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Effects of Biorational Approaches and Synthetic Pesticides on Fall Armyworm Management and Arthropod Diversity in Maize

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AIJ, FZAK and MA presented the concept and developed methodology. MA, HMH and FZAK did project supervision. AIJ did visualization and prepared original draft. FZAK helped in funding acquisition, data analyses, as well as reviewing and editing of the final draft.

Key words
Maize, Biorational, Predators, Pesticides, Biodiversity, Non-targets, IPM

ABSTRACT

Fall armyworm has emerged as a major pest of maize in Pakistan. Multiple fall armyworm management options exist, but their consequences for non-target arthropods in Pakistan have been underreported. Keeping in view this gap, current experiments, using the randomized complete block design, compared the effectiveness of synthetic pesticides and biorational options (including dried plant powders and sand mixtures, and eucalyptus based biopesticides) on fall armyworm control, as well as their effects on non-target fauna. The results showed that fall armyworm damage was lowest in synthetic pesticide treatment, followed equally by eucalyptus-based biopesticide, sand mixtures of neem, red pepper, ash and turmeric, while the highest damage was recorded where no management was done. For the occurrence of the non-target arthropods during live observations, ants and whiteflies were significantly higher as compared to other groups. Overall, live observations showed higher arthropod abundance in biorational treatments as compared to synthetic insecticide treatment. The pitfall trapping differences showed significant differences in the insect orders captured. Moreover, the maize yield at the end of the trial was higher in synthetic pesticide treatments (field recommended doses) as compared to the plots managed using biorational approaches. Among biorational options, the yield of sand and mango wood ash mix showed a higher yield. The current evidence is useful for integrating biorational options into fall armyworm management, especially for smallholders.

INTRODUCTION

Zea mays L. is an important crop used as food source for human and animals. It is mainly used in industry to produce breads, corn flakes, starch, oil and syrup (Kumar *et al*., 2021). *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), commonly known as the fall armyworm (FAW), is a native to tropical and subtropical areas of the American continents. In 2016, it was reported for the first time in African continent in Nigeria (Keerthi *et al*., 2021). More than 28 countries in southern and eastern Africa have since reported it. Many maize-producing regions in India, Yemen, Thailand, Sri Lanka, Bangladesh, Myanmar, and China have reported it most recently. Since its arrival in Africa, FAW has resulted in significant economic losses worth millions of dollars (GC, 2020). Fall armyworm infestation have been confirmed in Pakistan, India, China, and other nearby nations has been noted due to the FAW adult's capacity for long flights (Lamsal *et al*., 2020). More than 80 crop species have reportedly to be affected by fall armyworm including maize, sorghum, rice, sugarcane, millet, and cotton serving as its most significant hosts (Kasoma *et al*., 2021). In Pakistan, fall armyworm has damaged maize and other fodder crops, and farmers rely completely on synthetic insecticides for its management (Khan *et al*., 2023).

Natural enemies, including predators and parasitoids, keep a check on the fall armyworm infestation in the

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field. In the last two decades, more than 69 parasitoids have been reported against fall armyworm, most of them are larval and egg parasitoids (Khan and Joseph, 2022). Egg parasitoid *Telenomus remus* (Nixon) (Hymenoptera: Platygastridae) (Pomari-Fernandes *et al.*, 2015) and larval parasitoid *Campoletis sonorensis* (Cameron) (Hymenoptera: Ichneumonidae) (Araiza, 2018) have been extensively reported. Some parasitoids also attack multiple immature stages of fall armyworm like *Chelonus insularis* Cresson (Hymenoptera: Braconidae) (Roque-Romero *et al.*, 2020). Predators also keep a natural check on fall armyworm larval infestation. Past data of 30 years shows that there are more than 20 predators reported to be effectively praying against fall armyworm. Among them, the most important are *Orius insidiosus* (Say) (Hemiptera: Anthocoridae) (Varella *et al.*, 2015), *Solenopsis* spp. (Hymenoptera: Formicidae) (Wyckhuys and O'Neil, 2006) and *Doru* spp. (Diptera: Forficulidae) (Toscano *et al.*, 2012). Most predators of fall armyworm were reported from maize crop while some were reported from turfgrass. Most of the experiments were conducted from the U.S. followed by Brazil and Honduras to check the efficacy of predator species against fall armyworm.

