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Effect of Tree Lucerne(*Chamaecytisus palmensis*) Alley Cropping on Soil Fertility Enhancements and Wheat *(Triticum aestivum)* Productivity in Bore District, Southern Ethiopia

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Abstract: Alley cropping is a promising agroforestry technology for the humid and sub humid tropics. In alley cropping, the addition of organic mulch has a favorable effect on soil properties and crop productivity. Therefore,this study was intended to evaluate the effect of Tree Lucerne (*Chamaecytisus palmensis*) alley cropping on soil fertility enhancements and wheat productivity in Bore District, Southern Ethiopia. The trial consisted of five treatments and it was laid out in randomized complete block design (RCBD) with three replications. Pre and post harvesting soil samples were collected and analyzed by using a standard procedure. Moreover, the yield of alley crop harvested was measured for two consecutive cropping seasons. Based on the findings of this study, the soil properties in Tree lucerne (*Chamaecytisus palmensis*) alleys such as pH,OC, total N, available P, available K, CEC, Ca and Mg were significantly higher than sole cropping of wheat with the recommended fertilizer rate. However, in terms of soil texture significant differences were not observed among the experimental treatments. The highest grain yields were obtained from 75% NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys (3650kg/ha), 100% NPS+Tree lucerne(*Chamaecytisus palmensis*) alleys (3645kg/ha) and 50% NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys (3425kg/ha) respectively. Therefore, alley cropping agroforestry practice has a high contribution to soil fertility enhancements and grown wheat with 75% NPS fertilizer application in between alleys of Tree lucerne (*Chamaecytisus palmensis*) was recommended for the study area and similar agroecologies.

Key words: Agroforestry · Alley Cropping · *Chamaecytisus palmensis* · Soil Fertility · Tree Lucerne Alleys · Wheat Productivity

INTRODUCTION

Agroforestry system is a dynamic, ecologically based, natural resource management system that, through the integration of trees in farm and range land, diversifies and sustains production for increased social,economic and environmental benefits [1]. In agroforestry system,there are different advantages of growing multipurpose tree species with crops. These include reducing wind velocity, controlling sheet and rill erosion, mediating solar radiation and regulating soil and air temperatures, increasing field moisture, improving soil nutrients and diversification of crop production [2].

Agroforestry practice encompasses several systems; among which alley cropping is considered a common practice and more than 40% of research projects in international agroforestry research institutes focus on this agroforestry system [3]. Alley cropping is an agroforestry system broadly defined as the planting of two or more sets of single or multiple rows of trees or shrubs at wide spacing, that permits the production of a variety of crops in alleys between widely spaced rows of trees [4]. Moreover, alley cropping increase tree cover, fuel wood supplies and infiltration of rain, provide protection against wind and reduce run off [5].

The trees can be planted in single or blocks of rows between the alleys. Also the tree rows can be planted with single or multiple tree species. Depending on the level of shade provided by the tree row over time, the alley crop could be changed to match the changing conditions. The tree themselves can also be managed by

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thinning, pruning and/or harvesting in order to maintain optimal growing conditions in the alley ways for the alley crops [6].

Alley cropping is an agroforestry practice where perennial, preferably leguminous trees or shrubs are grown simultaneously with arable crops. Both crops and trees are continually changing in response to environmental conditions and management that affect both the trees and crops. The effectiveness of a such a system depends on the successful management of competition for light, nutrients and water between woody species and crops [7]. The trees, managed as hedgerows, are grown in wide rows and the crop is planted in the inter space or "alley" between the tree rows. This cropping system has been widely practiced in many parts of the world, especially in the tropics [8].

Many studies showed that, alley cropping is a promising agroforestry technology for the humid and sub humid tropics. One of the most important premises of alley cropping is that the addition of organic mulch, especially nutrient-rich mulch, has a favorable effect on the physical and chemical properties of soil and hence on crop productivity [9]. Furthermore, the relative rates of decline in the status of Nitrogen, Phosphorus, pH and exchangeable bases of the soil are much less under alley cropping than under non alley cropped or continuous cropping without trees [10].

