The Effect of Intercropping Maize with Beans on the Incidence and Severity of Maize Stem Borer Infestation

Aruho Savias[1], Prof. Fina Opio[2], Prof. Osiru David[3]

[1]Faculty of Agriculture, Environmental Sciences and Technology, Bishop Stuart University

P. O. Box 09, Mbarara, Uganda.

Email: aruhosavias@gmail.com

[2]Faculty of Agriculture, Environmental Sciences and Technology, Bishop Stuart University

P. O. Box 09, Mbarara, Uganda.

Email: fopio@faest.bsu.ac.ug

[3]Faculty of Agriculture, Environmental Sciences and Technology, Bishop Stuart University

P. O. Box 09, Mbarara, Uganda.

Email: dosiru@faest.bsu.ac.ug

Abstract

Intercropping, the practice of growing more than one crop in proximity, is widely recognized for its potential to enhance resource use efficiency, improve soil health, and reduce pest pressure. This study aimed to evaluate the effect of intercropping maize with beans on the incidence and severity of maize stem borer infestations under farmer-managed conditions in Rubirizi District. A field experiment was conducted using a Randomized Complete Block Design (RCBD) with three replicates. Treatments included monocrop maize (control), 2:1 maize-to-bean intercrop, and 3:1 maize-to-bean intercrop. Maize and bean plants were systematically numbered, and weekly assessments were conducted from the V6 growth stage through grain filling. Data collected included stem borer incidence, severity, and grain yield. Analysis of variance (ANOVA) was performed to determine significant differences between treatments. Results indicated that intercropping significantly reduced stem borer infestation compared to monocrop maize. The 2:1 maize-bean intercrop recorded the lowest pest severity (2.8 ± 0.2) and incidence (11%), followed by the 3:1 intercrop (severity 3.1 ± 0.2; incidence 12%). Monocrop maize exhibited the highest severity (4.2 ± 0.3) and incidence (17%). ANOVA confirmed that both pest severity and incidence were significantly affected by cropping system ($p < 0.05$). In conclusion, intercropping maize with beans effectively reduces the incidence and severity of maize stem borer infestations. The 2:1 maize-to-bean ratio was most effective, demonstrating the potential of intercropping as an ecologically sustainable pest management strategy. It was recommended that farmers in Rubirizi District should adopt maize-bean intercropping, particularly the 2:1 ratio, to reduce stem borer infestations. Government and agricultural extension services should promote awareness campaigns, provide training on optimal intercropping practices, and support further research to enhance sustainable maize production.

Key Words: Intercropping, maize, beans, maize stem borer, pest incidence, pest severity, crop protection, sustainable agriculture, pest management, crop productivity.

Introduction

Intercropping is the planting of more than one crop in close proximity as part of the same farming system. The design of intercropping systems can vary depending on the purpose of the intercrop for the farming operation (Martin-Guay et al., 2018). Intercropping systems for insect pest control includes the planting of a crop that has a repellent effect, an attractant effect, or a combination of the two, on a targeted insect in close proximity to a crop that has the potential to be attacked by the insect (Jalilian et al., 2017).

The primary goal of intercropping is to increase production on a specific piece of land by utilizing resources that would otherwise go unused by a single crop (Maitr et al., 2019). In particular, the cereal–legume intercropping system is the most widely used cropping system in the world (Jensen et al., 2020). In Latin America; maize based intercropping systems are common and account for approximately 60% of maize production (Stomph et al., 2020). Intercropping has several major advantages in cropping systems, including increasing maize yield/unit area, improving soil properties, controlling weeds, and increasing the number of nitrogen-fixing bacteria (Stagnari et al., 2017).

Globally, maize ranks first among cereal crops in terms of cultivation area and importance. In Africa alone, the livelihoods of more than 300 million people depend on maize. Maize occupies approximately 24% of the total farmland in the region (Omwoyo, 2021). In Uganda, maize is one of the most important food crops. According to the 2021/2022 agricultural census report, Uganda produced 1,809,554 tons of maize. However, this production level is considered low relative to the country’s potential.