Biorational techniques have been used to manage fall armyworm infestation in the field. Mixture of sand with ash are applied in the central whorl of maize plant. Smallholders are using ash and soil for fall armyworm control by a long time in Americas (Babendreier *et al.*, 2020). *B. thuringiensis* toxicity was tested by using different microbial pesticides, feeding stimulants and proteins to check its efficacy against fall armyworm (Priyanka *et al.*, 2021). The application of wood ash and cocoa pods is one of the indigenous techniques, which also improved the soil's phosphorous, potassium, calcium, and magnesium status and pH (Harrison *et al.*, 2019). Moreover, the farmers have also been reported to use ash in addition with common insecticides like Mocap (ai: Ethoprophos), Sevin (ai: Carbaryl) and Gamalin (ai: Gamma-hexachlorocyclohexane) or Kerosene application to the central whorl of plant (Ajala *et al.*, 2019).

The current study was performed to evaluate the efficacy of biorational strategies against fall armyworm where different sand mixtures with ash, red pepper, turmeric and neem were used and eucalyptus based biopesticide and synthetic pesticides were tested against immature stage of fall armyworm in maize. The objectives of this study were to check the efficacy of different biorational and synthetic chemical management strategies and their effect on the arthropod fauna present in the field.

MATERIALS AND METHODS

Site selection

Multan district is mostly flat and has been categorized as tropical desert with cold winters and severely hot summers. The average winter low is 4.5 °C (40.1 °F) and summer high is 50 °C (122 °F). The experiment was conducted in the fall 2022 and maize field was maintained in the experimental farm of MNS University of Agriculture, Multan. The farm area was previously used for the cultivation of spring and fall maize for the last two years. The experimental plot was surrounded by North Indian rosewood trees *Dalbergia sissoo* Roxburgh (Fabaceae), Gum Arabic trees *Vachellia nilotica* (L.) PJH Hurter and Mabb. (Fabaceae), Alfalfa *Medicago sativa* L. (Fabaceae) and mustard Brassica sp. fields, while boundary wall on the eastern side.

Experiment layout

The trial was conducted on a maize crop field covering an area of 4,046.86 m^2. For fertilizer applications, 58 kg of phosphorus, 37 kg of sulfate of potash (SOP), and 31 kg of nitrogen (urea) were applied at the time of sowing. An additional 23 kg of nitrogen was applied at a height of 1-1.5 feet of the plant, another 23 kg at 2.5-3.0 feet, and the remaining 23 kg of nitrogen was applied before flowering. Irrigation scheduling was done based on the water needs and a total of 9 irrigations were applied. The field was divided into two equal halves of 2023.43 m^2 each where one half was treated with pesticides while on the other half, only biorational treatments were applied. The hybrid maize (P4040, Corteva Agrisciences, Pakistan) was sown on September 01, 2022. Sowing was done manually, and a plant-to-plant distance of 6-9 inches was maintained.

Blocking and tagging of the field

The field was divided into ten blocks using randomized complete block design. To make replication sub-blocks in the field, the area of field was measured from both biorational and synthetic insecticide treatments. Both fields were divided into 5 equal blocks and a gap was maintained by removing a row of two plants. Biorational and synthetic insecticide treatments were applied and replicated five times. Flagging was done to separate the blocks.

