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Growth and Yield Performance of Maize in *Flemingia semialata* Roxb. ex W.T. Aiton and *Senna timoriensis* (DC.) H.S. Irwin and Barneby Alleys under Different Conservation Farming Practice

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ABSTRACT

Background: A comprehensive agronomic investigation was undertaken to assess the impact of different conservation farming practices on growth and yield of maize (*Zea mays*) within alley cropping systems established using *Flemingia semialata* and *Senna timoriensis* as companion woody hedgerow species in Sakawrtuichhun, Mizoram, during 2021 (April-July) and 2022 (April-July) for two seasons respectively.

Methods: A Factorial Randomized Block Design with eight treatments (T_0-T_7) and three replications was used, with alleys spaced at 3 m having a plot size of 2 m × 3 m. Treatments comprised various combinations of tilling, crop residue mulching and crop rotation with the application of pruned biomass from the hedgerow species.

Result: The data analysis revealed significant variations ($p<0.05$) among treatments and maize performance. Maize exhibited superior growth and yield parameters in *Flemingia semialata* alleys compared to *Senna timoriensis* alleys. Treatment T_3 (Tilling + crop residue as mulch + crop rotation) demonstrated the highest grain yield and benefit-cost ratio among all treatments. The findings conclusively suggest *Flemingia semialata* alley cropping system combined with crop residue application as mulch, conventional tilling and crop rotation by a legume crop as an effective agroforestry approach for optimizing maize yields under the specific agroecological conditions of the study area.

Key words: Alley cropping, Benefit cost ratio, Grain, Mulch, Tilling, Woody perennial.

INTRODUCTION

Shifting cultivation remains the dominant agricultural practice in Mizoram, a hilly state in northeast India. The traditional system of land-use maintained soil health through cultural practices and extended fallow periods (Giri *et al.,* 2020). Increasing population pressure has resulted in short fallow cycles, leading to soil degradation and reduced crop yields (Das *et al.,* 2023). This necessitates the development of sustainable farming alternatives optimizing land use, while maintaining soil fertility. Alley cropping emerges as a *via*ble solution, where crops are cultivated between rows of trees or shrubs. This system offers benefits of both short-term income from crops and long term returns from woody perennials by improving soil fertility through mulching with pruned biomass (Fahad *et al.,* 2022) and enriching the soil with nitrogen and organic matter (Rawat *et al.,* 2022). As a result, it serves as an economically *via*ble and ecologically sustainable land-use approach.

Maize (*Zea mays*) plays a crucial role in India's agricultural landscape and ranks the third most important cereal crop. As per the World Data Atlas 2023, the average maize yield for India was 3.43 tonnes per hectare, experiencing world's sixth largest producer with an average annual increase of 3.35% between 1974 and 2023 (Maize Outlook 2023). This crop is also an important cereal crop in Mizoram and is primarily cultivated alongside rice in a jhum land (Singh *et al.,* 2019). Lately, agroforestry has been popularized in the state as an alternative to age-old shifting cultivation practice.

Introduction of maize in agroforestry systems has shown a positive impact on yield with 16% higher than

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other land use system (Lenga *et al.,* 2024). Tillage and crop residue management are important components of conservation farming practices as it provides favorable conditions for plant growth influencing soil health and crop yield to a greater extent. Although alley cropping system is highly advocated as a soil conservation strategy for sustaining agricultural productivity in a sloppy terrain, little work has been done on this cropping system in the region. It is hypothesized that mulch from the pruned biomass, zero tillage and crop rotation gives better yield and growth than ordinary/traditional cropping systems. Therefore, the present study was done to assess the growth and yield of maize in cropping systems using two leguminous woody perennials *viz.*, *Flemingia semialata* and *Senna timoriensis* managed under different conservation farming practices.

MATERIALS AND METHODS

Study area

The study was carried out in a farmer's field near Mizoram University during 2021 (April-July) and 2022 (April-July) for two seasons at Sakawrtuichhun (23°46′24.14″N and 92°40′18.92″E; 710 masl) of Aizawl district, Mizoram. The area experiences a warm, humid climate, with a mean annual rainfall of 2700 mm. The soil is acidic (pH 5-6) and well-drained with a sandy clay loam texture. Two woody perennials *viz.*, *Flemingia semialata* and *Senna timoriensis* were planted in a spacing of 2 m apart with an alley width of 3 m with maize grown in between the alleys of two woody perennials, respectively. The woody perennials were planted in 2018 and pollarded at a height of 0.5 m above ground 1 year before the experiment was laid.