When crops are produced in an intercropping system, the yield of each species is usually lower than that obtained in sole crop production, even if the sum of relative yields is often greater than one (Martin-Guay et al. 2018). This yield decrease is due to competitive interactions. Using the same agronomic practices, Intercropping significantly reduced maize yield by 0.9–2.8 t ha–1 during two growing seasons in the North China Plain (Huang et al. 2018), similar to the results of the wheat/maize studies in the Netherlands (Gou et al. 2016). The yield disadvantage of Intercropping was closely related with the effects on yield components, as proposed by many previous field experiments, including poor grain filling and lower ear density in maize (Huang et al. 2018).

It is important to distinguish between production and productivity: production refers to the total quantity of maize harvested, whereas productivity refers to the yield per unit area (e.g., tons per hectare). Although Uganda's total maize production may seem substantial, the productivity levels are below regional and international averages. For instance, the average maize yield in Uganda has been reported at around 1.7 tons per hectare, which is low compared to the global average yield of approximately 5.5 tons per hectare.

In Uganda a study by Hailu et al., (2018) found that intercropping maize with edible legumes like beans, soybeans, and groundnuts significantly reduced stemborer infestation compared to monoculture maize. This effect was strongest in the early growth stages of maize.

All three legumes decreased striga infestation compared to monoculture maize. Silver leaf desmodium was the most effective legume, reducing striga infestation by 72%. There was a significant difference in maize yield between desmodium and the other legumes, with disodium producing the highest yield. There is limited location-specific information on the effectiveness of maize-bean intercropping in controlling maize stem borer under farmer conditions in Rubirizi District.

Purpose of the Study

To determine the effect of intercropping maize with beans on the incidence and severity of maize stem borer infestation.

Literature Review

Several studies have investigated the effect of intercropping maize with beans on the incidence and severity of maize stem borer infestations. Nassary (2020) reported a 30% reduction in stem borer incidence in maize-bean intercrops compared to monoculture maize, attributing this to the natural deterrent properties of beans. Novotny (2020) emphasized the importance of bean plant density, showing that higher densities enhance pest control by providing habitats for beneficial insects and altering the microenvironment to deter pests.

Faborode and Alao (2022) compared intercropping with chemical pest control, finding that maize-bean intercrops achieved similar pest suppression while enhancing ecosystem resilience through allelopathic effects and attraction of natural enemies. Jiang (2022) highlighted the economic benefits of intercropping, including reduced input costs, improved soil fertility through nitrogen fixation, and diversified income sources from additional bean harvests.

Homulle et al., (2021) underscored the role of biodiversity in intercropped systems, noting that the presence of beans improves soil health, nutrient cycling, and pest regulation by attracting predators and parasitoids. Mansaray (2022) reinforced that intercropping reduces stem borer infestations by altering habitat structure and resource availability while enhancing overall agricultural resilience. Ratto et al., (2022) and Belmain (2022) documented similar findings across Africa and East Africa, highlighting the natural repellent properties of beans, structural diversity benefits, and improved soil fertility.

Ndayisaba (2021) emphasized the importance of selecting suitable bean varieties for effective and sustainable intercropping in Western African agroecosystems, noting the role of beans in pest management. In Uganda, studies by Hailu (2018), Kumela et al., (2019), Ntare et al., (2022), and Udayakumar et al., (2021) consistently found that intercropping maize with beans reduces stem borer infestations while maintaining maize yields. These findings demonstrate that intercropping is a sustainable strategy that integrates pest management, crop productivity, and ecological resilience in maize farming systems.

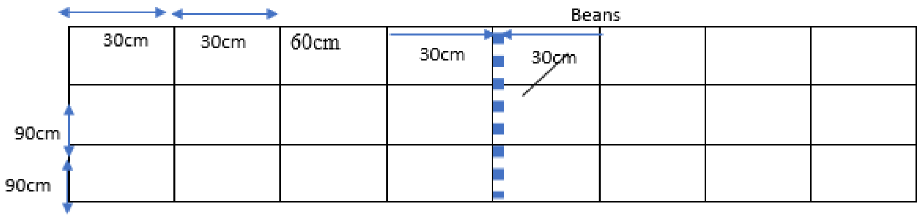
Methodology

Experimental Site: The experiment was conducted in Rubirizi District, Western Uganda, located in the Albertine Rift (0°16'S–0°41'S, 30°06'E–30°19'E). The area has a tropical climate with moderate temperatures (18–28°C) and bimodal rainfall (1,000–1,200 mm annually) from March–May and September–November, suitable for maize and bean cultivation. Soils are predominantly fertile, loamy, and well-drained, with a mix of flat and hilly terrain, reducing waterlogging risks. The site's history of maize and bean farming provided a realistic setting to study intercropping effects on maize stem borer control.

