ANSF
APPLIED AND NATURAL SCIENCE FOUNDATION

Journal of Applied and Natural Science
17(1), 65 - 77 (2025)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Research Article

Herbicide-free weed management in kharif maize (*Zea mays* L.) intercropping Systems: Advancing environmental sustainability, productivity, and economic efficiency

Bunga Enosh
Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara144411 (Punjab), India
N. Nanda Kishore Reddy
Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara144411 (Punjab), India
Anita Jaswal
Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara144411 (Punjab), India

*Corresponding author. E-mail: anita.27139@lpu.co.in

Article Info
https://doi.org/10.31018/jans.v17i1.6135
Received: August 22, 2024
Revised: January 26, 2025
Accepted: January 31, 2025

How to Cite
Enosh, B. *et al.* (2025). Herbicide-free weed management in kharif maize (*Zea mays* L.) intercropping Systems: Advancing environmental sustainability, productivity, and economic efficiency. *Journal of Applied and Natural Science*, 17(1), 65 - 77. https://doi.org/10.31018/jans.v17i1.6135

Abstract
Maize (*Zea mays* L.), commonly known as the "queen of cereals," is extensively cultivated with wide spacing, facilitating intercropping with legumes to improve productivity and sustainability. Intercropping systems are advantageous for weed management, decreasing dependence on herbicides, and enhancing environmental sustainability. The current study sought to determine whether intercropping maize with legumes may reduce weeds, increase productivity, and improve economic efficiency without using herbicides. A field experiment was executed in the Kharif 2022 season at Lovely Professional University's agricultural research farm in Phagwara, Punjab, employing a randomized block design with seven treatments replicated three times. The treatments comprised sole maize, sole moong bean, sole soybean, and intercropping systems of maize with moong bean or soybean in 1:2 and 1:3 ratios. The intercropping system of maize and moong bean (1:3) overcame all treatments, achieving the maximum grain production (5882.0 kg ha^{-1}), harvest index (43.86%), cob diameter (8.5 cm), grains per cob (17.67), and straw yield (7519.0 kg ha^{-1}). This system demonstrated exceptional weed suppression, achieving the lowest total weed density (5.22 no. m^{-2}), minimal weed biomass (6.4 g m^{-2}), and the highest weed smothering efficacy (68.7%). Moreover, it attained the highest land equivalent ratio (1.99), maize equivalent yield (10.17 t ha^{-1}), and monetary advantage index (₹4800), emphasizing its economic and ecological advantages. This research illustrates the innovation and effectiveness of herbicide-free weed management in maize-legume intercropping systems. The maize and moong bean (1:3) system promotes environmental sustainability, increases production, and enhances economic efficiency, offering a sustainable alternative to monocropping in the Punjab region.

Keywords: Legume, Intercropping, Yield assessment, Weed dynamics, Sustainability

INTRODUCTION

The effective production of any crop was significantly impeded by crop weed competition, which was one of the primary constraints on productivity. The maize productivity in India is significantly lower than that of the global average due to a variety of factors, with the inadequate management of weeds being the most significant (Elhabbak and El-mehy (2023). Weeds are the primary factors that reduce the productivity of maize in India (Hirwe *et al.,* 2023). The critical period of crop weed competition was from the time of sowing until the crop was to be maintained in a weed-free environment to achieve a higher yield. During the initial 4-6 weeks of growth, it is susceptible to competition from weeds (Anyoni *et al.,* 2023). In the past, various weed control methods have been employed to reduce the impact of weed competition on maize, such as using high-yielding varieties, synthetic fertilizers, and pesticides. Nevertheless, the evaluated methods were either inefficient and ineffective or not environmentally safe. In order to enhance crop yields, modern agricultural methods significantly rely on synthetic fertilizers and pesticides to mitigate crop pests (weeds, insects, and diseases) (Namatsheve *et al.,* 2024).

Even though these agricultural practices have significantly increased the yield per unit area, they have also led to an increase in the cost of production, the development of herbicide resistance in weeds, and a negative impact on human health and crop ecology, such as the loss of biodiversity, water and soil contamination, and habitat degradation (Solanki *et al.,* 2023). Weed control technology has evolved from manual weeding or basic tillage to the more costly chemical control methods currently in use. Chemicals have emerged as the most prevalent approach to weed management in modern agriculture. Nevertheless, the desire for reduced herbicide use on farms has been prompted by the emergence of weeds that are more resistant to herbicides and the environmental and economic costs thereof. Herbicides have been employed extensively by Punjab farmers for the purpose of weed control for an extended period. Despite the global prohibition of herbicide use, it is not possible to eradicate it immediately. The necessity of non-chemical and environmentally safe weed management in agro-ecosystems has been prompted by the detrimental effects of herbicides on the environment (Kaur *et al.,* 2023). One of the environmentally favorable methods is intercropping cereals (such as maize, wheat, and rice) with legumes (such as mungbean, cowpea, and berseem). To ensure that both crop components were in an environment free of weeds, it was necessary to implement concentrated scientific endeavors for weed management in an intercropping system.

The productivity of maize was 65 to 90% higher when weed control practices were implemented compared to unweeded conditions (Sahoo *et al.,* 2024). The major maize cultivating Districts in Punjab are Hoshiarpur, Roopnagar, Jalandhar, Ludhiana, Patiala, Shaheed Ajit Singh Nagar, Shaheed Bhagat Singh Nagar as shown in Fig. 1. Maize with wider row spacing could be utilized to cultivate short-duration legumes, which would provide an improved yield and function as a smoother crop. The weed management approach that involved intercropping in maize and maize-based intercropping systems was crucial for achieving high production by providing effective and acceptable weed control. Moreover, weed suppression has been noted as one of the advantages of intercropping (Bilalis *et al.,* 2010). Intercropping is a cultural method that makes weeds and crops more competitive. It can enhance light interception in a less competitive crop and may assist in weed suppression as part of a long-term weed management approach (Ouda and Zohry, 2024). The quantity of light captured by the constituent crops in an intercrop system is contingent upon the crop geometry and foliage development. At reduced maize density, beans absorbed 50% of the incident light. Intercropping systems are documented to utilize more resources, diminishing weed proliferation availability. A search for a suitable cereal-legume intercropping system in Punjab that incorporates appropriate weed management practices has become imperative, as weed management was previously recognized as a critical factor in the system's ability to enhance productivity under Punjab conditions. The present work aimed to identify a suitable cereal-legume intercropping system for Punjab that integrates effective weed management practices to enhance overall productivity.