Pitfall trap

Pitfall traps were used to catch the ground dwelling arthropods and created using disposable cups, and the trap cover consisted of a disposable plate attached with three bamboo sticks to elevate it above the ground (Gireesh and Joseph, 2021). The trap was leveled with the soil surface, and the bamboo sticks were secured to the plate using paper pins. The disposable plate with the fixed bamboo sticks was positioned on top of the pitfall trap by inserting the sticks into the soil, raising the plate to approximately 15 cm above the ground. The cover was placed over the trap to avoid the entry of rain water. The contents of pitfall cup included 90 ml ethylene glycol, 90 ml water, and few drops of dish washing liquid. For the installation of pitfall traps, a hole of 6 inches was dug into the soil. A disposable cup of 300 ml was suppressed and leveled to the soil. Ethylene glycol (90 ml) was added into the disposable cup by mixing a few drops of dish washing liquid. Ethylene glycol was added into the cup so that insects trapped into cup could not escape from the trap and purpose of dish washing liquid was that the insects could be submerged in the solution and do not float on the solution present in the trap. A glass beaker was used to measure the amount of ethylene glycol to be added into the pitfall trap.

Arthropod collection and identification

Pitfall traps were fortnightly deployed, with a total of six times during the maize season. A total of twenty-four traps were installed at one time, with 12 traps in each of the chemical and the biorational managed plot. The pitfall traps were collected on the 7th day of installation. The ethylene glycol having all the trapped arthropods were put into a plastic jar and transported back to the laboratory. The arthropods were separated with the help of camel hair brush. After separation, the arthropods were washed using the diluted ethyl alcohol. After washing, the arthropods were stored in glass vials having 70% ethyl alcohol solution with water. The preserved arthropods were then observed under the stereomicroscope (Olympus SZX10, Japan) up to the order level.

Biorational and chemical treatments

Ash was obtained after burning mango wood, while hot pepper, turmeric, and neem powder were purchased from the local market. The neem powder was prepared by shade-drying neem leaves and then grinding them using a grinder. The eucalyptus based biopesticide was obtained from MNS-University of Agriculture Multan. Each of the botanical, except biopesticide was mixed with an equal volume of sand, while biopesticide was mixed with water. The botanical powder and sand mix was applied in the central whorl by hand and the biopesticide was applied using a 20L handheld knapsack sprayer having t-jet nozzle. No application was done in the control plot. The insecticides used included Match® (lufenuron 50 EC, Syngenta, Pakistan Ltd.), Proclaim® Emamectin benzoate 19 EC, Syngenta, Pakistan Ltd.), and Radiant SC (Spinetoram 120 SC, Dow AgroSciences Ltd). In the synthetic insecticide block, a single insecticide was sprayed in central plant whorl, when fall armyworm larval damage crossed 15% at the recommended field dose. A knapsack sprayer with a T-Jet nozzle was used to spray the central whorls.

Damage assessment

Fall armyworm damage was recorded after every 3 days (during vegetative phase) and 7 days (during reproductive phase). During the data recording, the parameters measured were the growth stage, infestation score, name and number of insects on that plant. The growth stage was measured by counting number of leaf collars of the plant.

To check the infestation score, foliar damage on that plant was observed and it was compared using a scale from 1 to 9. Scale 1 showed no damage on the plants while scale 9 was maximum.

Live observations

For live observations of beneficial arthropods and pest populations in the maize field, plants were observed for 1 minute between 11:00 am and 2:00 pm, and the fauna on each plant was recorded (Chen *et al*., 2022). Five random plants were selected from each sub-plot, and the arthropods on those plants were recorded. Live observations were conducted every three days during the vegetative stage (early September to early November) and every seven days during the reproductive phase (mid-November onwards).

Yield data

For yield data, a 1-meter square area of plants was chosen, and corn ears were harvested from those plants. These corn ears were placed on the roof with covers for sun drying to reduce moisture content in the corn seeds. After one week, the covers were removed, and the corn ears were left for an additional week to dry. Once the corn ears were fully dried, the seeds were separated from each ear, and tagging was performed. The seeds were then gathered in a paper bag and individually weighed. Subsequently, the total weight of all the corn ear seeds was determined, and the total yield per acre was calculated.

