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IMPACT OF MAIZE-LEGUME INTERCROPS FOR THE MANAGEMENT OF FALL ARMYWORM, *Spodoptera frugiperda* J. E. SMITH (LEPIDOPTERA; NOCTUIDAE) IN CHITWAN, NEPAL

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ABSTRACT

Fall armyworm (Spodoptera frugiperda J. E. Smith, 1797) is an invasive, polyphagous, voracious, and destructive pest that threatens maize production globally, including in Nepal. This study aimed to evaluate suitable maize intercropping systems and assess their impact on fall armyworm damage, the abundance of natural enemies, and maize grain yield. Field experiments were conducted in 2022 on spring maize in Chitwan, Nepal. The study employed a Randomized Complete Block Design (RCBD) with six treatments, each replicated four times. The treatments included maize intercropped with rajma bean (Phaseolus vulgaris L.), mungbean (Vigna radiata L.), cowpea (Vigna unguiculata L.), soybean (Glycine max L.), and black gram (Vigna mungo L.), along with a maize monoculture as the control. Data on fall armyworm damage were collected at 10-day intervals starting from 21 days after maize sowing. Visual observations were made to count the total number of crop stands, infected plants, live larvae, and the number of predators and parasitoids. The results showed that maize-soybean intercropping had the lowest fall armyworm infestation on maize, followed by maize with black gram and maize with mungbean. In contrast, mono-cropped maize had the highest percentage of plant infestation. The abundance of beneficial insects was higher in legume-intercropped maize fields. Additionally, among the intercropping combinations, the yield of maize-mungbean intercropped was higher (8.09 mt/ha) than that of mono-cropped maize (6.24 mt/ha). Therefore, intercropping with legumes could be an effective and sustainable management strategy to control fall armyworm, increase beneficial arthropod diversity, and boost maize yield.

Keywords:

Maize, Fall armyworm, Beneficial insect, Insecticides, Legume intercrops

INTRODUCTION

In Nepal, maize (*Zea mays* L.) is the second most important crop among cereals in terms of area (9,85,565 ha) and production (31,06,397 mt), with a productivity of 3.15 mt/ha, following rice, which occupies almost 29% of the total area and accounts for 27% of the total production of cereal crops in 2022/23 (MoALD, 2023). Since the pest invasion was reported in 2019, maize farmers in Nepal have faced high levels of fall armyworm (*Spodoptera frugiperda* J.

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E. Smith) damage, resulting in an estimated yield loss of approximately 25-35% (GC et al., 2019; PQPMC, 2019). Chemical insecticides have been widely used to control fall armyworm (Yang et al., 2021). Excessive use of these chemicals leads to the development of insecticide resistance (Fatoretto et al., 2017), pest resurgence, toxicity to natural enemies (Desneux et al., 2007), and environmental and human health hazards (Tambo et al., 2020). Consequently, cost-effective, environmentally friendly, and sustainable management approaches are essential to controlling the fall armyworm infestations in maize. Under these circumstances, intercropping has been proposed as one of the alternative methods to reduce fall armyworm infestations and is a key component of integrated pest management (IPM) strategies.

Intercropping cereal with legumes is recognized as the most popular agricultural practice in many developing countries (Songa et al., 2007; Kiwia et al., 2019). Maize intercropped with other edible legumes, when integrated with various sustainable management techniques, is an effective strategy for managing *S. frugiperda* (Hailu et al., 2018). This is because certain crop combinations and their arrangements can disrupt pests' host location, serving as repellents or deterrents. Intercropping operates as both a push and pull system, where plants release semio-chemicals that may either attract or repel pests away from the main crop (Khan et al., 2010). The study suggests that intercropping cereals with legumes can maintain maize productivity while enhancing the population of beneficial insects, such as parasitoids, predators, and pollinators, compared to a maize monocropping system. The findings of this research could aid in identifying the most effective intercropping options for pest management and stable yield.