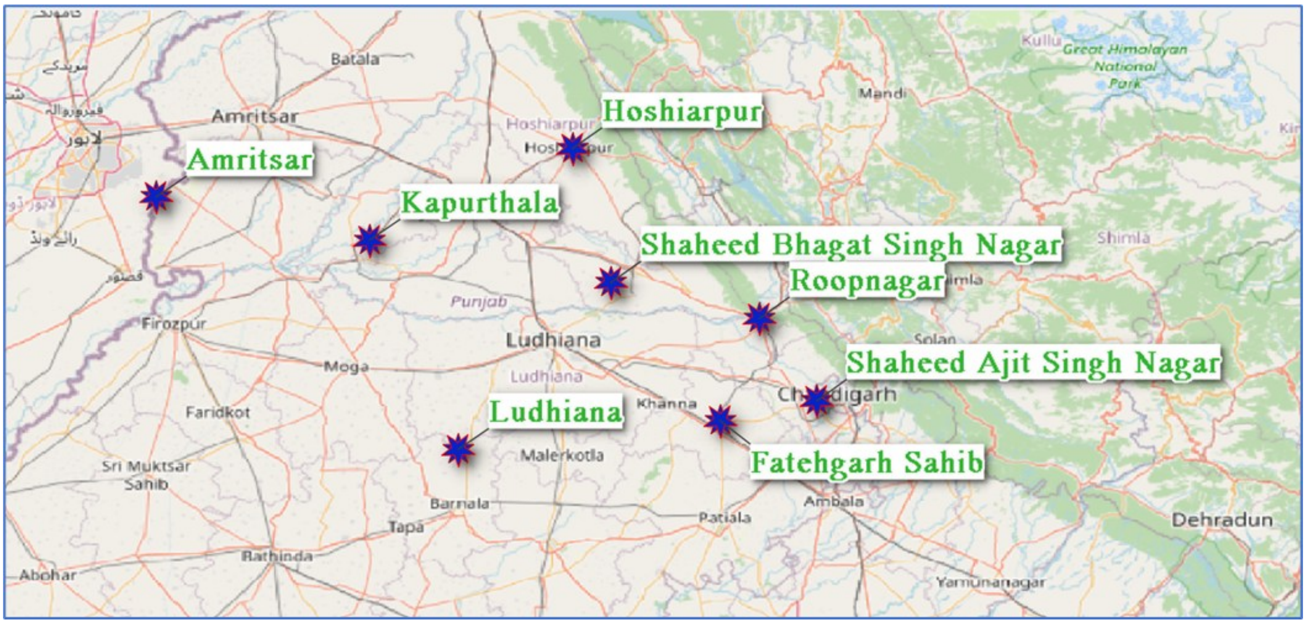

Fig. 1. *Representing the maize-growing districts in Punjab*

MATERIALS AND METHODS

The experiment was conducted at the Agriculture Research Farm located at Lovely Professional University, Phagwara. This research location is situated in the Northern plain zone, specifically between 31°14'43"N latitude and 75°42'00"E at 243m mean sea level, as presented in Fig.3. The meteorological data was gathered from the Agromet observatory of the university located at 31°14'41"N, 75°42'05"E latitude and longitude during the crop growing season presented in Fig. 2. In the crop season temperatures was as high as 38.4° C and as low as 15.3° C. The treatments include T_1- Sole maize, T_2- Sole moong bean, T_3- Sole soybean, T_4 -Maize + moong bean 1:2, T_5 -Maize + soybean 1:2, T_6 -Maize + moong bean 1: 3, T_7-Maize + soybean 1:3. Maize (*Zea mays*). Row intercropping system followed, the configuration and arrangement as shown in Fig. 4. Maize variety (TA 5084), Soybean (Him soya) and green gram (SML 668) were sown on June 29, 2022, in row according to the treatments. A seed rate of 25Kg ha^{-1} (maize), 30Kg ha^{-1} (soybean) and 15-20Kg ha^{-1} (green gram) was used. On 3rd Sep 2022 (Green gram), 25th oct 2022 (Maize) and 22nd Oct 2022 (Soybean) the crops were harvested. The soil in the experimental field had a sandy loamy texture and a neutral pH of 7.5. The soil exhibited moderate levels of accessible nitrogen (273.6 kg ha^{-1}) and available phosphorus (19.14 kg ha^{-1}), whereas potassium levels were high (378.6 kg ha^{-1}).

Weed studies

A 1 m^2 quadrant was used in each plot to randomly choose two spots from which the number of weeds was counted at 30 and 60 days after planting. The count of weeds was given as the number of weeds per square meter. The weeds collected at 30 and 60 DAS from each plot are gathered and stored in a brown paper bag. They are then dried in the sun for two days and placed in a hot air oven at a temperature of 70 degrees. Finally, dry matter weight was recorded. This index is used to determine the effect of intercropping on the suppression of weeds compared to sole crop stand.

WSE% =Weed dry weight in sole crop stand plots – Weed dry weight in intercropped plots/ Dry matter of weeds in sole crop stand X 100 (1)

Yield attributes of maize

The mean value per plant was determined for each experimental unit by recording the number of cobs of five tagged plants at harvest. The total number of rows cob^{-1} and the number of grains per row were used to estimate the average number of grains cob^{-1}. Five plants were randomly chosen, and their cob lengths were measured using a centimeter scale. The selected cobs were shelled, and the grains from each plot of the selected plants were weighed after cleansing. The resulting weight was converted to kg ha^{-1}. 1000 seeds were collected from the produce and weighed in grams. This was referred to as the test weight. Dry matter of the crop was referred to as stover yield after the separation of cobs from the plant. The dry weight of selected plants from each plot was recorded and converted to per hectare land. The formula provided by Donald and Hamblin (1976) was employed to calculate the harvest index.

Yield assessment studies

Land equivalent ratio

The Land Equivalent Ratio (LER) was computed by Caballero *et al.* (1995):

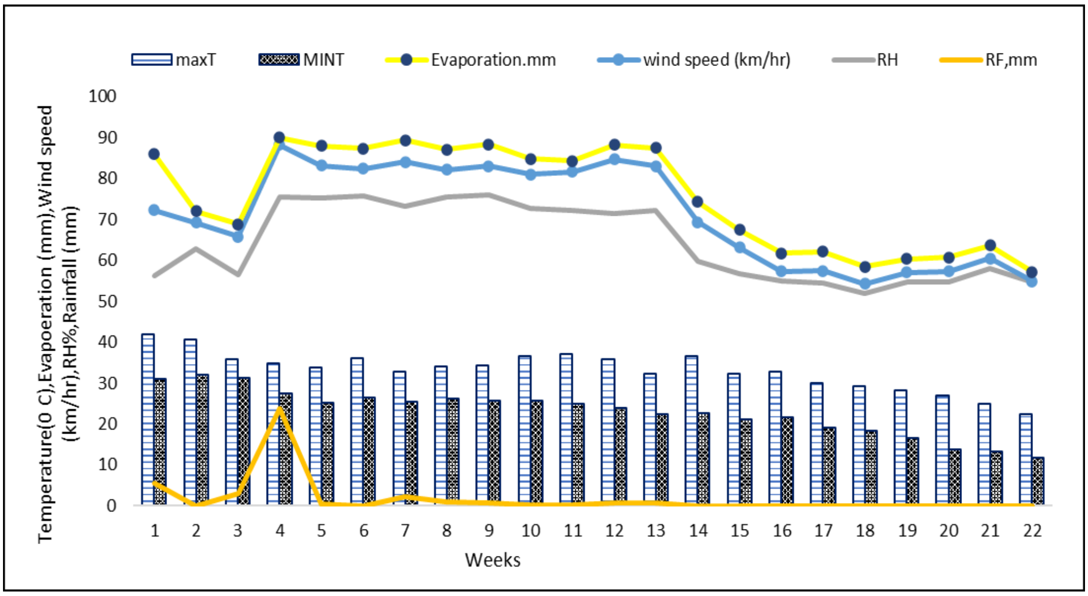

Fig. 2. *Weekly averages of weather data of Kapurthala district, recorded during the experiment*

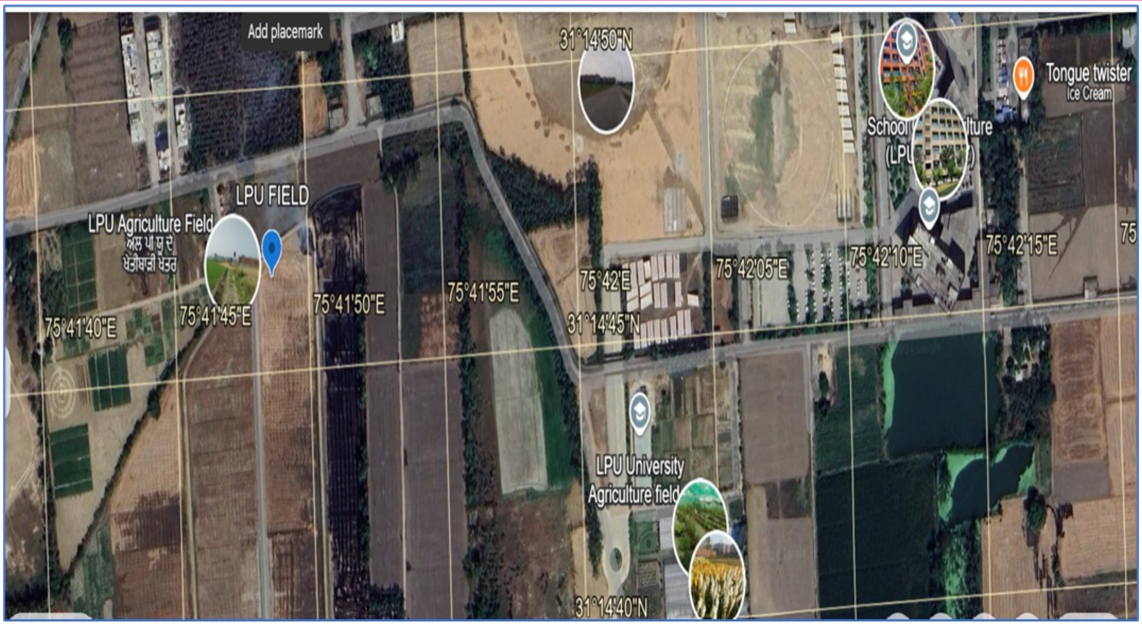

Fig. 3. *Agronomy research trial of Lovely Professional University, Phagwara location with coordinates*

$$\mathrm{LER} = \frac{\mathrm{Yab}}{\mathrm{Yaa}} + \frac{\mathrm{Yba}}{\mathrm{Ybb}} \quad (2)$$

Yab = Intercropped yield of crop a, Yba = Intercropped yield of crop b, aa = Sole crop yield of crop a, Ybb = sole crop yield of crop b.