Statistical analysis

For the statistical analysis of diversity in the maize field, Shannon's and Simpson's diversity indices were applied. Shannon's diversity index (H), Shannon's Equitability (EH), Simpson's index (D), and Simpson's Equitability (ED) were calculated for both pitfall traps and live observations diversity data. Abundance data was analyzed using two-way analysis of variance (ANOVA) and Tukey's HSD in Statistix 8.1 (Analytical

Software, Tallahassee, Florida, USA) to identify statistical differences within the data. For the statistical analysis of fall armyworm management and yield data, the same software was used to determine significant differences between different management options through analysis of variance (ANOVA) and Tukey's HSD test for post-analysis of management options.

RESULTS

Arthropods diversity and abundance in pitfall traps

There was no significant difference in the values of Shannon and Simpson diversity and equitability indices for both chemical and cultural block (Table I). Pitfall trap captures showed highly significant difference between different insect orders. Spiders (Araneae) were significantly higher in the chemical treated plot as compared to the biorational plot (Fig. 1).

Table I. Pitfall traps data and live observation data recorded in maize from September to December 2022. (Mean±SE) and t test for Shannon's diversity index (H), Shannon's equitability (EH), Simpson's diversity index (D) and Simpson's equitability (ED).

Treatments	H	E_H	D	E_D
Pitfall traps				
Synthetic pesticide	1.22±0.17	0.81±0.04	2.98±0.43	0.62±0.08
Biorational scheme	1.26±0.17	0.83±0.03	3.20±0.38	0.64±0.05
t; df	-0.61, 5	-2.51, 5	-0.77, 5	-1.99, 5
P	0.56	0.05	0.47	0.10
Live observation				
Synthetic pesticide	2.18±0.06b	0.82±0.02	7.16±0.47	0.49±0.03
Biorational scheme	2.22±0.07a	0.80±0.01	7.91±0.58	0.47±0.03
t; df	-2.4, 15	-1.9, 15	-1.5, 15	-1.2, 15
P	0.03	0.07	0.16	0.24

Arthropod diversity and abundance in live observations

For the live observations, Simpson's diversity index (H) was significantly higher for cultural block as compared to chemical block. Shannon's equitability (EH), Simpson's diversity index (D) and Simpson's equitability (ED) values were not significantly different in chemical and cultural block (Table I).

In September 2022, a significant difference existed in the average number of all insects recorded on maize plants ($F = 91.3$, df = 24, $P < 0.001$). A significantly higher number of whiteflies were recorded in September 2022, and beetles also exhibited a significant difference from other insects.

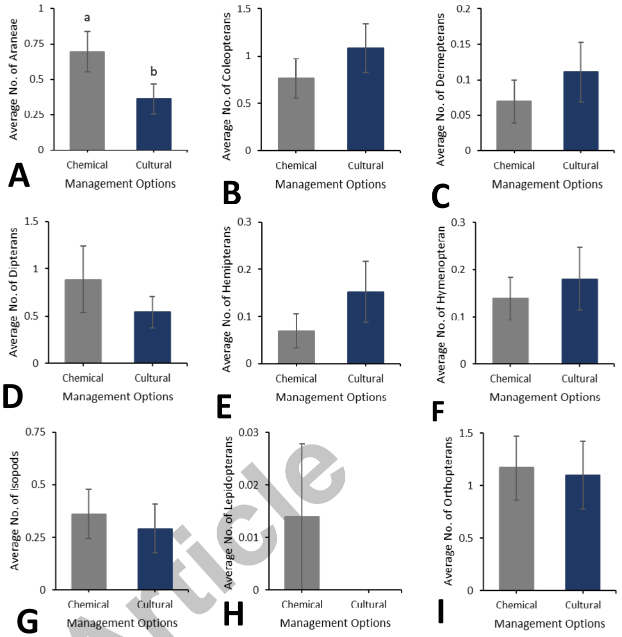

Fig. 1. Arthropod biodiversity recorded in pitfall traps: (A) Araneae, (B) Coleopterans, (C) Dermepterans, (D) Dipterans, (E) Hemipterans, (F) Hymenopterans, (G) Isopods, (H) Lepidopterans and (I) Orthopterans.