MATERIALS AND METHODS

The experiment was conducted on spring maize (crop variety: Rampur Composite) from March to June 2022 in Rampur, Chitwan, Nepal. The experimental field was located in the inner Terai region (27.6504070 N latitude and 84.3501430 E longitude, at an elevation of 228 meters above sea level), characterized by a humid and subtropical climate, which is ideal for maize cultivation. The experimental design was laid out in a Randomized Complete Block Design (RCBD) with six treatments, including maize sole cropping as a control, replicated four times. The potential intercrops tested are listed in Table 1. To ensure proper establishment, legume crops were sown 15 to 20 days before maize planting. Each plot for each treatment measured 4 m × 3 m and included four rows of maize and three rows of legumes. After the establishment of the legume crops, maize was sown at a spacing of 75 cm × 20 cm. The intercrops were sown between the maize rows, with maize and intercrops planted alternately. All agronomic practices, including fertilization, irrigation, and pest management, adhered to the guidelines set forth by the National Maize Research Program (NMRP) in Rampur, Chitwan, Nepal, ensuring consistency and standardization across treatments.

Table 1: Potential maize legume intercropping as a treatment

S. N.	Treatments (Intercropping)	Legume Plant- Plant space	Scientific Name of Legume Crops	Maize: Legume ratio	Another name for a legume	Legume variety
1	Maize + Rajma bean	15 cm	*Phaseolus vulgaris* L.	1:1	Kidney bean	PDR-14
2	Maize + Mung bean	10 cm	*Vigna radiata* L.	1:1	Green gram, green bean, moong	Pratikshya
3	Maize + Cowpea	15 cm	*Vigna unguiculata* L.	1:1	Black-eye pea, crowder pea	Surya
4	Maize + Soyabean	15 cm	*Glycine max* L.	1:1	Golden bean	Puja
5	Maize + Black gram	10 cm	*Vigna mungo* L.	1:1	Urad bean, mash bean	Khajura Mas- 1
6	Sole crop (Maize only)	-	-	-	-	

The total number of crop stands, infected plants, live larvae, predators and parasitoids was counted from the middle two rows of maize. Predators and parasitoids were counted through visual observation, while soil-dwelling carabids were sampled using pitfall traps (Morris, 1960; Mills, 2005; Kogan and Herzog, 2012). Simple plastic cups were used as traps, placed at ground level and half-filled with water. Data were collected at 10-day intervals, starting 21 days after the maize was sown. The percentage of plant infestation by fall armyworm was calculated using the following formula:

Statistical analysis

The collected data were tabulated and maintained in an Excel spreadsheet. The data on the percentage of plant infestation and the number of fall armyworm larvae underwent a square-root transformation to meet the normality assumption. Data analysis was performed using Analysis of Variance (ANOVA) in R-Studio version 4.1.3. Multiple comparisons among the treatments were conducted using the LSD at 5% and 1% significance levels (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Effects of intercropping on fall armyworm infestation and crop damage

The percentage of plant infestation caused by fall armyworm larvae varied significantly ($p<0.05$) among the tested treatments. Based on the damage symptoms observed on the whorl and the upper four leaves, maize-legume intercropping consistently showed better performance compared to sole maize cropping. In regions such as Africa and the Americas, intercropping maize with legumes like common beans, groundnuts, cowpeas, and lima beans is a traditional practice. This method has gained popularity in modern agroecological farming systems (Pierre et al., 2021; Pierre et al., 2022). Cereal-legume intercropping has reduced specialist pests while providing additional resources for arthropod predators, such as shelter and food (Norris et al., 2018).

Non-significant results were observed when data were collected at 21 days after maize sowing. However, the data collected at 31 days after sowing revealed significant differences among the tested intercrops. Maize intercropped with soybean exhibited the lowest percentage of plant infestation (3.66%), followed by maize intercropped with cowpea (4.03%), mung bean (4.15%), and black gram, which were statistically similar to one another. Higher plant infestation was observed in maize grown alone, with an average infestation of 5.46%. This was followed by maize intercropped with rajma bean, which had a mean plant infestation of 4.68% (Table 2).