Experimental design

A factorial randomized block design (RBD) was used in the experiment. It consists of three (3) *Senna* alleys and three (3) *Flemingia* alleys as the main plots with eight (8) subplots (2 × 3 m^2) in each alley in which treatments were laid out consisting of three replications for each treatment. The guard area between plots was 50 cm, the woody perennials were pruned in the month of March 2021 and the pruned materials were spread evenly throughout the subplots. The treatments laid were as follows: T_0: Tilling + no crop residue as mulch+ no crop rotation; T_1: Tilling + no crop residue as mulch + crop rotation; T_2: Tilling + crop residue as mulch + no crop rotation; T_3: Tilling + crop residue as mulch + crop rotation; T_4: No Tilling + no crop residue as mulch + no crop rotation; T_5: No Tilling + no crop residue as mulch + crop rotation; T_6: No Tilling + crop residue as mulch + no crop rotation; T_7: No Tilling + crop residue as mulch + crop rotation. Tilling was done at a depth of 10 cm twice before sowing the crop by hand hoeing. In the treatments with no-tilling, the plots were left undisturbed, except when the seeds were sown by dibbling. Manual weeding was done before and after the crop establishment.

Sowing and harvesting

Local maize variety 'Mimban' was sown with 45 cm × 60 cm spacing using three plants per hill. All plots except the control (T_0) received basal fertilizer at 80:60:40 NPK/ha. Five randomly selected plants per plot were evaluated at harvest (100 DAP) for growth and yield parameters (plant height, leaf numbers, cob length and weight, grain number and weight). Results were presented separately for plantings under *Flemingia semialata* and *Senna timoriensis*, expressing the mean values of growth parameters on per plant basis and yield parameters calculated per hectare basis.

Economic analysis

Maize grained was priced at Rs. 40 based on local market prices and a labor cost was Rs. 249 per 8-hour workday, as per MNGREGS, Mizoram. Variable costs include land preparation, pruning, tilling, fertilizer application, sowing, weeding, residue management and harvesting.

Statistical analysis

All the recorded data were computed using OPSTAT (online software) for ANOVA using a Factorial Randomized Block Design at a significance level of 0.05. Microsoft Excel was used for the data organization.

RESULTS AND DISCUSSION

Growth parameters

Growth parameters of maize were not significantly different between the alleys and across the various treatments. From the pooled data (Table 1), *Flemingia* alley in T_3 (198.20 cm) exhibited the highest plant height, whereas T_5 (138.37 cm) from the *Senna* alley had the shortest height. The highest number of leaves was recorded under the *Flemingia* alley T_3 (12.60), whereas the lowest leaf count was observed in T_5 (9.25) from the *Senna* alley. The height and number of leaves in both alleys had a pronounced effect on tilling treatments compared to other treatments. Similar results were obtained by Kumari *et al.* (2024) on the growth and yield of sweet corn under conventional tillage compared with zero tillage. Hakim *et al.* (2022) and Sumitra *et al.* (2025) also found a positive effect of tillage on the growth and yield components of green gram and wheat respectively. Tilling might have created favorable environment for faster decomposition and release of nutrients from the applied plant biomass at initial stages of plant growth thereby resulting in taller height of maize in treatments T_3 of *Flemingia* alley and T_0 of *Senna* alley. This finding is in line with the findings by Ramadhan (2021), where deep tillage, conventional tillage and mulch treatments recorded taller plants. da Costa Leite *et al.* (2019) also observed that the plant height, panicle diameter, panicle length of sorghum perform better in *Gliricidia sepium* and *Leucaena leucocephala* alleys than mono-cropping system of sorghum. Higher plant height and crop yield on maize and soybean was also reported by Liu *et al.* (2023) under straw mulching and intercropping. The lower plant height in the treatments between *Flemingia* and *Senna* alleys in the present study could be due to zero tillage or minimum tillage which is also reported by Anjum *et al.* (2014). Overall, the growth and germination of maize in all treatments of the *Flemingia* alley were superior to those of *Senna* alley. This could be due to higher shading effect of *Senna* during the middle growth stages of maize. This effect was also reported by Koyejo *et al.* (2023) where an increase in the space between the tree and maize resulted in better yield. The tallest plant height of maize was also obtained by Taye and Kelil (2023) in alley cropping of *Sesbania sesban* and *Cajanus cajan* which was similar to the results obtained in the present study.

Yield parameters

The cob length and weight was found maximum in T_2 from the *Senna* alley and minimum in *Flemingia* alley at T_4. The number of seed per cob and seed weight was also found highest in *Senna* alley in T_2 and the lowest in T_4 from *Flemingia* alley (Table 2). The high yield parameters observed under *Senna* alley (T_1 and T_2) and *Flemingia* alley (T_0) may be attributed to tilling and application of pruned materials incorporated as mulch gives better yield in maize. Also crop residue used as mulch in T_2 had a residual advantage in sustaining the yield parameters of cob length and cob weight in the next cropping season. Manu *et al.* (2018) in their study reported that application of thick mulch and hedgerow increases the yield of taro. The effect of crop residue retention on the growth and performance of maize was also reported by Malgaya *et al.* (2023) and Sahoo *et al.* (2024). Liu *et al.* (2023) recorded higher yield of maize and soybean under residue management in the form of mulching than the yield in mono-cropping system. Similarly, Baier *et al.* (2023) and Dey *et al.* (2023) also reported from their study that higher yield of maize and pulses due to addition of tree pruning and crop rotation.