Area× time equivalent ratio: The ATER calculated by formulae (Naveena *et al.,* 2015)

$$\mathrm{ATER} = \frac{\mathrm{La} \times \mathrm{Da} - \mathrm{Lb} \times \mathrm{Db}}{\mathrm{T}} \quad (3)$$

La and Lb, are relative yields or partial LER of component crops a and b, respectively. Da and Db are duration of crops a and b, respectively T is the total duration of the intercropping system.

Competition Ratio: Competitive ratio (CR) has been developed as a way to assess intercrop competition.

$$\mathrm{CR} = \frac{L_a}{L_b} \times \frac{Z_{ba}}{Z_{ab}} \quad (4)$$

Where, L_a = LER of Maize, L_b = LER of Black gram/ French bean, Z_{ab} = sown proportion of a in mixture with b, Z_{ba} = sown proportion of a in mixture with b

Monetary Advantage Index (MAI): MAI was arrived at as follows:

$$\mathrm{MAI} = \frac{(\text{value of combined intercrops}) \times (\mathrm{LER}-1)}{LER} \quad (5)$$

Maize equivalent yield: The yield of individual crops was converted into equivalent yield (q ha^{-1}) based on the prevailing market price of the crop. It was calculated by following formula.

MEY= Grain yield of maize + (Grain yield of intercrop/ Market price of maize) X Market price of intercrop (6)

Statistical analysis

A one-way analysis of variance (ANOVA) and a Duncan's multiple range test at the 95% confidence level was used to find any significant differences between treatments. The LSD test was employed as a post-hoc analysis to determine whether the means differed significantly. SPSS version 22.0 software program was used for all statistical studies. The relationship between the weed density and weed smothering efficiency was examined using a linear regression equation.

RESULTS AND DISCUSSION

Effect of intercropping on yield and yield attributes of maize

Cobs determine the yield of a crop and its growth. Cobs plant^{-1} was recorded highest (1.83) in maize+ mung bean (1:3) followed by maize+ soybean (1:3). Lowest number of cobs (1.17) was recorded in sole maize. Nitrogen fixation in association with legumes plays an important role in the metabolic activity of maize plants, which causesan increase in the number of cobs in intercrop combination. The results were similar to the findings of Manasa *et al*., 2020 in Maize-Legume intercropping system with 2:2 maize and black gram. The greater diameter of the cob indicated more the number of rows cob^{-1}. Maximum number of rows cob^{-1} (17.6) was recorded in maize+ moong bean 1:3 followed by Maize+ Soybean (1:2). The least number of rows (14.3) were recorded with Sole maize. This might be due to an increase in the length and girth of stem and an improvement in productivity due to the synergistic effect of maize with moong bean association. The results conformed with the findings of (Hetta *et al.,*2023), who

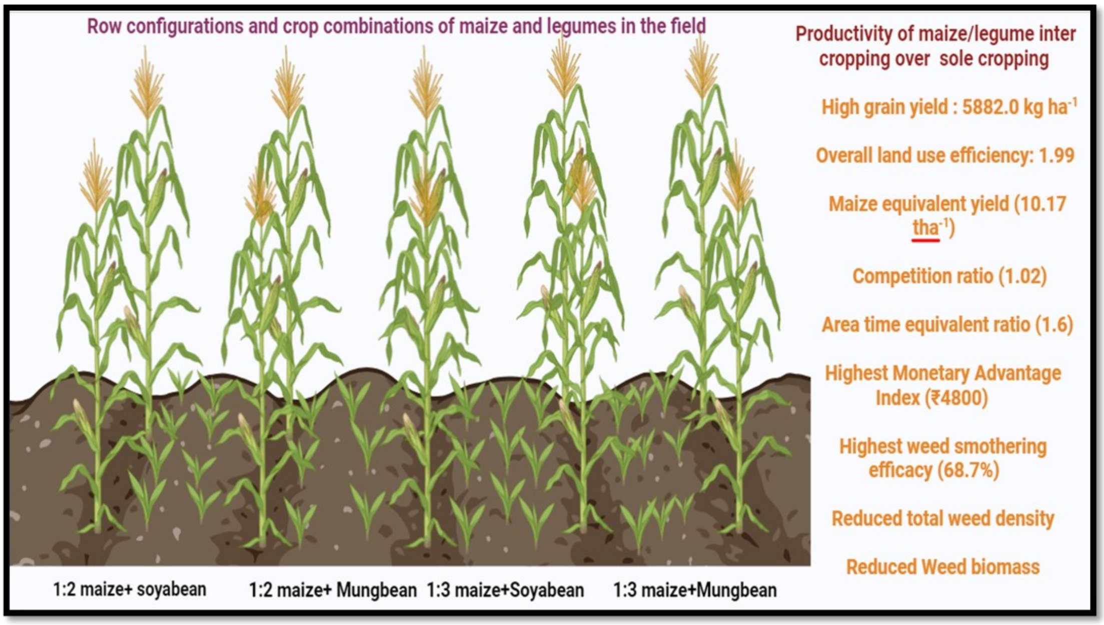

Fig. 4. *Representing row configuration and crop combinations in maize-legume intercropping and productivity of maize legume intercropping over sole cropping*

found that vegetable crops (cowpea, French bean, coriander) intercropped with maize reduced the weed density and dry weight accumulation by weeds, which resulted in higher maize equivalent yield. A greater number of grains cob^{-1}(484.3) were noticed in Maize+ Mung bean (1:3) and Maize+ Soybean (1:3) followed by Maize+ Soybean (1:2). The lowest number of grains cob^{-1} (458) were recorded with Sole maize.

The greater number of grains cob^{-1} recorded in intercrop combination might be due to different growth stages of crop and different timings of utilizations of resources from different soil layers. The results conformed with the findings of Kaur *et al.,*2023) for fodder maize +cowpea intercropping with 1:2 proportion. The deciding factor in determining whether one treatment is more appropriate than another is yield. Grain yield obtained at harvest was converted to kg ha^{-1} and the results are presented in Table 1. The maximum grain yield (5882.0 kg ha^{-1}) was recorded with Maize+ Mung bean (1:3). The second highest grain yield was recorded in (5794.0 kg ha^{-1}) followed by Maize+ Mung bean (1:2) and Maize+ Soybean (1:2) that were non-significant among themselves. Lowest grain yield was recorded in Sole maize (5611.0 kg ha^{-1}). The higher yield in the intercropping system compared to sole crop was due to better resource use efficiency and the synergistic effect of maize in association with moong bean in high density paired row pattern is greater. The results were in conformity with Manasa *et al.,*2020, Maitra *et al.*, 2020 where sole maize does not show any significant variation with intercropping maize+ groundnut 2:1 that were statistically at par.

Stover yield was influenced by the different intercropping and mono cropping patterns. Maximum stover yield (7519.0 kg ha^{-1}) was obtained in maize+ moong bean (1:3) intercropping system followed by Maize+ Soybean (1:3) and Maize+ Moong bean (1:2). The lowest stover yield (7155.6kg ha^{-1}) was observed in Sole maize. This might be due to less weed infestation and minimal pest and insect attack in intercrop combination attributed to increased plant biomass and nutrient uptake. The results are in corroborate the findings of Panda *et al.*, 2022 in rabi maize legume intercropping system with 2:2 of maize-chick pea intercropping. Highest test weight (386.5 gm) was observed in Maize+ Mung bean (1:3) and showed a non-significant effect with Maize+ Soybean (1:3). The lowest test weight (320.9g) was recorded in Sole maize. The highest test weight in Maize + Moong bean (1:2) indicates the greater utilization of available nutrients in legume intercropping than sole maize. The results were similar with the findings of Sahoo *et al.,*2023 who revealed that competitive and complimentary relationships influenced yield attributes where devoid of competition resulted in higher values and complementarity was recorded in some treatments probably because of the proportion of crop species and their planting geometry.

Effect of intercropping of maize with legumes on weeds

Weeds cause damage to crops by about 50%; though there are many chemical methods to control weeds, they cause adverse effects on the environment and are expensive to reduce these impacts. Intercropping plays a major role in reducing weed density. Weeds interfere with crops for resources such as sunlight, water, and nutrients, and they also have an allelopathy effect on the main crop. Different intercropping patterns suppress weeds more effectively than mono-cropping and reduce the frequency of weeding. At the experimental site, the weed flora consisted of grasses, sedges, and broad leaves. The major weed species were: Grasses: *Cynodon dactylon* (Bermuda grass), *Digitaria sanguinalis* (Crab grass), *Dactyloctenium aegyptium* (Crow foot). Sedges: *Cyperus rotundus* (Nut grass), *Cyperus difformis* (Dila motha). Broad leaves: *Trianthema protulacastrum* (Giant pigweed), *Eclipta alba* (False daisy). The results were similar to the findings of Berdjour *et al.* (2020; Ananthi *et al.* (2017).