Alley cropping is an agroforestry system, similar in approach to contour hedgerow system, in which food crops are grown in alleys formed by hedgerows of trees and shrubs that are usually fast growing legumes, which enrich the soil through symbiotic nitrogen fixation and recycle nutrients from the soil [11]. The hedgerows are cut back at planting and periodically pruned during cropping, to prevent shading and to reduce competition with the associated crops. The hedgerows are allowed to grow freely to cover the land when there is no crops [12].

In Ethiopia, agricultural production system is intensively monoculture, either in large scale or in small-scale farmlands. The productivity declines from time to time due to soil fertility loss and insufficient supply of plant nutrients. The study area is also highly affected by soil erosion and necessary nutrients are also leaching continuously.This problem has a negative impact on farmers crop production, as a result of the soil of the area changed in to acidic soil overtime.

To address this problem, alley cropping agroforestry practices may play an important role for a sustainable agricultural production and soil fertility improvement; due to its ecological and economic feasibility. Therefore, the objectives of the study were to evaluate the effect of Tree lucerne (*Chamaecytisus palmensis*) alley cropping agroforestry practice on soil fertility enhancements and wheat (*Triticum aestivum)* productivity in Bore District, Southern Ethiopia.

MATERIALS AND METHODS

Description of Study Area: The experiment was conducted in Bore District, in Southern Ethiopia. The study district is located 385 km to the south of Addis Abeba, the capital city of Ethiopia. The study area is located within the latitude 6°22'30"-6°25'50" N and longitude of 44°32'30"-44°35'50" E (Fig. 1). The study district is characterized by two agroclimatic zones, namely humid which start in early April to November and sub-humid which starts late December up to beginning of March. The mean annual rainfall of the study area ranged from 1400-1800 mm with a bimodal pattern that is extended from April to November. The mean annual minimum and maximum temperature of the study district are 10°C and 20°C respectively. The dominant soil units of the study site are Nitosols (red basaltic soils) and Orphic Acrosols. The farmers of Bore district produce cereal crops such as wheat, barley and maize, pulse crops such as faba bean and chick pea. Moreover, farmers of the study district produce horticultural crops such as potato, head cabbage and other vegetables.

Selection of the Tree Species: Prior to the selection of the tree species for alley cropping agroforestry practice, there are different factors which are considered for tree species selection. These factors are: adaptability of the tree species to the study area, appropriate shade of the tree species, potential multiple products of the tree species and growth of the trees doesn't compete with inter-row cops.The multipurpose tree species (Tree lucerne) which was selected for this study is adapted to study site and fast growing tree species. Therefore, the selected multipurpose tree identified as most appropriate for soil improvement and crop sustainability for establishment of alley cropping agroforestry practice.

Design of the Tree Planting: Based on the main objective of alley cropping agroforestry practice and characteristics of the tree species selected various studies used different designs of tree planting. Thus, on this study due to the selected multipurpose tree has minimum canopy coverage, the following design of tree planting was used. Each treatment has two alleys/hedgerows and it was replicated three times. On each alleys/hedgerows, ten