Table 1: Mean growth of maize (Pooled for two years).

Treatments	Plant height (cm)				Number of leaves			
	Senna		*Flemingia*		*Senna*		*Flemingia*	
T_0	193.107		177.247		12.517		11.877	
T_1	191.443		191.198		12.34		12.138	
T_2	185.935		172.978		12.395		11.438	
T_3	174.873		198.205		12.085		12.603	
T_4	179.36		148.565		12.052		9.795	
T_5	138.367		174.952		9.25		11.893	
T_6	176.06		177.972		11.832		11.542	
T_7	176.327		175.975		11.472		11.682	
	CD	SE (m)	CD	SE (m)	CD	SE (m)	CD	SE (m)
At treatment level	N/A	13.863	N/A	10.597	N/A	0.809	N/A	0.777
At year level	18.94	6.264	N/A	6.83	1.248	0.413	1.007	0.333
Factor year at the same level of treatment	N/A	19.605	N/A	14.987	N/A	1.144	N/A	1.099

Table 2: Mean yield parameters and grain yield (kg/ha) of maize (Pooled for two years).

Parameters	Cob length (cm)		Cob weight (g)		No. of seeds per cob		Seeds weight (g)		Grain yield (kg/ha)	
Treatments	S	F	S	F	S	F	S	F	S	F
T_0	11.2	12.24	33.2	37.66	360.7	405.7	66.6	85.95	1473.11	2808.88
T_1	12.0	12.13	40.3	36.99	399.8	428.3	85.2	89.12	2306.22	2976.88
T_2	12.6	11.25	43.3	33.26	431.5	379.2	90.5	75.95	2187.11	2557.56
T_3	12.0	12.19	40.8	39.16	393.0	416.5	82.4	88.77	2158.22	3713.33
T_4	11.7	9.07	35.9	25.99	380.9	280.1	71.9	53.13	1656.44	1076.17
T_5	9.8	11.88	30.2	38.8	321.6	386.1	66.6	82.92	1103.84	2112.44
T_6	11.5	11.64	34.1	35.35	376.0	383.3	69.0	80.21	1044.35	1949.78
T_7	11.4	11.22	35.9	33.58	362.1	370.0	66.1	69.87	1239.78	1865.95
	C.D.	SE(m)	C.D.	SE(m)	C.D.	SE(m)	C.D.	SE(m)	C.D.	SE(m)
Treatment level	N/A	0.71	N/A	2.55	N/A	21.41	N/A	6.54	750.90	220.74
Alley level	N/A	0.37	N/A	1.18	N/A	9.46	N/A	2.4	255.13	77.03
Alley at the same level of treatment	N/A	1.01	N/A	3.6	N/A	30.28	N/A	9.25	734.8	312.17

Grain yield

The mean grain yield for the two cropping seasons (2021-2022) among treatments (p=0.01), between alleys (p=0.001) and the interaction between treatments and alleys was found to be significantly (p=0.02) different. From the pooled data in Table 2, the highest grain yield in *Senna* alley was observed in T_1 (2306.22 kg/ha) compared to T_6 (1044.35 kg/ha) which produced the lowest grain yield. Similarly, in *Flemingia* alley, the highest grain yield was obtained from T_3 (3713.33 kg/ha) and T_4 (1076.17 kg/ha) recorded the lowest grain yield. Similar level of grain yield was recorded by Mupangwa *et al.* (2021) under maize-legume intercropping under conservation agriculture with grain yield of 3709 kg/ha. During the cropping years, fall armyworm (FAW) (*Spodoptera frugiperda* JE Smith) infestations posed a significant challenge during the initial crop growth stages. These pest attacks threatened to reduce grain yields below the projected maximum potential yield of 4620 kg/ha under rainfed conditions in Aizawl district (FAO, 2021). However, favourable rainfall patterns and effective agronomic practices helped mitigate the pest damage and ultimately supported an enhancement of the grain yield. A positive effect on yield was observed in the first year which might be due to the land not being used for intensive agriculture for a long period. The same observation was reported in a study on conservation agriculture by Ngwira *et al.* (2012). The lower grain yield under no-till plots in the present study may be due to non-uniform seedling emergence from the compacted soil, resulting in a slower growth rate which was also reported by Otieno *et al.* (2020). Yu *et al.* (2023) also recorded higher yield of maize in deep tilling when compared to no tillage experiment. Furthermore, Gong *et al.* (2023) and Menaie *et al.* (2024) mentioned that optimum tilling improves root growth, development and the yield of crops.