Effect of intercropping on weed density of grasses (no. m^{-2}): The density of grassy weeds at the experimental site in different plots was recorded at 30 and 60 DAS. The data recorded at 30DAS showed that the lowest weed density was observed in Sole moong bean, Sole soybean (3.27, 3.44) m^{-2} and were non-significant among themselves. Second lowest weed density (3.76, 3.91) m^{-2} was recorded in maize+ moong bean (1:3) and maize+ soybean (1:3). Highest weed density (4.93 m^{-2}) was recorded with Sole maize as indicated in Table 2. At 60 DAS, the weed density gradually decreased. The lowest weed density (3.38,3.71 m^{-2}) was noticed in Maize+ Moong bean (1:3), and Maize+ Soybean (1:3). Highest weed density was observed in Sole maize (6.61 m^{-2}). The results were similar to the findings of Abbas *et al.* 2021 who reported that maize-gram intercropping systems significantly reduced weed density compared to Sole maize in single rows (60 cm apart) and double rows (90 cm apart).

Effect of intercropping on weed density of sedges (no. m^{-2})

The data related to the weed density of sedges was recorded at 30 DAS and 60 DAS. At 30 DAS, a minimum number of sedges (2.81m^{-2}) was observed in Maize+ Moong bean (1:3). Second least density of sedges (3.21m^{-2}) was observed in Maize+ Soybean (1:3) and Sole soybean. Maximum number of sedges was recorded in Sole maize (4.7m^{-2}). Sole maize recorded more sedges might be due to less plant competition for soil-derived growth resources, such as moisture and nutrients, as well as for environmental resources (light and CO_2), compared to intercropping systems. At 60, DAS Maize+ Moong bean (1:3) recorded minimum weed density (2.94m^{-2}). The second lowest weed density was recorded with Maize+ Soybean (1:3), followed by Sole soybean, which was statistically at par with sole moong bean. Maximum weed density (5.6m^{-2}) was recorded in Sole maize. The highest percent reduction was observed in Maize+ Moong bean (1:3) followed by Maize+ Soybean (1:3). Additionally, intercropping cereals with spreading varieties of legumes (black gram, green gram etc.) continued to be successful in reducing weed incidence through weed-seed bank in the upper soil strata. The results conformed with the findings of Naderi *et al.,*2022 found that the intercropping of maize and soybean decreased weed density compared to the maize sole cropping system. The soybean plants may have had this effect by reducing the number of niches available for weed growth. This outcome supports past research on the impact of intercropping systems on weed control.

Effect of intercropping on weed density of broad leaves (no.m^{-2})

The weed density of broad leaf data was recorded at 30 DAS and 60 DAS. At 30 DAS, Maize+ Moong bean (1:3) recorded the lowest weed density (3.04m^{-2}), and the second lowest broad leaves (3.07 m^{-2}) were noticed with Maize+ Soybean (1:3) followed by Sole moong bean and Sole soybean. The highest weed density was noticed in Sole maize (4.50 m^{-2}). At 60DAS, the lowest weed density (5.36) was observed in Maize+ Moong bean (1:3) and Maize+ Soybean (1:3) that were non-significant among themselves, which was followed by Sole moong bean, Sole soybean. The highest weed density was recorded in Sole maize (5.36 m^{-2}). Thus, Intercrops perform better than sole crops in terms of weed management by increasing crop yields while reducing weed development by appropriating weeds' resources and inhibiting weed growth through allelopathy. The results were similar to the findings of Lebreton *et al.* (2024). The density was significantly reduced by intercropping of legumes with maize in a row ratio of 1:2 compared to legume intercropping with a 2:2 row proportion.

Effect of intercropping on total weed density (no.m^{-2}).

The different species of weeds were collected at the experimental site and data was recorded at intervals of 30DAS and 60DAS. At 30DAS, minimum weed density (6.24 m^{-2}) was observed in maize+ moong bean (1:3), second lowest weed density was observed in Maize+ Soybean (1:3) followed by Sole moong bean, and Sole soybean that failed to cause significant increase among themselves. Minimum weed density was recorded in Sole maize (9.08m^{-2}) followed by Maize+ Soybean (1:3) and Maize+ Soybean (1:2). This might be due to less space available in the cereal-legumes intercropping system. The effect of companion crops' closely spaced row strips on weed suppression was amplified. At 60 DAS, the least density (5.73 m^{-2}) of all species at the experimental site was recorded in maize+ moong bean (1:3) and Maize+ Soybean (1:3). Highest weed density was observed in sole maize (18.2 m^{-2}). The results showed at 60 DAS, the percent reduction of weeds over Sole was greatly increased. This shows that with the increase in crop duration, the de-

Table 1. Effect of intercropping of maize with legumes on maize yield attributes and yield

Treatments	Test weight(g)	Cob^{-1} plants	Cob diameter (cm)	No of rows cob^{-1}	No of grains cob^{-1}	Grain yield (kg ha^{-1})	Straw yield (kgha^{-1})	H.I (%)
T_1-Sole Maize	$320.9^{a} \pm 3.9$	$1.17^{c} \pm 0.24$	$7.4^{c} \pm 0.2$	$14.3^{d} \pm 0.47$	$458.0^{c} \pm 1.6$	$5611.8^{d} \pm 4.40$	$7155.67^{e} \pm 22.9$	$43.89^{b} \pm 0.16$
T_4-Maize +Mung bean (1:2)	$339.0^{bc} \pm 11.5$	$1.3^{b} \pm 0.47$	$7.8^{b} \pm 0.1$	$15.3^{bc} \pm 0.47$	$462.1^{c} \pm 1.6$	$5722.6^{c} \pm 8.73$	$7324.67^{c} \pm 22.6$	$44.32^{a} \pm 0.07$
T_5-Maize+Soybean (1:2)	$347.7^{b} \pm 15.1$	$1.3^{b} \pm 0.47$	$7.8^{b} \pm 0.1$	$15.6^{b} \pm 0.47$	$475.7^{b} \pm 3.3$	$5724.9^{c} \pm 11.7$	$7232.3^{d} \pm 15.5$	$43.76^{b} \pm 0.082$
T_6-Maize +Mung bean(1:3)	$386.5^{a} \pm 13.4$	1.83^{a} 0.24	$8.5^{a} \pm 0.3$	$17.6^{a} \pm 0.47$	$484.3^{a} \pm 1.7$	$5882.0^{a} \pm 5.72$	$7519.0^{a} \pm 43.2$	$43.86^{b} \pm 0.074$
T_7-Maize+Soybean (1:3)	$384.0^{a} \pm 7.9$	$1.67^{b} \pm 0.42$	$8.2^{a} \pm 0.1$	$16.3^{b} \pm 0.47$	$480.5^{a} \pm 1.5$	$5794.0^{b} \pm 4.32$	$7414.67^{b} \pm 17.0$	$43.86^{b} \pm 0.091$

*Data is in the form of mean ± SDM at $p \le 0.05$ the mean followed by different letters was significantly different at $p \le 0.05$, according to DMRT for separation of mean

Table 2. Effect of intercropping of maize with legumes on weed density at different intervals