Lower infestation levels on maize intercropped with cowpea and beans could be due to natural enemies, as leguminous plants attract predators and parasitoids that may enhance the effectiveness of biological control agents, thereby reducing the pest population, as demonstrated by Hailu et al. (2018), Udayakumar et al. (2021) and Keerthi et al. (2023). Similar results were observed by Kumar et al. (2014) and Reddy et al. (2019), who found that intercropping maize with legumes such as cowpea, soybean, red gram, and green gram enhances the population growth of natural enemies of the fall armyworm, thereby reducing its effectiveness. In Uganda, the damage caused by fall armyworms was significantly reduced when maize was intercropped with legumes, such as *Phaseolus vulgaris* L., *Glycine max* L., and *Vigna unguiculata* L., reported by Hailu et al. (2018).

Observation of *S. frugiperda* at 41 days after sowing revealed significant differences among the intercropping treatments ($F = 33.79$, $p < 0.001$). The lowest crop damage percentage was recorded in maize intercropped with soybean (3.70%) and maize intercropped with mung bean (3.75%), which were statistically similar to maize intercropped with black gram (4.02%) and maize intercropped with cowpea (4.07%). In contrast, the highest plant infestation percentage (5.76%) was observed in maize sole cropping, followed by maize intercropped with rajma bean at 4.27%, with this difference being statistically significant.

The data recorded at 51 days after sowing revealed significant differences among the treatments, with plant infestation percentages ranging from 3.62% to 5.80%. Maize intercropped with soybean showed the lowest infestation (3.62%), providing the most effective protection against *Spodoptera frugiperda*, followed by maize intercropped with black gram (3.84%), which was statistically similar. Maize intercropped with mung bean (4.11%) and cowpea (4.19%) also demonstrated relatively lower infestation levels. In contrast, sole maize cropping exhibited the highest infestation percentage (5.80%), followed by maize intercropped with rajma bean (4.40%). These findings are consistent with previous studies by Hailu et al. (2018), as well as Udayakumar et al. (2021) and Guo et al. (2022).

The observations made at 61 days after sowing indicated that the percentage of plant infestation varied significantly among the plots, ranging from 3.32% to 5.80%. The combination of maize intercropped with soybean showed the lowest percentage of plant infestation (3.32%). This was followed by maize intercropped with mung bean (3.74%), which was statistically similar to maize intercropped with black gram (3.81%) and maize intercropped with cowpea

(4.03%), respectively. A higher percentage of plant infestation (5.80%) was observed in maize sole cropping, statistically similar to maize with rajma bean (4.15%). The percentage of plant infestation and the severity of fall armyworm were greater during the early growth stage of maize, declining as the plants matured across the different treatments. Hailu et al. (2018) noted that intercropping maize with leguminous crops significantly reduced the presence of stem borers and fall armyworm compared to mono-cropped maize, particularly in the early growth stages leading up to tasselling. Tanyi et al. (2020) stated that maize intercropped with beans was better protected from *S. frugiperda* infestation compared to a sole maize monocrop; this finding was similar to the results of this study. The maize intercropped with beans experienced less infestation compared to mono-crop maize because the green leaves of the bean emit green leaf volatiles that may repel *S. frugiperda*, thereby reducing infestation in the maize plants.

Table 2: Plant infestation percentage on maize legume intercropping by fall armyworm larvae in Chitwan, Nepal, 2022

Intercropping	Plant infestation (%)				
	21 DAS	31 DAS	41 DAS	51 DAS	61DAS
Maize + Rajma bean	5.12 (26.34)	4.68 (21.88)[b]	4.27 (18.21)[b]	4.40 (19.41)[b]	4.15 (17.35)[b]
Maize + Mung bean	5.09 (25.96)	4.15 (17.28)[c]	3.75 (14.10)[c]	4.11 (16.96)[bc]	3.74 (14.03)[c]
Maize + Cowpea	4.74 (22.62)	4.03 (16.26)[c]	4.07 (16.60)[bc]	4.19 (17.64)[bc]	4.03 (16.28)[bc]
Maize + Soybean	4.83 (23.57)	3.66 (13.45)[d]	3.70 (13.74)[c]	3.62 (13.11)[d]	3.32 (11.08)[d]
Maize + Blackgram	5.02 (25.69)	4.21 (17.72)[c]	4.02 (16.26)[bc]	3.84 (14.83)[cd]	3.81 (14.74)[bc]
Maize (sole)	4.94 (24.82)	5.46 (29.88)[a]	5.76 (33.23)[a]	5.80 (33.70)[a]	5.80 (33.71)[a]
Grand mean	4.96	4.37	4.26	4.33	4.14
SEm	0.06	0.26	0.31	0.32	0.35
LSD	0.92	0.27	0.40	0.39	0.37
CV %	12.30	4.03	6.17	6.01	5.91
p-value	ns	***	***	***	***
F-value	0.24	51.00	33.79	35.24	49.49