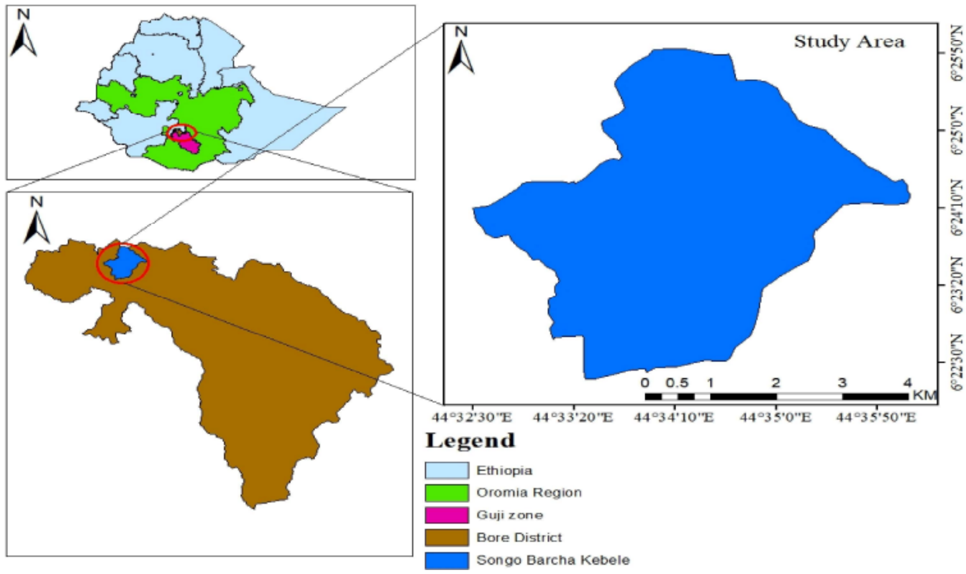

Fig. 1: Map showing the location of the study area

Tree lucerne (*Chamaecytisus palmensis*) seedlings were planted at 1.5m spacing. The space between each treatment (between the two alleys) was 10 m wide.

Management of the Tree Species: At the nursery site, seedlings of the Tree lucerne (*Chamaecytisus palmensis*) multipurpose tree species were prepared at the proper soil-mix ratio for better growth of the seedlings. After seedlings of the tree species grew effectively at the nursery site, their planting was carried out on the experimental site. For better performance of the crop which was planted between alleyways, canopy management (Pruning) was carried out at a proper time. Because, if there is too much shade under an existing stand of trees, the canopy can be pruned to allow more light to reach the under story plants. Moreover,branch pruning of the tree was left on the experimental site and improving soil fertility through decomposition. However, only up to 40% of the tree branches were pruned simultaneously. Because, most of the studies indicated that removing more than 40% of the trees foliage was significantly reduced the growth of the tree species.

Description of Crop Component

Selection of the Crop Variety: For this experiment, alley crop which was selected and planted between the Tree lucerne (*Chamaecytisus palmensis*) alleys was cereal crop. From different cereal crops common to the study area and their adaptability had been done at Bore Agricultural Research Center so far, one improved wheat variety was selected based on its adaptability, disease resistance and high yielder of the crop.

Crop Spacing and Design: The first year involved the establishment of Tree lucerne (*Chamaecytisus palmensis*) multipurpose tree on experimental site. After the selected multipurpose tree species established, the subsequent years involved alley cropping between the tree alleys. After one year duration of the tree alleys, Huluka bread wheat variety was used as an alley crop and planted on a plot size of 20m x 8m between the tree alleys. Within the Tree lucerne (*Chamaecytisus palmensis*) alleys the selected bread wheat variety was planted in rows at a recommended planting space.

Experimental Design and Treatments: The trial was conducted at Bore Agricultural Research Center, on Songo Berecha Research station in a Randomized complete block design (RCBD) with five treatments and three replications. The experiment was conducted with one improved bread wheat variety which is called Huluka adapted to the area and planted between alleys of the Tree lucerne(*Chamaecytisus palmensis*) legume tree species. The treatments were as follows;

25% NPS fertilizer + Tree lucerne (*Chamaecytisus palmensis*) alleys

50% NPS fertilizer + Tree lucerne (*Chamaecytisus palmensis*) alleys

75% NPS fertilizer + Tree lucerne (*Chamaecytisus palmensis*) alleys

100% NPS fertilizer + Tree lucerne (*Chamaecytisus palmensis*) alleys

Sole cropping of bread wheat with recommended fertilizer rate

Data Collection

Soil Sample: Before establishing the Tree lucerne (*Chamaecytisus palmensis*) alleys and after each alley cropping seasons soil samples of each plots were collected. A total of 16 soil samples were collected randomly from 0-30 cm soil depth and bulked into a composite soil sample. The composite soil samples were air dried, grounded and sieved with 2 mm mesh for chemical analysis. Soil pH was determined in free ion water and KCl 1M solution in 1:5 (soil: solution ratio), The organic carbon of the soils was determined by Walkley and Black method [13], Total nitrogen was determined using the micro-Kjeldahl method [14] and the available phosphorus (AP) was determined following the Olsen procedure [15]. The Potassium contents of the extract was determined with flame photometer. Meanwhile, Ca and Mg were determined with an atomic absorption spectro-photometer. The Cation Exchange Capacity (CEC) was determined after extraction of the samples with 1 N ammonium acetate [16].