Treatments	Weed density grasses at (30 DAS) ($No.m^{-2}$)	Weed density grasses at (60 DAS) ($No.m^{-2}$)	Weed density sedges at (30 DAS) ($No.m^{-2}$)	Weed density sedges at (60 DAS) ($No.m^{-2}$)	Weed density broad leaf weeds at (30 DAS) ($No.m^{-2}$)	Weed density broad leaf weeds at 60 DAS($No.m^{-2}$)	Total weed density at 30 DAS (no. m^{-2})	Total weed density at 60 DAS (no. m^{-2})
T_1-Sole maize	4.93^{a}(19.67) ±0.14	6.61^{a}(37.3) ±0.14	4.78^{a}(18.33) ±0.14	5.66^{a}(26.67) ±0.12	4.50^{a}(36.0) ±0.07	9.50^{a}(81.0) ±0.12	9.08^{a} (73.7) ±2.5	18.2^{a}(36.1) ±1.31
T_2-Sole moong bean	3.27^{d}(7.67) ±0.09	4.15^{C}(13.33) ±0.17	3.77^{b}(10.67) ±0.07	3.26^{cd}(7.67) ±0.23	3.29^{c}(19.0) ±0.09	6.30^{b}(33.7) ±0.11	6.61^{c} (37.3) ±0.5	12.1^{d}(17.1) ±1.10
T_3-Sole soybean	3.44^{d}(8.67) ±0.08	4.19^{c}(13.67) ±0.17	3.39^{c}(8.33) ±0.08	3.32^{c}(8.00) ±0.14	3.36^{c}(20.3) ±0.05	6.50^{b}(36.0) ±0.14	6.58^{c} (37.0) ±0.0	12.3^{cd} (16.2) ±0.45
T_4- Maize + Mung bean (1:2)	4.42^{b}(15.33) ±0.06	5.04^{b}(20.67) ±0.14	3.71^{b}(10.33) ±0.07	3.81^{b}(11.00) ±0.12	3.39^{b}(23.7) ±0.13	6.24^{b}(33.0) ±0.12	7.48^{b} (48.7) ±1.7	12.8^{bc} (19.9) ±0.88
T_5-Maize + Soya bean (1:2)	4.33^{b}(14.67) ±0.06	5.26^{b}(22.67) ±0.13	3.81^{b}(11.00) ±0.12	3.81^{b}(11.00) ±0.12	3.50^{b}(22.0) ±0.09	6.47^{b}(35.7) ±0.14	7.33^{b} (46.7) ±1.7	13.0^{b} (21.6) ±1.04
T_6-Maize+Mung bean (1:3)	3.91^{c}(10.67) ±0.07	3.38^{d}(8.33) ±0.21	2.81^{d}(5.33) ±0.10	2.58^{e}(4.33) ±0.11	3.04^{e}(11.3) ±0.07	5.36^{c}(23.7) ±0.13	5.73^{e} (27.3) ±1.2	10.2^{e} (11.2) ± 0.91
T_7-Maize+ Soybean (1:3)	3.76^{c}(11.67) ±0.14	3.71^{d}(10.33) ±0.19	3.21^{c}(7.53) ±0.09	2.94^{d}(6.00) ±0.17	3.07^{d}(14.0) ±0.11	5.22^{c}(22.3) ±0.18	6.24^{d} (33.0) ±0.8	10.4^{e} (11.9) ±0.66

Figures in the parenthesis are original values as observation, while without parenthesis are transformed values (√□ + 0.5). Data is in the form of mean ± SDM at $p \le 0.05$; the mean followed by different letters was significantly different at $p \le 0.05$, according to DMRT for separation of mean creased weed density might be due to resource competition. The results were similar to the findings of Naher *et al.* (2020) and Abbas *et al*. (2021), who reported a 40% decrease in weed infestation when planting field beans in narrow rows compared with wide rows. Compared to the sole maize and soybean crops, the maize–soybean intercrop may substantially decrease the number of grass, broadleaf, and sedge species. This could be attributed to the decrease in the number of niches accessible for weed species growth under the intercropping system.

Effect of intercropping of maize with legumes on weed biomass of grasses (no.m^{-2})

The weeds, namely *Dactyloctenium aegyptium* (crow foot) and *Cynodon dactylon* (scutch grass) were collected at 30 DAS and 60 DAS to record their dry weight. The lowest weed biomass was recorded with Sole soybean (2.1 gm^{-2}) and Sole moong bean (2.10gm^{-2}), as represented in Table 3. The second lowest weed biomass was observed with Maize+ Mung bean (1:3) followed by Maize+ Soybean (1:3). Sole maize recorded the highest dry weight (3.53gm^{-2}). The data studied under 60 days revealed that the lowest weed biomass (2.5gm^{-2}) was noticed in Maize+ Mung bean (1:3). Second lowest weed biomass was recorded in Maize+ Soybean (1:3). Highest weed biomass was recorded in Sole maize (4.08 gm^{-2}). Intercropped legumes compete fiercely with weeds for essential resources, including space, light, nutrients, and moisture, which may cause interference in intercropping systems. The results were similarly corroborated with the findings of Ananthi *et al.,* 2017 and Lebreton *et al.,* 2024 that intercropping maize with legumes had a higher weed biomass relative to the sole crops of the legumes. In contrast with this result, Bedoussac *et al.,* 2015 reported higher weed biomass in a sole legume crop relative to the intercrop of wheat–faba bean and barley–faba bean intercropping. The increase in weed biomass with increasing soybean intra-spacing could also be attributed to reduced soybean plants per unit area.

Effect of intercropping on weed biomass of sedges (no.m^{-2})

The weed biomass of Cyperus rotundus (Nut grass) sedges and *C. difformis* (Dila motha) was recorded at 30 DAS and 60DAS. Maize+ Mung bean (1:3) recorded the lowest weed biomass and was statistically at par with Maize+ Soybean (1:3). Highest weed biomass of sedges was observed in Sole maize (3.42gm^{-2}). At 60DAS, maize+ mung bean (1:3) recorded the lowest weed biomass, which was statistically at par with maize+ soybean bean (1:3), followed by sole soybean bean (2.1). The highest weed biomass recorded in Sole maize (3.16gm^{-2}) increase in the weed density is the reason to highest dry weight in sole maize. The results

Table 3. Effect of intercropping of maize with legumes on weed biomass (g m^{-2}) and weed smothering efficiency %

Treatments	Weed biomass of grasses at (30 DAS) (gm^{-2})	Weed biomass of grasses at (60 DAS) (gm^{-2})	Weed biomass of sedges at (30 DAS) (g.m^{-2})	Weed biomass of sedges at (60 DAS) (gm^{-2})	Weed biomass broad leaf weeds at (30 DAS) (gm^{-2})	Weed biomass of broad leaf weeds at 60 DAS (gm^{-2})	Total weed biomass at 30 DAS (g m^{-2})	Total weed biomass at 60 DAS (gm^{-2})	Weed smothering efficiency %
T_1-Sole maize	3.53^a(9.3) ±0.13	4.08^a(12.8) ±0.05	3.42^a(8.51) ±0.01	3.16^a(7.1 ±0.12	4.05^a (12.5) ± 0.04	4.5^a (16.1) ± 0.05	6.01^a (30.4) ± 0.08	10.2^a (36.1 ± 0.17	-
T_2-Sole moong bean	2.1^e(2.6) ±0.07	2.90^c(5.8) ±0.09	2.21^{cd} (2.93) ±0.01	1.81^{bc} (1.75) ±0.20	3.29^c (7.8) ± 0.06	3.6^b (9.5) ± 0.11	4.15^c (13.3) ± 0.07	7.6^b (17.1) ± 0.23	52.6cd ± 3.62
T_3-Sole soybean	2.1^e(2.8) ±0.09	2.16^c(5.8) ±0.08	2.12^d(2.63) ±0.11	1.71^{bc} (1.49) ±0.14	3.36^{bc} (8.2) ± 0.00	3.5^b (8.8) ± 0.05	4.18^c (13.6) ± 0.06	7.4^b (16.2) ± 0.12	55.1c ± 2.72
T_4- Maize + Mung bean (1:2)	2.93^b(5.9) ±0.06	2.56^b(9.6) ±1.46	2.29^{bc} (3.21) ±0.01	1.86^b (1.87) ±0.13	3.39^{bc} (8.4) ±0.03	3.4^b (8.4) ±0.04	4.68^b (17.5) ± 0.04	7.2^b (19.9) ± 0.53	44.7 e± 4.14
T_5-Maize + Soya bean (1:2)	2.85^b(5.5) ±0.04	3.71^b(10.3) ±0.09	2.33^b (3.36) ±0.05	1.76^{bc} (1.59) ±0.02	3.50^b (9.0) ± 0.04	3.6^b (9.7) ± 0.09	4.72^b (17.9) ± 0.05	7.8^b (21.6) ± 0.13	40.0f ± 3.15
T_6-Maize+Mung bean (1:3)	2.49^d(4.0) ±0.04	2.50^e(4.0) ±0.15	1.55^e(1.10) ±0.04	1.33^d(1.59) ±0.02	3.04^d (6.4) ± 0.05	3.1^d (6.5) ± 0.06	3.89^d (11.5) ± 0.05	6.4^d (11.2) ± 0.12	68.7a ± 2.86
T_7-Maize+ Soybean (1:3)	2.65^c(4.6) ±0.05	2.67^d(4.7) ±0.17	2.20^{cd} (2.88) ±0.02	1.54^{cd} (0.68) ±0.07	3.07^d (6.6) ± 0.07	3.0^d (6.0) ± 0.04	4.25^c (14.1) ± 0.08	6.6^d (11.9) ± 0.08	66.9ab ± 3.06

Values in the parenthesis are original values as observation, while without parenthesis are transformed values (√□ + 0.5). Data is in the form of mean ± SDM at p ≤ 0.05; the mean followed by different letters was significantly different at p ≤ 0.05, according to DMRT for separation of mean were similar with the findings of Wienberg and Gerowitt (2024) and Gazoulis *et al.,* 2022 who reported that the intercropping system's lower weed species indices in comparison to the sole maize cropping system may be attributed to the plant architecture differences, which result in a higher plant density per unit area in the latter.