In October 2022, a significant difference was found in the average number of all insects recorded on maize plants ($F = 70.2$, df = 24, $P < 0.001$). Whitefly, *Bemisia tabaci* (Hemiptera: Aleyrodidae) adults were significantly more abundant than all other insects. Shoot flies (Diptera: Muscidae), beetles (Coleoptera), and houseflies (Diptera: Muscidae) were also significantly higher in the data recorded in October. Spiders (Araneae), ants (Hymenoptera), jassid (Hemiptera: Cicadellidae), fall armyworm (Lepidoptera: Noctuidae), bugs and hoppers (both Hemiptera) exhibited significant differences in their populations from other insects. Aphids (Hemiptera: Aphididae), bees (Hymenoptera: Apidae), borers, butterflies (both Lepidoptera), crickets (Orthoptera), damselflies, dragonflies (both Odonata), fruit flies (Diptera: Tephritidae), grasshoppers (Orthoptera:Acrididae), green lacewings (Neuroptera: Chrysopidae), mosquitoes (Diptera: Culicidae), moths (Lepidoptera), sepsid flies (Diptera: Sepsidae), wasps (Hymenoptera), and weevils (Coleoptera: Curculionidae) were significantly less abundant in the October data recordings.

In November 2022, a significant difference was observed in the average number of all insects recorded on maize plants ($F = 29.4$, df = 24, $P < 0.001$). The abundance of ants and whiteflies was significantly greater in the data recorded in November. Fall armyworm, aphid, lepidopteran borer, damselfly, dragonfly, wasp, and weevil populations were significantly lower than other insects recorded in November 2022.

In December 2022, a significant difference was found between different arthropods recorded on maize plants (*F* = 25.9, df = 24, *P* < 0.001). The populations of houseflies, ants, and shoot flies were significantly greater. Spiders, mosquitoes, and beetles were not significantly different from each other. Aphids, bees, borers, butterflies, crickets, damselflies, dragonflies, fruit flies, grasshoppers, green lacewings, mosquitoes, moths, sepsid flies, whiteflies, hemipteran bugs, wasps, and weevils were significantly less abundant (Table II).

Overall, a significantly lower number of arthropods were recorded in the chemical treatment block as compared to the biorational and control plots (Fig. 2).

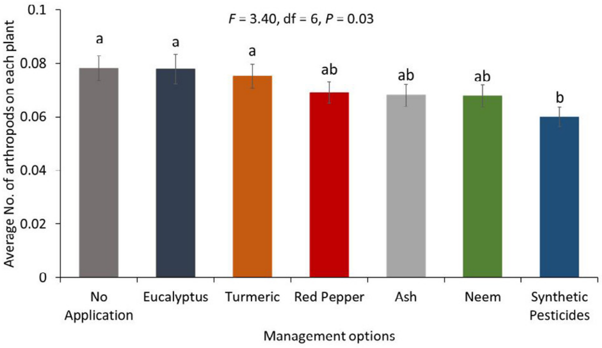

Fig. 2. Arthropods observed on each plant in different management scheme in maize.

Table II. Arthropods biodiversity according to months of data recordings in maize crop from September to December 2022. Data is shown as Mean± SE.