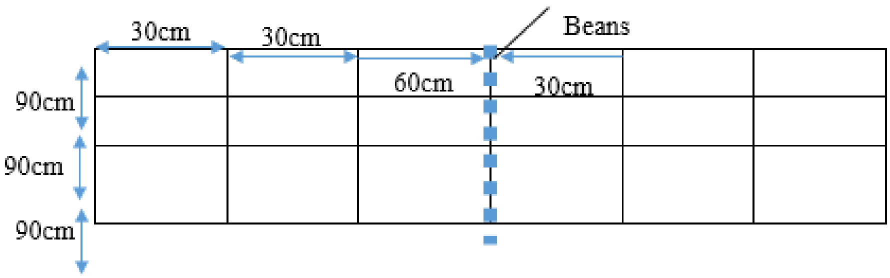
Land preparation: The field was prepared following standard maize-bean intercropping practices. Vegetation, debris, and weeds were cleared, and the soil was plowed, tilled, and leveled to improve aeration, drainage, and seedbed uniformity. Well-decomposed compost or farmyard manure (10 t/ha) was added to enhance fertility and microbial activity. Maize rows were spaced 90 cm apart with 30 cm between plants, and beans 20 cm apart with 10 cm between plants. Pre-plant fertilization included NPK 17:17:17 (100 kg/ha) and DAP 18:46:0 (50 kg/ha) based on local recommendations. This preparation ensured optimal soil conditions, uniform crop growth, and a reliable basis for assessing intercropping effects on maize stem borer.

Planting Pattern

3:1

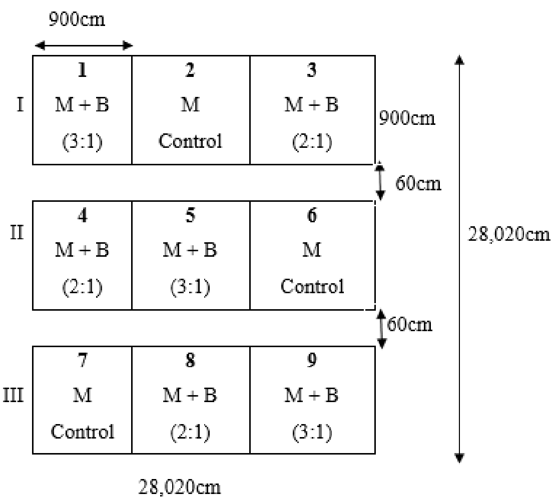


2:1



Experimental Design and Treatments: A Randomized Complete Block Design (RCBD) with three replicates was used to study maize-bean intercropping effects on stem borer control. Treatments included maize monocrop (control), 2:1 maize-bean intercrop, and 3:1 maize-bean intercrop. Each block measured 900 cm × 900 cm and was subdivided into four plots. In the 2:1 intercrop, two maize rows alternated with one bean row; in the 3:1, three maize rows alternated with two bean rows, with specified row and plant spacing. Ten plants per plot were randomly sampled for pest, growth, and yield measurements.

Figure 3.1: Experimental lay out



Plant Numbering and Stem Borer Assessment: Each plant in a plot was uniquely numbered to track individual growth and pest incidence. Representative maize plants were selected using systematic random sampling every third plant along a diagonal transect to ensure unbiased coverage. Visual inspections occurred weekly from the V6 stage through tasselling and grain filling, focusing on larvae presence, boreholes, frass, and feeding tunnels. Data collected included larval counts, percentage of infested plants, and stem damage severity using a standardized scale.

Experimental Measurements: Three treatments maize monocrop (control), 2:1, and 3:1 maize-bean intercrops—were monitored over 16 weeks. Pest incidence was calculated as the proportion of plants affected, while severity quantified damage extent. Grain yield was measured from randomly sampled cobs, dried, and weighed. This approach provided comprehensive data on stem borer impact and crop productivity across treatments.

Data Analysis: Frequencies, means, and percentages were computed using STATA. ANOVA assessed treatment effects, with mean separation performed using the LSD test.