CV: Coefficient of Variation; LSD: Least Significant Difference; SEm: Standard Error of Mean; ***: Significance at < 0.1% (p<0.001); ns: Non-significance; DAS: Day After Sowing; Mean values in columns separated by the same letters are not statistically different by LSD at P≤ 0.05; figure in parenthesis indicate original values and figure outside parenthesis indicate the square root transformed values.

Effects of intercropping on fall armyworm larval density, beneficial insect abundance, and maize yield

The analysis of variance for fall armyworm larval counts at 61 days after sowing revealed a highly significant difference among the tested intercropping treatments ($p < 0.001$), with an overall mean of 1.41 ± 0.22 larvae per plant. The lowest larval population was observed in the maize intercropped with soybean (0.97 larvae), followed by maize intercropped with cowpea (1.18), maize intercropped with mung bean (1.18), maize intercropped with black gram (1.22), and maize intercropped with rajma bean (1.40), which were statistically at par with each others. Liu et al. (1988) reported that volatile compounds, namely tetradecene and dodecene, emitted by resistant soybean leaves, were the primary components responsible for repelling insect pests. The olfactory response tests showed that soybeans had a strong deterrent effect against fall armyworm adults. Soybean and groundnuts likely emitted semiochemicals that repelled the fall armyworm from maize, as reported by Kusi et al (2024) and Tao et al (2024). In contrast, sole cropping of maize resulted in a higher mean larval population of 2.48. This pattern aligns with the findings of Udayakumar et al (2021). Their study found that the number of fall armyworm larvae decreased when maize was intercropped with soybean, and no significant differences were noted in pest population reduction among the other tested legumes. According to Wink et al (2004), allelochemicals in leguminous crops can reduce pests' oviposition. These legumes contain quinolizidine alkaloids, which have allelopathic effects on fall armyworms in maize fields. Additionally, green leaf volatiles released by companion legume crops help repel fall armyworm larvae from maize plants. Root exudates from beans may also contain novel flavonoid compounds that interfere with the pupation phase of the fall armyworm life cycle in the soil, thereby disrupting the pest's ecological development (Chamberlain et al., 2006; Khan et al., 2010).

During the study period, 26 different predator species and 11 parasitoid species were recorded in the maize experimental field. Among the top beneficial insects, the black ant (2231), ladybird beetle (1185), spider (615), pirate bug (95), parasitic wasp (51), and carabids (23) were observed in the highest numbers. Matova et al (2020) suggest that intercropping generally creates a protective microclimate that enhances the diversity and abundance of beneficial insects. Maize intercropped with soybean showed a higher number of parasitoids compared to other combinations. Research by Andow (1991); Amala and Shivalingaswamy (2018) highlights the role of intercrops in increasing the abundance and diversity of natural enemies, as well as in reducing the population of phytophagous insects. Many researchers reported that legume crops, such as cowpea flowers, provide pollen, nectar, and shelter to natural enemies, encouraging their growth in maize intercropping systems (Dannon et al., 2010; Day et al., 2017; Mudare et al., 2022). Research has shown that natural enemies can detect olfactory cues from intercrops and border crops (Hoballah et al., 2002), which enhances natural parasitism and predation of *S. frugiperda*.