Arthropod (Taxa)	September	October	November	December
Ant (Hymenoptera)	0.09 ± 0.01 cde	0.26 ± 0.02 ab	0.42 ± 0.08 a	0.23 ± 0.03 ab
Aphid (Hemiptera)	0.00 ± 0.00 f	0.00 ± 0.00 f	0.01 ± 0.00 f	0.00 ± 0.00 fg
Bee (Hymenoptera)	0.00 ± 0.00 f	0.00 ± 0.00 f	0.01 ± 0.01 def	0.01 ± 0.00 fg
Beetle (Coleoptera)	0.12 ± 0.02 c	0.21 ± 0.02 bc	0.12 ± 0.02 cd	0.11 ± 0.02 cde
Borer (Lepidoptera)	0.01 ± 0.00 f	0.00 ± 0.00 f	0.00 ± 0.00 f	0.00 ± 0.00 g
Bug (Hemiptera)	0.03 ± 0.01 ef	0.14 ± 0.02 de	0.08 ± 0.01 cdef	0.03 ± 0.01 efg
Butterfly (Lepidoptera)	0.00 ± 0.00 f	0.00 ± 0.00 f	0.02 ± 0.01 def	0.03 ± 0.01 fg
Crickets (Orthoptera)	0.00 ± 0.00 f	0.01 ± 0.01 f	0.02 ± 0.01 def	0.02 ± 0.01 fg
Damselfly (Odonata)	0.01 ± 0.00 f	0.00 ± 0.00 f	0.00 ± 0.00 f	0.00 ± 0.00 fg
Dragonfly (Odonata)	0.01 ± 0.00 f	0.02 ± 0.01 f	0.01 ± 0.00 f	0.01 ± 0.01 fg
Fall armyworm (Lepidoptera)	0.05 ± 0.01 def	0.30 ± 0.02 a	0.00 ± 0.00 f	0.00 ± 0.00 g
Fruit fly (Diptera)	0.00 ± 0.00 f	0.01 ± 0.00 f	0.02 ± 0.01 def	0.02 ± 0.01 fg
Grasshopper (Orthoptera)	0.02 ± 0.00 f	0.02 ± 0.00 f	0.02 ± 0.01 def	0.01 ± 0.00 fg
Green lacewing (Neuroptera)	0.00 ± 0.00 f	0.00 ± 0.00 f	0.01 ± 0.00 def	0.01 ± 0.00 fg
Hopper (Hemiptera)	0.04 ± 0.01 ef	0.16 ± 0.01 cd	0.04 ± 0.01 def	0.04 ± 0.01 defg
House fly (Diptera)	0.10 ± 0.01 cd	0.15 ± 0.01 cd	0.38 ± 0.03 a	0.30 ± 0.03 a
Jassid (Hemiptera)	0.08 ± 0.01 cde	0.09 ± 0.01 e	0.02 ± 0.01 def	0.01 ± 0.01 fg
Mosquito (Diptera)	0.00 ± 0.00 f	0.00 ± 0.00 f	0.04 ± 0.01 def	0.11 ± 0.02 cd
Moth (Lepidoptera)	0.00 ±0.00 f	0.02 ± 0.00 f	0.03 ± 0.01 def	0.02 ± 0.01 fg
Sepsid fly (Diptera)	0.01 ± 0.01 f	0.26 ± 0.02 ab	0.26 ± 0.04 b	0.08 ± 0.02 cdef
Shoot fly (Diptera)	0.25 ± 0.02 b	0.15 ± 0.01 cd	0.12 ± 0.02 cde	0.15 ± 0.03 bc
Spider (Araneae)	0.10 ± 0.01 cd	0.13 ± 0.02 de	0.17 ± 0.03 bc	0.13 ± 0.02 c
Wasp (Hymenoptera)	0.01 ± 0.00 f	0.01 ± 0.00 f	0.01 ± 0.00 ef	0.02 ± 0.01 fg
Weevil (Coleoptera)	0.00 ± 0.00 f	0.00 ± 0.00 f	0.00 ± 0.00 f	0.00 ± 0.00 g
Whitefly (Hemiptera)	0.48 ± 0.04 a	0.18 ± 0.02 cd	0.06 ± 0.01 def	0.04 ± 0.01 defg
F; df	91.3,24	70.2, 24	29.4, 24	25.9, 24
P	<0.001	<0.001	<0.001	<0.001

Table III. Damage scale of fall armyworm (Mean± SE) in different management options in months of 2022.