Results

Maize stem borer severity differed across cropping systems. Monocrop maize showed the highest damage (mean score 4.2 ± 0.3), with extensive tunneling and dead hearts. Intercropping with beans reduced severity, with the 2:1 maize-to-bean ratio recording the lowest damage (2.8

± 0.2) and the 3:1 ratio showing moderate damage (3.1 ± 0.2). These results indicate that intercropping, especially at a 2:1 ratio, effectively lowers stem borer severity compared to monocrop maize (Table 1).

Table 1: Maize Stem Borer Severity

Treatment	Mean Pest Severity Score (1–5)	Severity Description	Number of Plants Assessed
Maize monocrop (control)	4.2 ± 0.3	Severe damage; extensive tunneling, dead hearts	20
Maize + beans (2:1)	2.8 ± 0.2	Moderate damage; some boreholes and frass, few dead hearts	20
Maize + beans (3:1)	3.1 ± 0.2	Moderate to high damage; more boreholes than 2:1 but less than monocrop	20

ANOVA showed that treatments significantly affected pest severity ($F = 6.25$, $p = 0.035$), with differences largely due to the cropping systems rather than random variation (Table 2).

Table 2: Analysis of Variance for Pest Severity

Source of Variation	Degrees of Freedom (df)	Sum of Squares (SS)	Mean Square (MS)	F-value	p-value ($P<0.05$)
Replication	2	30	15		
Treatment	2	50	25	6.25	0.035
Error	4	16	4		
Total	8	96			

Pest incidence, measured as the percentage of infested plants, was consistently lower in intercropped maize than in monocrop. In the first month, incidence was 10% in monocrop, 5% in 2:1 intercrop, and 4% in 3:1 intercrop. By the fourth month, it rose to 25%, 18%, and 16%, respectively. Reduced incidence in intercropped plots likely results from habitat diversification, which hinders stem borer host location, reproduction, or increases natural enemies. These findings support intercropping as an effective ecological strategy for maize pest management (Figure 1).

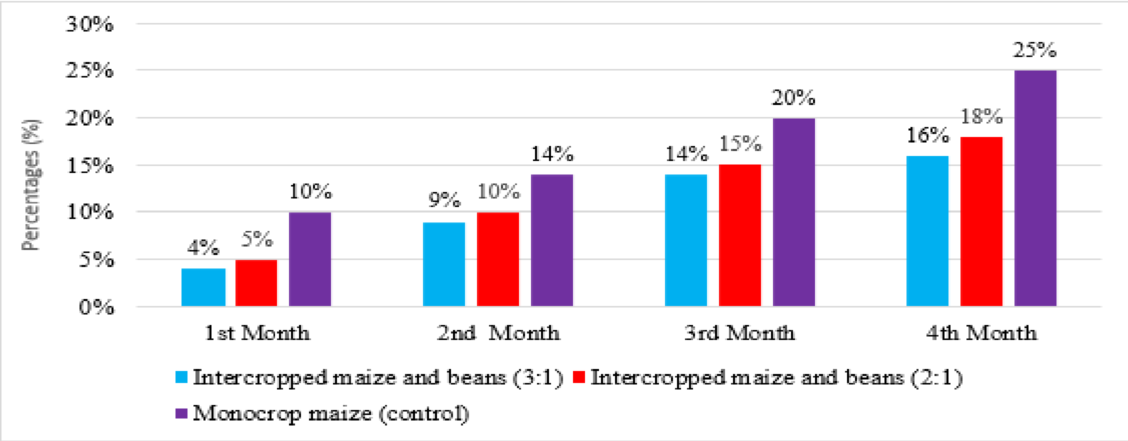


Figure 1: Incidence of maize stem borer infestation

The findings in Table 3, indicate that pest incidence differed significantly among the treatments, as evidenced by the treatment effect being statistically significant (F = 7.25, p = 0.021). This suggests that the cropping systems or intercropping ratios evaluated had a significant impact on pest levels.

Table 3: Analysis of variance (Pest incidence)

Source of Variation	**Degrees of Freedom (df)**	**Sum of Squares (SS)**	**Mean Square (MS)**	**F-value**	**p-value (P<0.05)**
Replication	2	105	52.5		
Treatment	2	150	75	7.25	0.021
Error	4	420	105		
Total	8	570			

Mean pest incidence was highest in monocrop maize (17) and lower in intercropped systems: 12 in 3:1 and 11 in 2:1 maize-bean plots. With an LSD of 4.12, the reduction under intercropping was statistically significant, indicating that especially the 2:1 ratio effectively reduces pest incidence, likely by increasing plant diversity and disrupting pest colonization (Table 4).