There were significant differences in maize grain yield between maize-legume intercropping and sole maize cropping. The results indicated that intercropping alone can lead to higher yields. These findings are consistent with previous studies by Assefa and Ayalew (2019), Hruska and Gould (1997), and Nboyine et al (2022). The highest grain yield was recorded in the maize intercropped with the mungbean (8.09 mt/ha), followed by maize intercropped with soybean (7.91 mt/ha), likely due to reduced larval incidence and a higher abundance of beneficial insects. However, no differences in maize grain yield were observed among the various legume intercropping combinations. In contrast, the lowest yield occurred in sole maize cropping (6.24 mt/ha) (Figure 1). Intercropping is typically cultivated to maximize the use of space that the main crop does not fully utilize during its early growth stages. Depending on the species and spatial arrangement of the component crops, intercropping can either decrease or increase the yield of the main crop (Ananthi et al., 2017).

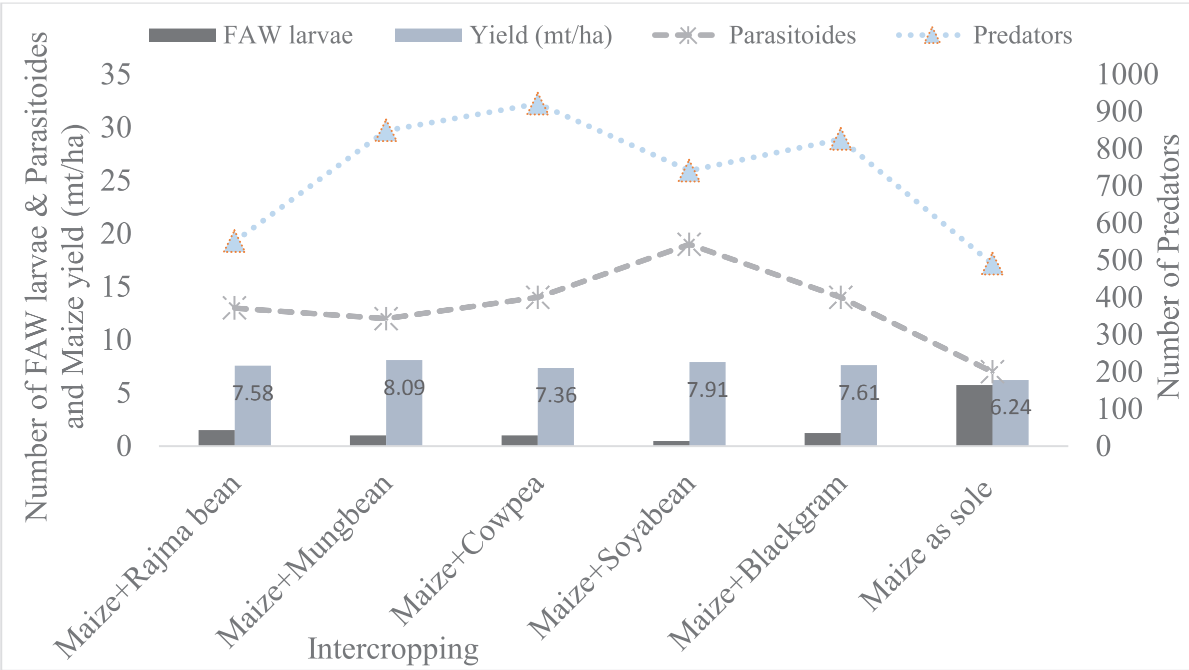

Figure 1: Number of fall armyworm live larvae, predators & parasitoids, and maize grain yield (mt/ha) across the different maize-legume intercropping systems

CONCLUSION

This study revealed that intercropping maize with legumes, particularly pulses like soybean, black gram, mung bean, cowpea, and kidney bean (rajma), significantly reduced the incidence and damage caused by fall armyworm while improving maize yields compared to sole maize cropping. Furthermore, intercropping reduces reliance on synthetic insecticides, provides additional income from legumes, and holds significant potential to enhance the livelihoods of smallholder maize farmers. The maize-legume intercropping system also positively impacts the presence of natural enemies within the crop ecosystem. Overall, it offers a sustainable solution easily adopted by smallholder farmers in Nepal and beyond. However, further research is needed to validate the effectiveness of legume intercropping in managing fall armyworm under diverse agroecological conditions.

DECLARATION

The authors declare no conflict of interests.

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