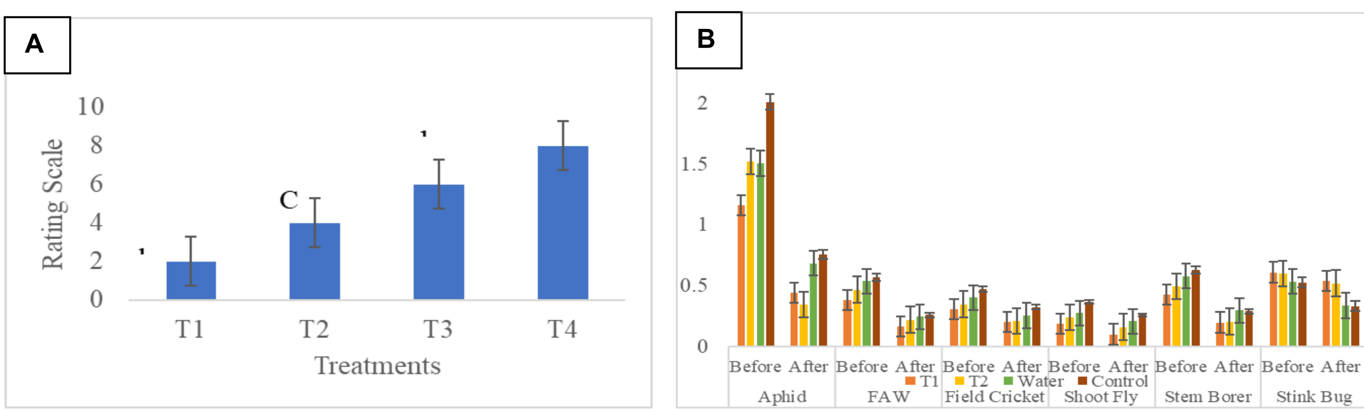

Figure 2. (A) Damage rating scale of *S. frugiperda* in four treatments. T1 = 17kg/hectare of jaggery solution application, T2 = 8.5 kg/hectare ,T3 = water application and T4 = control unsprayed (B) ows pest abundance in Autumn season in four treatments before and after spray of jaggery solution.

Table 2 shows abundance of pest (Fall armyworm, shoot fly, stink bug, stem borer, field cricket and aphid) and predators (ladybird beetle, rove beetle, spider and ants) observed in maize in Spring season from V3 –V12 stage after and before spray of jaggery solution on maize on four treatments T1=17kg/hectare jaggery solution, T2= 8.5 kg/hectare jaggery solution T3 =Water Spray and T4 =Control. In case of predators ants (2.91,2.57,2.50,2.40 per plant on T1 to T4 respectively) shows high population after spray application followed by lady bird beetle (0.69,0.51,0.43, 0.37 per plant), spider(0.70, 0.64, 0.59,0.60 per plant) and rove beetle(0.68,0.59,0.51,0.33 per plant) and on the other hand in pest Aphid shows high population (0.48,0.53,0.55,0.55 per plant from T1 to T4) followed by Stink bug (0.43,0.35,0.31,0.30 per plant) shoot fly(0.34 ,0.14,0.17,0.23 per planyt) fall armyworm (0.16,0.23,0.27,0.28 per plant), stem borer (0.17,0.18,0.19,0.23 per plant) and field cricket (0.12,0.17 ,0.25,0.27) after spray application.

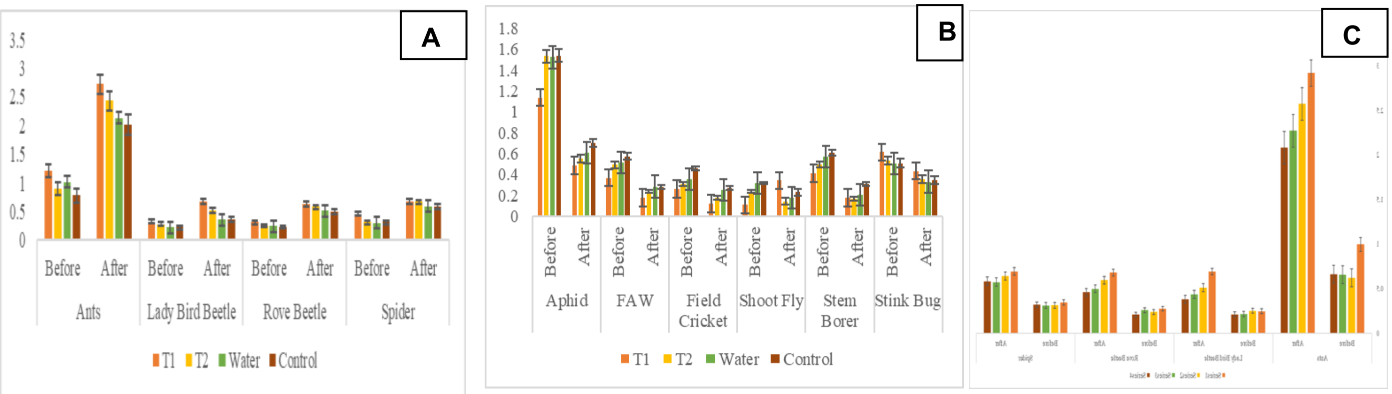

Figure 3. (A) shows predator abundance in Autumn season in four treatments before and after spray of jaggery solution (B) shows pest abundance in Spring in four treatments before and after spray of jaggery solution (C) shows predator abundance in Spring season in four treatments before and after spray of jaggery solution.