Effect of intercropping on weed biomass of broad leaves (no.m^{-2})

The weed biomass of broad leaves *Trianthema protulacastrum* (Giant pigweed), *Eclipta alba* (false daisy) *Amaranthus viridis* (pig weed) was recorded at 30 DAS and 60 DAS. At 30DAS, the lowest weed biomass was noticed in Maize+ Mung bean (1:3) and Maize+ Soybean (1:3). Sole moong bean recorded the second lowest (3.29 gm^{-2}) weed biomass followed by Maize+ Soybean (1:2). Maximum dry weight (4.05 g m^{-2}) was recorded in the sole crop of maize (4.05 gm^{-2}). At 60, DAS Maize+ Soybean (1:3) recorded the lowest weed biomass and it was non-significant with Maize+ Mung bean (1:3). Highest weed biomass recorded with Sole maize (4.5 gm^{-2}). As, the intercrops show greater efficiency in converting available resources to productivity they become less available to weeds, decreasing their biomass. Broad leaf weeds were more tolerant to shade effect in intercrop and thus increase their number than grasses and sedges. The results conform with the findings of Berdjour *et al. (*2020); Sharma and Rayamajhi (2022), who suggest that intercropping early maize maturity type with soybean at 10 cm intra spacing could be used to increase grain yield, LER and control of grass and broadleaf weeds in a maize-based cropping system in the Guinea savanna zones of West Africa.

Effect of intercropping on total weed biomass (no.m^{-2})

The weeds from different species were collected at the experimental site and weighed at intervals of 30DAS and 60DAS. At 30DAS, the total weed biomass was minimum in (3.89gm^{-2}) in Maize+ mung bean (1:3). Second lowest weed biomass was recorded in Maize+ Mung bean (1:2), Maize+ Soybean (1:2). Maximum biomass was recorded in sole maize (6.01gm^{-2}). At 60DAS, least weed biomass was recorded in Maize+ Mung bean (1:3) and Maize+ Soybean (1:3). Highest weed biomass was recorded in sole maize (36.1gm^{-2}). Additionally, it has been suggested that the shade effects produced by intercrops' (green and black gram's) canopies negatively influence weed germination, growth, and biomass production and caused the fresh and dry weights of the weed flora to decrease. The result was similar to Berdjour et al., 2020 and Falade *et al.,* 2023 who reported that maize intercropping reduced weed density and biomass.

Effect of intercropping on weed smothering efficiency (%)

Weed smothering efficiency is an index that measures the reduction in weed density, weed biomass between Sole and different intercropped pulses. Weed smothering efficiency was highest (68.7%) in Maize+ mung bean (1:3) and was followed by Maize+ Soybean (1:3). Second highest weed smothering efficiency (55.1%) was noticed in Sole soybean, as represented in Table 3. Lowest weed smothering efficiency (40.02, 44.7%) was observed in Maize+ Soybean (1:2) and Maize+ Mung bean (1:2). Different planting patterns in intercropping system attributed to high coverage of land that suppress the weed emergence and the growth. Maximum weed smothering efficiency was noticed in Maize+ Moong bean (1:3) intercropping compared to all other intercrops and mono-cropping as it might be due to heavy competition between the main crop and intercrop during vegetative growth that results in suppressing the weeds. The regression equation is expressed in Fig. 5. The results conform to the findings of Pierre *et al.,* 2022, who reported that cereals with legume intercropping suppress the weed population.

Intercropping efficiency and yield assessment

Land equivalent ratio (LER)

The impact of intercropping on land use efficiency was assessed using the land equivalent ratio (LER). From the results obtained, LER was significantly higher (1.99) in intercropping maize with moong bean (Maize+ moong bean 1:3) and it was followed by Maize+ soybean (1:3) with 1.87 LER, other intercropping combinations were also close to higher value. This might be due to higher yield noticed in maize+ green gram (1:3) intercropping system. Lowest LER was observed in pure stand crops sole maize, sole mung bean, and Sole soybean with (1.0), as represented in Table 4. This indicates more land is required for Sole crops to produce equivalent yield to intercrops. The regression equation is represented in Fig.6.Land use efficiency was good in intercrops compared to mono-cropping. LER >1 shows the benefits of intercropping and when grown in pure stand. The results conformed with the findings of Manasa *et al.,* 2020 who reported that the highest average combined land equivalent ratio (LER) of maize and legume was obtained with maize (PR) + chickpea (2:2) and it was closely followed by maize (PR) + field pea (2:2), maize (UR) + chickpea (1:1) and maize (UR) + field pea (1:1).

Maize equivalent yield (MEY)

MEY is a metric that compares the yield of different intercrops and sole crops based on market prices. The intercropping system of maize and soybean (1:3) exhibited a significantly higher maize equivalent yield (MEY) of 11.34 t ha^{-1}, indicating a substantial increase com-

Table 4. Effect of maize with legumes intercropping on intercropping efficiency on competitive ability

Treatment	Land equivalent ratio	Maize equivalent yield (t ha^{-1})	Monetary advantage index	Area Time Equivalent ratio	Competition ratio
T_1-Sole maize	1.0 ± 0.00	5.88^e ± 5.715	--	1.0±0.00	1.00± 0.000
T_2-Sole moong bean	1.0± 0.00	--	--	1.0±0.00	1.00±0.000
T_3-Sole soya bean	1.0 ± 0.00	--	--	1.0±0.00	1.00±0.000
T_4-Maize+Mung bean (1:2)	1.75^c ± 0.00	9.09^d ± 17.240	4143.51^b±18.491	1.45^b±0.00	1.02^b±0.002
T_5-Maize+ Soybean (1:2)	1.72^d± 0.006	10.38^b ± 25.409	2609.95^d±12.608	1.68^b±0.04	1.00±0.001
T_6-Maize+ Mung bean (1:3)	1.99^a ± 0.013	10.17^c ± 39.139	4800.80^a±32.427	1.60^c±0.01	1.02^a±0.003
T_7-Maize+ Soybean (1:3)	1.87^b ± 0.011	11.34^a ± 28.323	2910.25^c±23.595	1.78^a±0.01	1.00±0.001

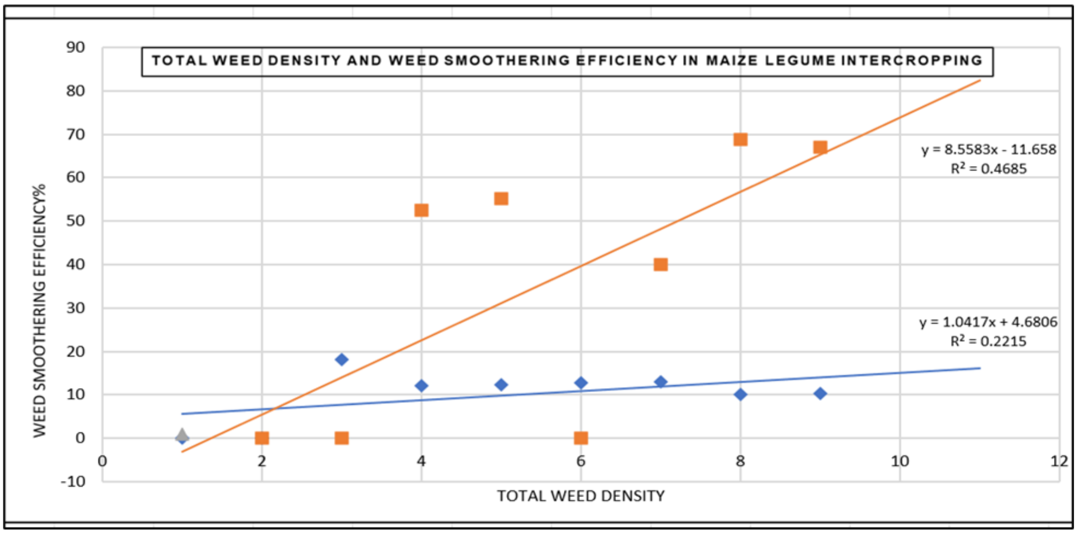

Fig. 5. *Determination of the linear regression of total weed density with weed smothering efficiency % (P ≤ 0.05, N=7, R^2=0.4685, y= 8.5583-11.658), R^2 = 0.6474, y= 1.0417x-4.6806)*

pared to other intercropping systems. The second greatest MEY of 10.38t ha^{-1} was reported in the Maize+ Soybean (1:2) cropping system. Subsequently, Maize+ Mung bean (1:3) and Maize+ Mung bean (1:2) were observed in close succession. The lowest MEY of 5.88 tons per hectare was recorded in plots where only maize was grown. The assessment of maize equivalent yield in different treatments demonstrated that intercropping maize with legumes resulted in significantly greater yields of both kernels and stover. This phenomenon can be ascribed to the increased productivity achieved through the combination of legume and cereal crops and the additional yield produced from intercropping, in contrast to the exclusive cultivation of maize. Moreover, the market price of maize and intercrops impacted the equivalent yield. Enhanced growth and yield attributes had a notable effect on the production of maize and intercrops. The results were consistent with the findings of Bekele *et al.,* 2021. The findings are consistent with the results reported by Villegas-Fernández *et al.,* 2024, which similarly indicated that intercropping with maize yielded positive outcomes.