Performance of the Tree: After Tree lucerne (*Chamaecytisus palmensis*) multipurpose tree was planted on experimental site, close supervision was carried out and their survival rate was recorded effectively. If some of the seedlings not survive, those un survived seedlings were replaced soon.

Yield Measurement: In each cropping season, the yield of the alley crop (wheat production) harvested from each Tree lucerne (*Chamaecytisus palmensis*) alleys was measured for two consecutive years. The manual harvesting of wheat production from between the alleys and sole cropping (without trees) was conducted at a proper harvesting time.

Statistical Analysis: Wheat grain yield data was recorded in each plot and analyzed using analysis of variance (ANOVA). In addition, the soil sample data was also analyzed using analysis of variance (ANOVA). The treatment means that were significantly different at a 5% level of significance were separated using Duncan and LSD tests by using Gen stat 18th Edition Software Programme.

RESULTS AND DISCUSSION

Pre and Post-harvesting soil Properties: Composite soil samples were taken and subjected for analysis for Soil texture, pH, OC, total N, available P,CEC, available K, Ca and Mg. The soil laboratory results of Pre-planting and Post harvesting soil Physical and Chemical properties are indicated below in Table 1-4.

Table 1: Pre-planting soil physical and chemical properties

Soil Properties	Values of Soil Properties
Sand %	26
Silt %	32
Clay %	42
Textural class	Clay
pH (H_20)	5.10
Organic carbon %	2.87
Total Nitrogen %	0.32
Available Phosphorus (mg/kg)	2.15
Calcium (mg/kg)	171.4
Magnesium (mg/kg))	200.84
Available Potassium (mg/kg)	153.73
Cation Exchange Capacity (CEC) c mol/kg	12.5

Pre-planting Physical and Chemical Soil Properties: Table 1 shows, the pre-planting physical and chemical soil properties of the study site before the establishment of the Tree lucerne *(Chamaecytisus palmensis)*alleys at a depth of (0-30 cm). The soil analysis results showed that the soil textural class of the experimental site was clay. According to Brady and Weil [17], water holding capacity, compactability, ability to store plant nutrients and resistance to pH change of the soil is high. However, decomposition of organic matter and susceptibility to water erosion of the soil is slow and suitability to tillage after rain is very poor.

The pre-planting pH of the soil was 5.1. According to the Landon [18] tropical soil rating manual the soil was strongly acidic. The findings of Ward Chesworth [19] also indicated that high soil acidity is accompanied by a low cation-exchange capacity and a low base saturation, both of which lead to problems when these soils are utilized in agriculture. Nutrient deficiency and high levels of exchangeable aluminum are the main problems. Therefore acidic soils require liming and constant fertilization when used in agricultural production. The pre-planting soil analysis results of soil organic carbon (OC), total N and available P were 2.87%, 0.32% and 2.15mg/kg, respectively (Table1). According to the classification of Landon [18] the total N was high. The recorded total N content which was 0.32%, is higher than the 0.15% N critical level for crops recommended by Sobulo and Osiname [20]. However, the values of soil organic carbon (OC) and available P were low according to the classification of tropical soil rating manual of Landon [18] and Enwezor *et al.* [21].

Table 2: Post-harvesting soil properties of experimental site along study years (2021-2022)