S. No	Management options	September	October	November	December
1	Ash + sand mixture	3.35 ± 0.10 a	4.73 ± 0.14 ab	4.73 ± 0.17 ab	4.86 ± 0.24 a
2	Synthetic pesticides	2.91 ± 0.08 b	3.24 ± 0.06 c	3.44 ± 0.18 c	3.38 ± 0.10 b
3	No application	3.14 ± 0.07 ab	5.27 ± 0.19 a	5.45 ± 0.19 a	5.38 ± 0.29 a
4	Eucalyptus based biopesticide	3.07 ± 0.08 ab	4.27 ± 0.15 b	4.52 ± 0.17 b	4.92 ± 0.23 a
5	Red Pepper + sand mixture	3.15 ± 0.11 ab	4.63 ± 0.12 b	4.96 ± 0.15 ab	5.16 ± 0.15 a
6	Neem leaves powder + sand mixture	3.13 ± 0.11 ab	4.32 ± 0.16 b	4.64 ± 0.17 b	4.68 ± 0.16 a
7	Turmeric powder + sand mixture	3.34 ± 0.09 a	4.79 ± 0.19 ab	4.79 ± 0.22 ab	4.96 ± 0.26 a
	F, df	2.6, 6	18.2, 6	12.3, 6	11.1, 6
	P	0.02	< 0.001	< 0.001	<0.001

Damage scale

A highly significant difference was observed in the mean damage scale among the months when data was recorded for the maize crop ($F = 172.8$, df = 3, $P < 0.001$). The damage scale was significantly lower in September 2022 and consistently increased in subsequent months (Fig. 3). For various management options for the maize crop, a highly significant difference was found in the average damage scale ($F = 34.3$, df = 6, $P < 0.001$) (Fig. 4). Table III shows the mean damage of fall armyworm in different treatment.

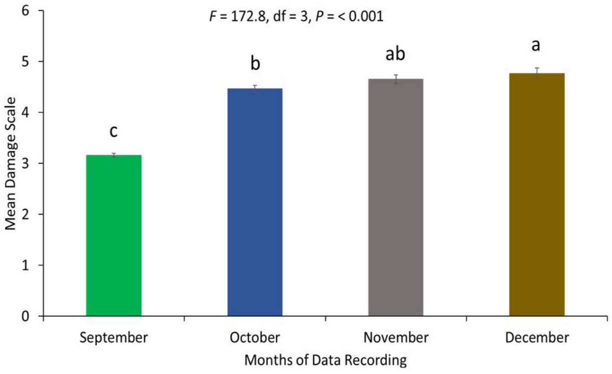

Fig. 3. Fall armyworm damage on maize leaves during different months.

Maize yield

In the yield data across various management options, a significant difference was observed among all the management techniques ($F = 19.7$, df = 6, $P < 0.001$). Significantly higher yields were achieved in the block where synthetic pesticides were applied. Overall, all management options exhibited significant differences (Fig. 5).

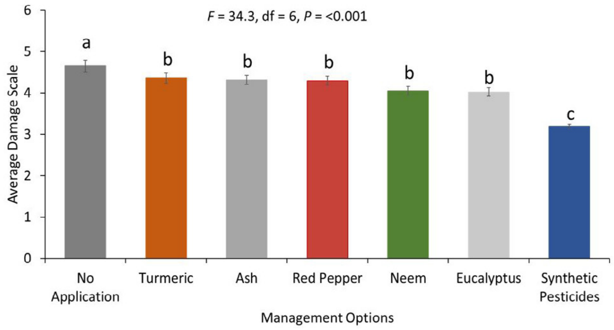

Fig. 4. Fall armyworm damage on maize leaves in different management options.