Monetary advantage (MA)

Different intercropping techniques exhibited different monetary advantages. Intercropping is advantageous since it not only leads to higher crop yield compared to growing a single crop, but also results in increased returns per unit area and greater financial benefits. The Maize+ Mung bean (1:3) combination yielded a higher monetary gain of ₹4800.80. The second greatest monetary advantage (₹4143.51) was observed in the Maize+ moong bean (1:2) combination, closely followed by Maize+ soybean (1:3) and Maize+ Soybean (1:2). The findings mentioned above suggest that a greater density of plants and minimal spacing result in the efficient exploitation of resources and available nutrients. Additionally, the data demonstrates that intercrop production costs are lower than solo cropping due to decreased labor needed for weeding. The findings, as published by Kutamahufa *et al.* (2022) and Atumo (2022), indicate that maize-based legume intercropping with a row proportion of 1:3 ratio resulted in significant monetary gains. The results conform with earlier studies (Manasa *et al.,* 2020), which reported that the high-

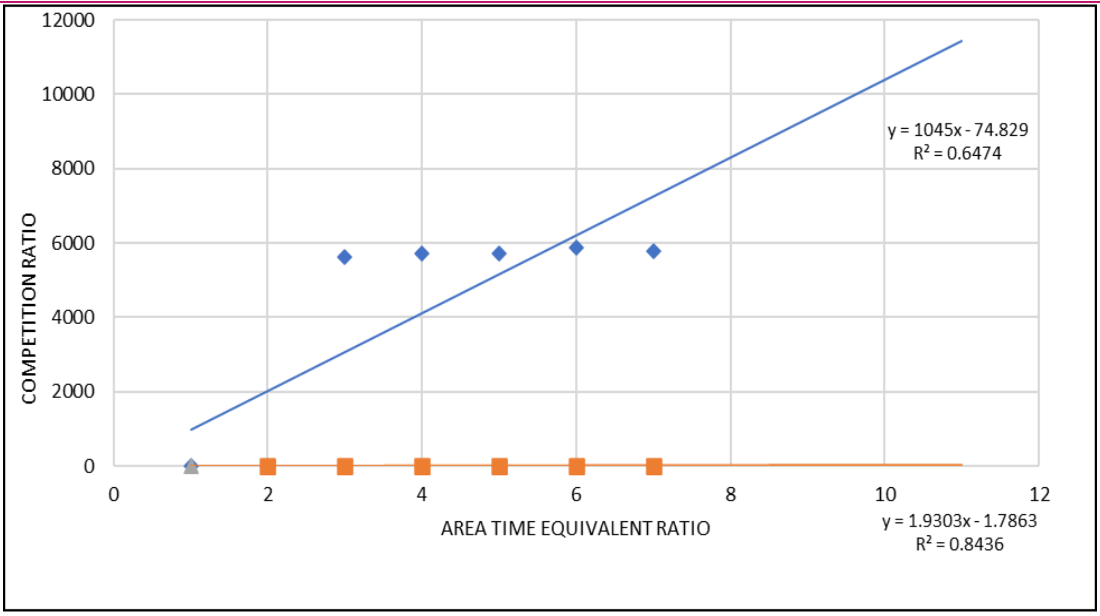

Fig. 6. *Determination of the linear regression of area time equivalent ratio with competition ratio (P ≤ 0.05, N=7, R^2=0.6474, y= 1.045x-74.829), (R^2 = 0.843, y= 1.930x-1.7863)*

est monetary advantage was recorded with maize + chickpea (2:2), followed by maize + chickpea (1:1).

Area time equivalent ratio (ATER)

The optimal utilization of area and time between intercropping and growing a single crop showed an ATER value greater than one (>1) was discovered in intercrops, while a value equal to 1 was reported in sloe crops. Out of all the intercropping treatments, the Maize+ soybean (1:3) combination had the highest ATER (1.79), with the Maize+ Soybean (1:2) combination coming in second place. The single crops in the cropping system exhibited no significant variance and had a value of one. The results were consistent with the findings of Mohammadkhani *et al.,* 2023, who determined that intercropping had a higher yield advantage than mono-cropping. Panda *et al.,* 2022 supported such results and suggested that Maize (PR) + field pea (2:3) had the highest ATER value (1.53), which was closely followed by maize (UR) + chickpea (1:2) (1.49), indicating that they used the land and time most efficiently than other intercropping systems.

Competition ratio (CR)

The competition ratio between sole crop and intercrop of legumes and maize was 1:1. The competition ratio was much greater in the Maize+ Mung bean (1:3) treatment compared to the other treatments. It was closely followed by the Maize+ moong bean (1:2) treatment. The remaining treatments did not show any significant differences among themselves. This statement indicated a reasonable and equitable competition between the intercrop and sole crop. The results were consistent with the findings of Panda *et al.,* 2022 who reported that among the legumes, the lower values were noted with maize when intercropped with legumes with a 2:2 ratio and it indicated that 2:2 proportions created a balanced competition in maize-legume intercropping system. The results clearly showed the complementary and competitive relationship among crops in the mixed stands, probably because of the adopted row proportion and planting geometry (Manasa *et al.,* 2020).

Conclusion

The research indicates that intercropping systems, specifically maize paired with mung bean in a 1:3 ratio, markedly enhanced maize yield and its attributes, weed management, and overall resource utilization efficiency compared to sole maize cultivation. This intercropping system achieved the highest metrics: cobs per plant (1.83), cob rows (17.6), grains per cob (484.3), grain yield (5882.0 kg/ha), stover yield (7519.0 kg/ha), and test weight (386.5 g). Augmented nitrogen fixation and synergistic relationships between maize and legumes facilitated these enhancements. Regarding weed dynamics, the maize+ mung bean (1:3) combination efficiently reduced weed density and biomass, attaining the maximum weed suppression efficacy (68.7%) due to the denser intercrop canopy. Moreover, the intercropping system exhibited enhanced land-use efficiency, achieving the highest land equivalent ratio (1.99), an elevated maize equivalent yield (11.34 t/ha), and notable economic advantages through augmented yields and diminished weed management expenses. These findings highlight the potential of intercropping as a sustainable method to enhance productivity and profitability while reducing weed pressure in maize cultivation systems.

ACKNOWLEDGEMENTS

We thank the Department of Agronomy, Lovely Professional University of Phagwara, for extending the support needed to complete this work.

Conflict of interest
The authors declare that they have no conflict of interest.