DISCUSSION

The fact that the abundance of predators increased with the application of jaggery can be attributed to two ecological processes that are not mutually exclusive, attraction, and retention. Sugar sprays have been able to work as carbohydrate subsidies that increase the survival of predators, their fecundity, and residence time in the field. Nonetheless, other trophic interactions might be also affected by sugar resources. Increased ant abundance might, as an example, indicate direct feeding with sugars as well as greater tending of insects producing honeydew. Though decline of aphid population was observed following spray in this study, the theory of sugar supplementation has a threat of nurturing honeydew-feeding pests in this case. As a consequence, jaggery sprays need to be tested using a more ecological framework that would take into account the multitrophic relationship and any undesired effects. It is noted that in such application of jaggery (sugar solution) to the maize fields there was significant increase in the number of individual predators and decline in pest populations was in proportion to reduction in the size of the attacked leaves and whorl infestations (Ribeiro et al., 2014). While there was a tendency where the whorl infestation rates increased as the sugar application rates increased, this was not a clear-cut trend as was the case with the percentage of the leaf area damaged by the pest, oppose to sugar applications. This means that the control the natural enemies provided through application of sugar was on small FAW larvae that were feeding on T. leaf material than the large larvae that were in whorl. Previous workers have also stressed on monitoring with fall armyworm before they infest maize whorls (Perfecto et al., 1992, Prasanna, 2021). Therefore, the ways used in preserving the natural enemies by manipulating the sugar may further improve the tactics for controlling fall armyworm pests. In the case of the reported densities which are much below the economic thresholds (Canas, 1993), there are findings that need to be conducted to determine whether application of sugar can reduce or even eliminate the economic effects from the fall armyworm populations. Based on the results of this study, it is suggested that further research should concentrate on first and second stadium larvae and their habitat conditions. More so, the number of ants observed and their densities were higher and significantly so in the maize that was sugar-treated in 1994 and 1995 (Luis,1998). Most notably, ants especially *S. geminata* has been acknowledged to be useful predators which feed on the early instar FW, PW (Perfecto, 1991) and that ants influence the level of FW, PW infestation (Perfecto, 1992). As unbelievable as it may sound, or even look, the solution to this problem lies in the calculations of a Honduran farmer, Sra. Marõ a Hubalda Castro, a Filipino entomologist who by exposing sugary baits attempted to attract fewer ants into her maize field to minimize FAW invasion (Clemente Orta et al.,2022).More research should be conducted concerning the later stages of the fall army worm to assess the impact of ants on the earlier instars, the density of ants within the field and surrounding area as well as how far they would have to go to enter the field when exposed to the utilization of sugar in maize. Other predators' reaction to sugar application was equally as follows: Others (for example Chelonus spp., *D. taeniatum*, *Chrysoperla spp*.) had no consistent response to sugar sprays and it was presumed that they were not affected by sugars. Despite this, other species had greater population densities in the sugar-treated-Maize even though their density levels were still not very high (e.g., coccinellids) (Adjaoke et al.,2023). However, using attractive solutions can theoretically prevent natural enemies from attacking places outside of the host, hence reducing their ability to search for hosts (M. A. Jervis, personal communication). The possible explanation for the absence of predatory attack by these animals which are present in a comparatively big number in the field, contemporaneous with host, may be many and this would again call for investigation (Luginbill, 1928). Effective management of crops natural enemies result in higher density or diversification of natural enemies that directly influence the damage potential or density of pests (Karp et al.,2018) Self in the current study we demonstrated that when sugar was applied on Honduran maize there was a rise in the number of natural enemies provided there was a proportional decrease in fall army worm damage as well as the infestation rates (Lundgren et al., 2009). Further work on the appropriate timing and rates of sugar applications and comparison of a sugar applications to conventional insecticide and relative cost-effectiveness is required; however, the drug of the farm er in designing biological control is shadowed (Leeuwen et al.,2007). Management programs can actively encourage idea generation from the farmers as they implement them and as they are involved in designing and analysis of pest controlling module (Koffi et al., 2020).

CONCLUSIONS

Jaggery-based sugar sprays have the capacity to stimulate predator activity in maize agroecosystems but they do not give excellent results on the efficiency to suppress the population of *S. frugiperda* when applied individually. Sugar sprays can therefore be useful in conservation biological control as an additional technique in integrated pest management initiative, and not as an isolated control measure.

ACKNOWLEDGEMENTS

Not applicable.

AUTHOR CONTRIBUTIONS

All the authors contributed equally to this research.

COMPETING OF INTEREST

No conflicts of interest have been disclosed by the authors.

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