	Sand %		Clay%		Silt%		Textural class	
Treatments	2021	2022	2021	2022	2021	2022	2021	2022
25% NPS + Tree lucerne alleys	31.33[a]	31.35[a]	38.00a	38.21[a]	30.67a	30.70[a]	Clay	Clay
50% NPS + Tree lucerne alleys	30.73[a]	30.75[a]	39.33a	39.55[a]	29.33a	30.10[a]	Clay	Clay
75% NPS + Tree lucerne alleys	31.25[a]	31.33[a]	39.33a	39.67[a]	29.33a	30.21[a]	Clay	Clay
100% NPS + Tree lucerne alleys	30.00[a]	30.25[a]	39.33a	39.47[a]	30.67a	30.72[a]	Clay	Clay
Sole cropping of wheat	33.00[a]	33.12[a]	39.00a	39.25[a]	28.00a	29.21[a]	Clay	Clay
Mean	31.26	31.36	39	39.23	29.60	30.18		
LSD(5%)	NS	NS	NS	NS	NS	NS		
CV(%)	10.2	10.2	5.3	5.3	7.2	7.2		

**Mean values in the same column with the same superscript are not significantly different, LSD- Least significance difference, CV-Coefficient of variance, NS-Non-Significant*

The recorded values of available K, Ca and Mg were 153.7,171.4 and 200.84 mg/kg respectively. Whereas, the amount of CEC soil result was only 12.5 c mol/kg (Table 1). The cation exchange capacity (CEC) of the soil reflects the soil's ability to hold K and other cations and store them in the soil for crop uptake. Clay minerals and soil organic matter are the two parts of soil that contribute to CEC. In general, the higher the CEC of the soil, the greater the storage capacity and supply power for K. The low K and CEC observed in this study could be due to low levels of organic matter. This showed that the soils of the study site had low nutrient reserve since both CEC and organic matter were widely used as indicators of soil fertility.

Post-Harvesting Physical and Chemical Soil Properties: The physical and chemical soil properties of post-harvesting results are presented in Table 2, 3 and 4 respectively.

Soil Texture: Knowledge of the proportions of different-sized particles in a soil that is soil texture is critical for understanding soil behavior and management. Soil texture is also one of the most important physical properties of soil that affects its fertility and productivity. Therefore, when investigating soils on a site, the texture of various soil horizons is often the first and most important physical properties of soil to determine, for one can draw many conclusions from this information. Based on the findings of this study, the percentage of clay, sand and silt was not significant among the treatments. In both cropping season,the soil texture of the experimental treatments were categorized under clay and it is also texturaly similar with soil tested results of the pre-planting soil properties.

Soil pH: In 2021 cropping year, the pH value of 100% NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys was significantly (P<0.05) increased over 25% NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys, 50% NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys and sole cropping of bread wheat (Table 3). However, significant differences in soil pH values were not recorded between 100% NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys and 75% NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys (Table 3).The recorded soil pH results of both treatments were pH 5.97 and pH 5.62, respectively and the degree of their acidity was categorized under moderately acidic soil.

In the 2022 cropping season, similarly the pH results of 100% NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys was significantly (P<0.05) higher than the others (Table 3). However,it is not significantly different with 75% NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys.The present study also showed that, significant differences in soil pH value were not observed among 25% NPS +Tree lucerne (*Chamaecytisus palmensis)* alleys and 50% NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys and the degree of their acidity was categorized under strongly acidic soil. However,the soil pH values of the bread wheat grown alone used as a control was pH 4.76 and it was very strongly acidic.

As compared to the sole cropping of bread wheat with the recommended fertilizer rate, the increase in pH values in all the alley treatments could be due to the decomposition of the incorporated materials from pruning of Tree lucerne *(Chamaecytisus palmensis)* alleys. In line with this study,on their former study results [22-24] have reported the beneficial effects of alley cropping on soil fertility maintenance as well as the differential effects of alley/ hedgerow species on soil fertility parameters.

Soil Organic Carbon: From the findings of this study observed that, soil organic carbon in all the Tree lucerne (*Chamaecytisus palmensis*) alleys treatments were significantly (P<0.05) higher than the fertilized treatment (Bread wheat + recommended fertilizer rate) (Table 3).