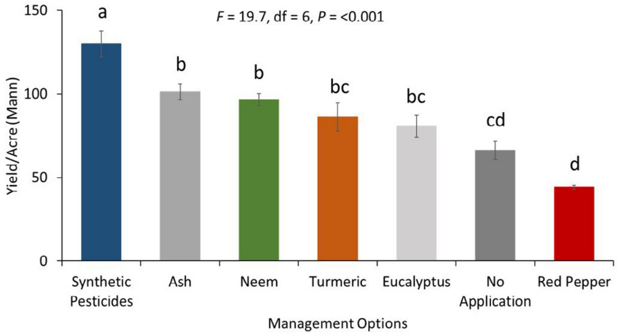

Fig. 5. Maize yield obtained in different management options.

DISCUSSION

Our study revealed the diversity of arthropod groups, fall armyworm damage, and maize yield in the biorational and chemical management of maize. Lower arthropod abundance was recorded in maize managed using the series of synthetic insecticide applications, aligning with previous findings that chemical management practices can negatively impact arthropod populations (Ghosal and Hati, 2019). The use of chemical inputs such as pesticides, fertilizers, and herbicides had a negative impact on hymenopterans, especially ants, resulting in lower predator abundance in maize crops (Del-Val *et al*., 2021). Unplanned and repeated application of same chemical might lead to pest resistance, increased insect pests in the crop, and other non-target effects (Arnes *et al*., 2013; Leon-Garca *et al*., 2012). Previous studies have shown that organic farming supports arthropod diversity and abundance in the field (Batary *et al*., 2011; Bengtsson *et al*., 2005; Chaplin-Kramer *et al*., 2011). Similarly, in our study, arthropod abundance was lower in pesticide treated maize as compared to the maize with biorational management.

Fall armyworm damage scale was higher in the biorational treatments. Evidence suggest that fall armyworm infestation could cause 20-50% yield losses in maize if no pesticides have been used (Prasanna *et al*., 2018). In another study, Montezano *et al*. (2018) reported that plants managed through chemical strategies experienced significantly lower levels of fall armyworm damage, reducing yield losses by 10%. Chemically managed plants incurred lower economic losses compared to non-chemically managed plants. Farmers using chemical strategies regained their investment through increased maize yield, while farmers practicing non-chemical management faced economic losses due to increased expenses on pest control strategies (Setamou *et al*., 2019; Kumar *et al*., 2019).

Maize yield in chemical management was higher compared to biorational treatments and control. Chemical pesticides plays an important role in pest management, consequently increasing the yield of maize crop (El-Naggar *et al*., 2020). A previous study highlighted the effectiveness of synthetic chemicals in controlling pests and weeds, reducing competition for nutrients and enabling maize plants to maximize their growth potential and yield (Lagogianni and Tsitsigiannis, 2019; Gressel, 2002). Using chemicals like cyantraniliprole and chlorantraniliprole as seed treatments reduced the need for chemical sprays against fall armyworm, resulting in lower production costs and greater economic maize yield (Thrash et al., 2013). According to the results of the current study, organic maize production is achievable with about ~20% decrease in yield compared to inorganic maize production. Synthetic maize production yields higher results by using high-yielding cultivars and synthetic inputs, while the organic system has the potential to achieve competitive yields through proper management (Duvick, 2005; Seufert *et al*., 2012).

Future studies could assess the broader impacts of biorational treatments on beneficial fauna. Additionally, organic maize farmers are encouraged to consider biorational approaches for fall armyworm management. Subsequent research should concentrate on identifying native biological control agents against fall armyworm in maize crops at the species level and developing strategies to protect local fauna by reducing pesticide usage. The potential of microbial strains, including fungal and bacterial insecticides like *Metarhizium* spp. and *Bacillus thuringiensis* (Bt), should be explored for biorational fall armyworm management in maize crops. These strategies could help in designing a tailored IPM plan for organic maize growers.

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Statement of conflict of interest

The authors have declared no conflict of interest.

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