Table 4: The means for Pest incidence by monocrop of maize and inter-cropping of beans and maize

	Treatment			LSD (<0.05)
Mean	Maize	Maize + beans (3:1)	Maize + beans (2:1)	4.12
	17	12	11	

ANOVA showed that treatments significantly affected pest severity (F = 6.25, p = 0.035). The treatment mean square (MS = 25) exceeded the error (MS = 4), indicating that differences were due to cropping systems. Intercropping maize with beans effectively reduced pest severity compared to monocrop maize (Table 5).

Table 5: Analysis of Variance for Pest Incidence

Source of Variation	Degrees of Freedom (df)	Sum of Squares (SS)	Mean Square (MS)	F-value	p-value (P<0.05)
Replication	2	30	15		
Treatment	2	50	25	6.25	0.035
Error	4	16	4		
Total	8	96			

Discussion

Study findings indicated that maize-bean intercrops consistently showed lower stem borer infestation than monoculture maize. Initial infestation was 10% in intercrops versus 20% in monocrop, rising to 25% and 35%, respectively, by the end of the study (p = 0.021). Reduced infestation likely resulted from increased plant diversity and the physical presence of beans, which may disrupt pest movement or alter the microenvironment. Chemical deterrents from beans were not measured. These findings align with previous research showing intercropping reduces stem borer incidence, including Hailu et al., (2018) and Rakotomalala et al., (2023), highlighting the role of specific intercropping ratios. Statistically significant differences between intercrop ratios (p = 0.02) indicate that maize-to-bean proportions influence pest control, possibly via spacing, resource competition, or habitat disruption. Optimizing intercropping ratios is therefore crucial for effective pest management.

Conclusion

Intercropping maize with beans effectively reduced both the incidence and severity of maize stem borer infestation. Treatments with intercropped maize and beans consistently exhibited lower infestation rates and lower pest severity scores compared to monoculture fields, demonstrating the potential of intercropping as a practical method for pest control.

Recommendations

The government need to encourage and support the adoption of intercropping systems in maize cultivation to reduce maize stem borer infestation. Promote awareness among farmers about the benefits of intercropping systems.

The government need to allocate funds for research and development in identifying and promoting effective treatment factors that can further reduce maize stem borer infestation and improve grain yield.

District Agriculture Officers need to conduct awareness campaigns and workshops to educate farmers about the importance of treatment factors, their impact on infestation reduction, and sustainable agricultural practices.

References

Belmain, S. R., Tembo, Y., Mkindi, A. G., Arnold, S. E., & Stevenson, P. C. (2022). Elements of agroecological pest and disease management. *Elem Sci Anth*, *10*(1), 00099.

Faborode, H., & Alao, O. (2022). Assessment of indigenous and chemical pest control measures for arable crops in Ejigbo Local Government Area, Osun State, Nigeria. *Alexandria Journal of Agricultural Sciences*, *67(*1), 1-9.

Gao, Y.; Duan, A.; Qiu, X.; Sun, J.; Zhang, J.; Liu, H.; Wang, H. (2010).Distribution and use efficiency of photosynthetically active radiation in strip intercropping of maize and soybean. Agron. J. 102, 1149–1157.

García-Lara, S., García-Jaimes, E., & Bergvinson, D. J. (2019). Mapping of maize storage losses due to insect pests in central Mexico. *Journal of Stored Products Research*, *84*, 101529.

Gou G.M.; Wratten, S.D.; Landis, D.A.; You. (2016) M. Habitat management to suppress pest populations*: Progress and prospects*. Annu. Rev. Entomol., 62, 91–109.

Hailu, G., Niassy, S., Bässler, T., Ochatum, N., Studer, C., Salifu, D., ... & Subramanian, S. (2021). Could fall armyworm, Spodoptera frugiperda (JE Smith) invasion in Africa contribute to the displacement of cereal stemborers in maize and sorghum cropping systems. *International Journal of Tropical Insect Science*, 41, 1753-1762.

Homulle, Z., George, T. S., & Karley, A. J. (2021). *Root traits with team benefits: understanding belowground interactions in intercropping systems*. Plant and Soil, 1-26.