REFERENCES

1. Abbas RN, Arshad MA, Iqbal A, Iqbal MA, Imran M, Raza A & Hefft DI. (2021). Weed spectrum, productivity and land-use efficiency in maize-gram intercropping systems under semi-arid environment. *Agronomy*, 11, 1615. https://doi.org/10.3390/agronomy11081615
2. Ananthi T, Amanullah MM & Al-Tawaha, ARMS (2017). A review on maize-legume intercropping for enhancing the productivity and soil fertility for sustainable agriculture in India. *Advances in Environmental Biology*, *11*, 49-64
3. Anyoni, O. G., Susan, T., Joseph, E., Barnabas, M., & Alfred, O. (2023). Effects of Intercropping on Maize and Soybean Yield Performance, Land Equivalent Ratio, and Maize Leaf Area in Conservation Agriculture. *Journal of Agricultural Science*, *16*(1). https://doi.org/10.5539/jas.v16n1p37
4. Atumo, T. T. (2022). Maize-lablab intercropping date improves yield and suppress parthenium weed. *Cogent Food & Agriculture*, *8*(1). https://doi.org/10.1080/23311932.2022.2055270
5. Bedoussac, L., Journet, E. P., Hauggaard-Nielsen, H., Naudin, C., Corre-Hellou, G., Jensen, E. S., ... & Justes, E. (2015). Ecological principles underlying the increase of productivity achieved by cereal-grain legume intercrops in organic farming. A review. *Agronomy for sustainable development*, *35*, 911-935. https://doi.org/10.1007/s13593-014-0277-7
6. Bekele, B., Ademe, D., Gemi, Y., & Habtemariam, T. (2021). Evaluation of intercropping legume covers with maize on soil moisture improvement in misrak azerinet berbere woreda, SNNPR, Ethiopia. *Water Conservation Science and Engineering*, *6*(3), 145-151. https://doi.org/10.1007/s41101-021-00109-w
7. Berdjour, A., Dugje, I. Y., Dzomeku, I. K., & Rahman, N. A. (2020). Maize–soybean intercropping effect on yield productivity, weed control and diversity in northern Ghana Melbourne: John Wiley & Sons Australia, 20(2),69-81 https://doi.org/10.1111/wbm.12198
8. Bilalis, D., Papastylianou, P., Konstantas, A., Patsiali, S., Karkanis, A., & Efthimiadou, A. (2010). Weed-suppressive effects of maize–legume intercropping in organic farming. *International Journal of Pest Management*, *56*(2), 173-181. https://doi.org/10.1080/09670870903304471
9. Caballero, R., Goicoechea, E. L., & Hernaiz, P. J. (1995). Forage yields and quality of common vetch and oat sown at varying seeding ratios and seeding rates of vetch. *Field crops research*, *41*(2), 135-140.
10. Donald, C. M., & Hamblin, J. (1976). The biological yield and harvest index of cereals as agronomic and plant breeding criteria. *Advances in agronomy*, *28*, 361-405. https://doi.org/10.1016/S0065-2113(08)60559-3
11. Elhabbak, A., & El-mehy, A. (2023). Eco-friendly treatments for weed control in maize fields intercropped with cowpea. *Environment, Biodiversity and Soil Security*, *7*,149-161 https://dx.doi.org/10.21608/jenvbs.2023.219835.1222.
12. Falade, A. A., Lagoke, S. T. O., Adigun, J. A., Pitan, O. R., & Osunleti, S. O. (2023). Growth and yield of maize (Zea mays L.) as influenced by cropping pattern and weed control treatments in the forest–savanna agro-ecological zone of southwest Nigeria. *Acta fytotechnica et zootechnica ,26*(2) 55–162. https://doi.org/10.15414/afz.2023.26.02.155-162
13. Gazoulis, I., Kanatas, P., Antonopoulos, N., Tataridas, A., & Travlos, I. (2022). False seedbed for agroecological weed management in forage cereal–legume intercrops and monocultures in Greece. *Agronomy*, *13*(1), 123. https://doi.org/10.3390/agronomy13010123
14. Hetta, G., Rana, S., Babal, B., Sharma, G., Sharma, R., & Kumar, S. (2023). Assessment Of Organic Weed Management Practices For Profitability And Energetics Of Maize-Based Cropping System In North-Western Himalayan Region. *Applied Ecology & Environmental Research*, *21*(4).
15. Hirwe, O. R., Kumar, S., Sri, K. H., Reddy, P. M., Kumar, N., Nandana, S. K., ... & Fayaz, S. (2023). Different Weed Management Techniques in Maize (Zea mays L.): A Review. *International Journal of Plant & Soil Science*, *35* (13), 179-191. https://doi.org/10.9734/ijpss/2023/v35i133003
16. Kaur, M., Singh, K., & Singh, H. (2023). Varying weed management treatments impact on weeds and fodder yield relationship in fodder maize.*Indian Journal of Weed Science*. 55(1):103-106
17. Kutamahufa, M., Matare, L., Soropa, G., Mashavakure, N., Svotwa, E., & Mashingaidze, A. B. (2022). Forage legumes exhibit a differential potential to compete against maize and weeds and to restore soil fertility in a maize-forage legume intercrop. *Acta Agriculturae Scandinavica, Section B—Soil & Plant Science*, *72*(1), 127-141. https://doi.org/10.1080/09064710.2021.1998593
18. Lebreton, P., Bedoussac, L., Bonnet, C., Journet, E. P., Justes, E., & Colbach, N. (2024). Optimal species proportions, traits and sowing patterns for agroecological weed management in legume–cereal intercrops. *European Journal of Agronomy*, *159*, 127266. https://doi.org/10.1016/j.eja.2024.127266
19. Maitra, S., Manasa, P., Ram, M. S., Shankar, T., & Gaikwad, D. J. (2020). A Review on Productivity of Maize Intercropping Systems. *Indian Journal of Natural Sciences*, *11*(63), 28617-28623.
20. Manasa, P., Maitra, S., & Barman, S. (2020). Yield attributes, yield, competitive ability and economics of summer maize-legume intercropping system. *International Journal of Agriculture, Environment and Biotechnology*, *13*(1), 33-38.
21. Mohammadkhani, F., Pouryousef, M., Yousefi, A. R., & Gonzalez-Andujar, J. L. (2023). Weed community changes in saffron+ chickpea intercropping under different irrigation management. *Plos one*, *18*(5), e0286474.
22. Naderi, R., Bijani, F., Weyl, P. S., & Mueller-Schaerer, H.

(2022). Intercropping sweet corn with summer savory to increase weed suppression and yield. *Weed Technology*, *36*(4), 544-547. https://doi.org/10.1017/wet.2022.54

23. Naher Q, Karim SMR, Begum M and Hossain MA. (2020). Production potential and weed dynamics in maize legumes intercropping system. *Bangladesh Agronomy Journal*, *23*, 1-12
24. Namatsheve, T., Cardinael, R., Chikowo, R., Corbeels, M., Rugare, J. T., Mabasa, S., & Ripoche, A. (2024). Do intercropping and mineral nitrogen fertilizer affect weed community structures in low-input maize-based cropping systems? *Crop Protection*, *176*, 106486. https://doi.org/10.1016/j.cropro.2023.106486
25. Naveena, K., Madhukumar, V., Prashanth, R., & Mallikarjuna, G. B. (2015). Statistical analysis for area× time equivalent ratio (ater) to maize-urd bean intercropping system. *International Journal of Agriculture Statistical Sciences. Vol*, *11*(1), 2015.
26. Ouda, S., & Zohry, A. E. H. (2024). Legumes Improve Wheat and Maize Productivity Grown in Different Cropping Systems Under Changing Climate. In *Integration of Legume Crops with Cereal Crops Under Changing Climate: Sustainably Increasing Food Production* (pp. 107-155). Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-68102-8_4
27. Panda, S. K., Sairam, M., Sahoo, U., Shankar, T., & Maitra, S. (2022). Growth, productivity and economics of maize as influenced by maize-legume intercropping system. *Farming and Management*, *7*(2), 61-66.
28. Pierre, J. F., Latournerie-Moreno, L., Garruña, R., Jacobsen, K. L., Laboski, C. A., Us-Santamaría, R., & Ruiz-Sánchez, E. (2022). Effect of maize–legume intercropping on maize physio-agronomic parameters and beneficial insect abundance. *Sustainability*, *14*(19), 12385. https://doi.org/10.3390/su141912385
29. Sahoo, S., Seleiman, M. F., Roy, D. K., Ranjan, S., Sow, S., Jat, R. K., ... & Gitari, H. (2024). Conservation agriculture and weed management effects on weed community and crop productivity of a rice-maize rotation. *Heliyon*, *10* (10) e31554 .https://doi.org/10.1016/j.heliyon.2024.e31554.
30. Sahoo, U., Maitra, S., Dey, S., Vishnupriya, K. K., Sairam, M., & Sagar, L. (2023). Unveiling the potential of maize-legume intercropping system for agricultural sustainability: A review. *Farming and Management*, *8*(1), 1-13.
31. Sharma, N., & Rayamajhi, M. (2022). Different aspects of weed management in maize (Zea mays L.): A brief review. *Advances in Agriculture*, *2022*(1), 7960175.
32. Solanki, K., Pandey, I. B., Kumar, M., Singh, R. S., Prasad, S. S., & Pradhan, J. (2023). Effect of Planting Pattern, Fertilizer Levels and Weed Management Practices on System Productivity and Economics of Pigeonpea-Based Intercropping System. *Journal of Experimental Agriculture International*, *45*(11), 49-57.
33. Villegas-Fernández, Á. M., Amarna, A. A., Moral, J., & Rubiales, D. (2024). Intercropping as a Strategy for Weed Management in Faba Bean (*Vicia faba* L.). *Agronomy*, *14* (6), 1170. https://doi.org/10.3390/agronomy14061170
34. Wienberg, J., & Gerowitt, B. (2023). Intercropping with Lolium spp. instead of applying soil-active herbicides confined weeds in three years of continuous maize cropping. *Crop Protection*, 106373. https://doi.org/10.1016/j.cropro.2023.106373