Neamatollahi *et al.* (2021), found a higher yield of melon when tillage was performed in combination with the incorporation of crop residue. Management practices like tilling; crop residue mulch and mulch from pruning materials have shown better growth and yield on maize (Isaac *et al.,* 2004; Hussain *et al.,* 2020; Buttar *et al.,* 2023). Akume *et al.* (2015) in their study also concluded that higher yield of maize was obtained in alley cropping due to soil improvement from the pruning materials. Between the alleys, maize grain yield was higher under *Flemingia* alley. The lower yield of maize under *Senna* alley could be due to the faster rate of decomposition of leaf litter, which allows the presence of nutrients for a shorter period while higher yield was obtained under *Flemingia* alley which decomposed slower allowing nutrient retention for longer period in soil which is also in accordance with the findings by Okogun *et al.* (2000) in *Albizzia lebbeck* alley cropping. Sharif *et al.* (2023) also reported that alley cropping system with *Sesbania grandiflora* and *Leucaena leucocephala* improved the yield performance of carrot due to increased soil fertility which is in consistent with the present findings.

Benefit cost analysis

In *Senna timoriensis* alleys, T_1 showed the highest gross returns, net returns and benefit-cost (BC) ratio, while T6 yielded negative net returns with lowest benefit-cost ratio. Similarly, in *Flemingia semialata* alleys, T_3 showed maximum economic efficiency, whereas T_4 resulted in negative net returns with lowest benefit-cost ratio. Labor requirement was highest in the beginning of pruning and higher weeds density was observed in *Senna* alley, as leaf litter decomposed faster. Similar findings were observed by Ruhigwa *et al.* (1994), where more laborers were used in the initial pruning and the occurrence of weeds was higher in *Senna, Gmelina* and *Alchornea*. In *Senna* and *Flemingia* alley, T_1 and T_3 showed the highest gross return, net return and BC ratio, respectively. The BC ratio in *Senna* alley ranged from 0.63-1.42 and 0.56-1.89 for *Flemingia* alley (Table 3). Similar findings was observed by Choudhary *et al.* (2020), where the BC ratio of *S. sesban* + *C. ciliaris* + pearl millet was 1.98 when compared to the mono-cropping

Table 3: Economic efficiency of maize cultivation under alley cropping systems (Pooled for two years).

Treatments	Variable cost (Rs/ha)		Gross return (Rs/ha)		Net return (Rs/ha)		Benefit: Cost ratio	
	S	F	S	F	S	F	S	F
T_0	57394.50	57394.50	58924.44	105333.33	1529.94	54961.06	1.03	1.83
T_1	77372.83	77372.83	92248.89	119075.56	24242.72	41702.72	1.42	1.54
T_2	78617.83	78617.83	87484.44	102302.22	18233.28	23684.39	1.34	1.31
T_3	78617.83	78617.83	86328.89	148533.33	17077.72	69915.50	1.29	1.89
T_4	77372.83	77372.83	66257.78	43047.11	-1748.39	-34325.72	1.01	0.56
T_5	77372.83	77372.83	44153.78	84497.78	-23852.39	7124.94	0.65	1.09
T_6	78617.83	78617.83	41774.22	77991.11	-27476.94	-626.72	0.63	0.99
T_7	78617.83	78617.83	49591.11	74638.22	-19660.06	-3979.61	0.74	0.95
							C.D.	SE (m)
Treatment level						0.479		0.141
Alley level						0.178		0.054
Alley at the same level of treatment						N/A	0.199	

S: *Senna*; F: *Flemingia*

system. Takawale *et al.* (2022) also found a BC ratio of 1.92 in maize and cowpea intercropping during the Kharif season. Additionally, Rahman *et al.* (2017) opined that any agroforestry system had a higher NPV and BC ratio higher than other land use systems. Similarly, Xu *et al.* (2019) also found that the Land Equivalent Ratio and BC ratio of alley cropping was higher than apple or crop monoculture.

CONCLUSION

The study revealed that maize growth and grain performance were higher under *Flemingia* alley compared to *Senna* alleys. Under *Flemingia* alley, maize growth, grain yield and B:C ratio increased significantly with the treatment involving incorporation of pruning materials, tilling, crop residue mulch and crop rotation. The study suggests that alley cropping based conservation farming practices such as crop residue mulching and crop rotation with a legume crop under conventional tillage can boost maize production in hilly terrains of Mizoram. However, long-term experimentation is needed to ascertain the benefits of this farming system before recommending it to the farmers of the region.

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Conflict of interest

The authors declare that there is no conflict of interest.

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