Huang, C. D., Liu, Q. Q., Li, X. L., & Zhang, C. C. (2018). Effect of intercropping on maize grain yield and yield components. *Journal of Integrative Agriculture*, *18*(8), 1690-1700.

Jalilian, J., Najafabadi, A., & Zardashti, M. R. (2017). Intercropping patterns and different farming systems affect the yield and yield components of safflower and bitter vetch. *Journal of Plant Interactions*, *12*(1), 92-99.

Jensen, E. S., Carlsson, G., & Hauggaard-Nielsen, H. (2020). Intercropping of grain legumes and cereals improves the use of soil N resources and reduces the requirement for synthetic fertilizer N: A global-scale analysis. *Agronomy for Sustainable Development, 40*(1), 1-9.

Jiang, L., Chen, Y., Wang, X., Guo, W., Bi, Y., Zhang, C., ... & Li, M. (2022). *New insights explain that organic agriculture as sustainable agriculture enhances the sustainable development of medicinal plants*. Frontiers in Plant Science, 13, 959810.

Kumela, T., Mendesil, E., Enchalew, B., Kassie, M., & Tefera, T. (2019). Effect of the push-pull cropping system on maize yield, stem borer infestation and farmers' perception. *Agronomy, 9*(8), 452.

Mansaray, A., Karim, A. B., Yormah, T. B. R., & Conteh, A. R. (2022). Effect of Cassava-Legume Intercropping Systems on the Population Dynamics of Legumes Insect Pests in Three Major Agro-Climatic Zones of Sierra Leone. *International Research Journal of Insect Sciences, 7*(1), 20-33.

Martin-Guay, M. O., Paquette, A., Dupras, J., & Rivest, D. (2018). The new green revolution: sustainable intensification of agriculture by intercropping. *Science of the total environment, 615*, 767-772.

Nassary, E. K., Baijukya, F., & Ndakidemi, P. A. (2020). Productivity of intercropping with maize and common bean over five cropping seasons on smallholder farms of Tanzania. *European Journal of Agronomy*, 113, 125964.

Ndayisaba, P. C., Kuyah, S., Midega, C. A. O., Mwangi, P. N., & Khan, Z. R. (2021). *Intercropping desmodium and maize improves nitrogen and phosphorus availability and performance of maize in Kenya*. Field Crops Research, 263, 108067.

Novotny, I. P. (2020). *Assessing household and landscape trajectories for improving ecosystem services and nutritional self-sufficiency in south Mexico* (Doctoral dissertation, Wageningen University and Research).

Ntare, J. G., Karungi, J., Muhumuza, J. B., & Talwana, H. (2022). Influence of farmers' practices on fall armyworm infestation levels in maize fields.

Omwoyo, C. O. (2021). *Assessment of Yield Losses and Farmers' Perceptions on Control Practices of Fall Armyworm: the Case of Maize Infestation in Trans-nzoia County, Kenya* (Doctoral dissertation, University of Nairobi).

Rakotomalala, A. A., Ficiciyan, A. M., & Tscharntke, T. (2023). *Intercropping enhances beneficial arthropods and controls pests: A systematic review and meta-analysis*. Agriculture, Ecosystems & Environment, 356, 108617.

Ratto, F., Bruce, T., Chipabika, G., Mwamakamba, S., Mkandawire, R., Khan, Z., ... & Sait, S. M. (2022*). Biological control interventions reduce pest abundance and crop damage while maintaining natural enemies in sub-Saharan Africa: a meta-analysis*. Proceedings of the Royal Society B, 289(1988), 20221695.

Stagnari, F., Maggio, A., Galieni, A., & Pisante, M. (2017). Multiple benefits of legumes for agriculture sustainability: an overview. *Chemical and Biological Technologies in Agriculture*, *4*(1), 1-13.

Stomph, T., Dordas, C., Baranger, A., de Rijk, J., Dong, B., Evers, J., & van der Werf, W. (2020). *Designing intercrops for high yield, yield stability and efficient use of resources: Are there principles?.* Advances in Agronomy, 160(1), 1-50.

Udayakumar, A., Shivalingaswamy, T. M., & Bakthavatsalam, N. (2021). Legume-based intercropping for the management of fall armyworm, Spodoptera frugiperda L. in maize. *Journal of Plant Diseases and Protection, 128,* 775-779.