Table 3: Post-harvesting soil properties of experimental site along study years (2021-2022)

	pH		OC(%)		TN(%)		Available P	
Treatments	2021	2022	2021	2022	2021	2022	2021	2022
25% NPS + Tree lucerne alleys	5.25[bc]	5.25[bc]	1.96[b]	3.14[a]	0.33[a]	0.27[b]	2.56[c]	2.66[c]
50% NPS + Tree lucerne alleys	5.04[c]	5.37[b]	3.16[a]	3.29[a]	0.35[a]	0.28[ab]	3.75[b]	3.85[b]
75% NPS + Tree lucerne alleys	5.62[ab]	5.79[ab]	3.25[a]	3.71[a]	0.34[a]	0.31[a]	5.65[a]	5.69[a]
100% NPS + Tree lucerne alleys	5.97[a]	6.28[a]	3.11[a]	3.43[a]	0.32[a]	0.32[a]	6.11[a]	6.23[a]
Sole cropping of wheat	4.62[d]	4.76[c]	1.85[b]	1.70[b]	0.28[b]	0.12[c]	2.24[d]	2.21[d]
Mean	4.45	5.49	2.66	3.05	0.85	0.26	4.07	4.45
LSD(5%)	0.59	0.59	0.57	0.44	0.09	0.05	0.95	0.59
CV(%)	7.1	5.7	11.4	7.7	6.3	11.6	12.8	7.1

**Mean values in the same column with the same superscript are not significantly different, Mean values in the same column with different superscript are significantly different, LSD- Least significance difference, CV-Coefficient of variance*

Whereas, only in 2021 cropping year significant differences in soil organic carbon were not recorded between 25% NPS+Tree lucerne *(Chamaecytisus palmensis)* alleys and bread wheat grown alone used as a control (Table 3).The findings of this study supported by previous study results of Atta-Krah *et al.* [25], reported that soils under alley cropping system were higher in organic carbon and total nitrogen than soils without alley/hedgerow tree. In support of this study, Taye and Kelil [26] also indicated that the soil organic carbon content of *Cajanus cajan* and *Susbania sesban* alley cropping plots was significantly higher than the fertilized plots.

During the study time, in the control treatment (Bread wheat + recommended fertilizer rate) the value of soil organic carbon was decreased in time from 1.85% (in 2021) to 1.7% (in 2022). However, the average soil organic carbon in Tree lucerne (*Chamaecytisus palmensis*) alleys treatments was increased in time from 2.87% to 3.39%. This could be due to incorporated pruning of the Tree lucerne (*Chamaecytisus palmensis*) alleys improved the soil organic carbon contents of the soil. In favor of the current study, on their study findings Okonkwo *et al*. [27], showed that the soil nutrient content gradually built up in the alley plots over time with continuous addition of pruning from the hedgerow trees.

Total Nitrogen: The soil analysis results showed that, in the 2021 cropping season amount of Total nitrogen (TN) recorded in Tree lucerne (*Chamaecytisus palmensis*) alleys was significantly (P<0.05) higher than in sole cropping of bread wheat. Whereas, significant differences were not observed among the Tree lucerne (*Chamaecytisus palmensis*) alleys treatments (Table 3). However, in the 2022 cropping year the values of Total nitrogen (TN) increased in the alley treatments over time with continuous addition of pruning from the Tree lucerne *(Chamaecytisus palmensis)* alleys. The highest Total Nitrogen content of 0.32% and 0.31% were obtained from 100% NPS+Tree lucerne (*Chamaecytisus palmensis*) alley and 75%NPS+Tree lucerne (*Chamaecytisus palmensis*) alley treatments respectively.

However, the control treatment (Bread wheat + recommended fertilizer rate) had a total soil N content of 0.28% and 0.12% in 2021 and 2022 study time respectively (Table 3). Therefore, from the findings of this study observed that the amount of total nitrogen in Tree lucerne *(Chamaecytisus palmensis)* alley treatments was increased progressively due to pruning materials of alley tree species improved the total nitrogen content of the soil. The finding of this study agreed with a study result of Okonkwo *et al.*[27] which showed that the total nitrogen (N) content increased in the alley plots over time with continuous addition of pruning from the hedgerow trees. The findings of this study also supported with the study results of Grime *et al.* [28], who found that soil nutrient status increased in alley plots with nitrogen fixing tree species.

Available Phosphorus: The levels of available Phosphorus in Tree lucerne (*Chamaecytisus palmensis*) alleys treatments were significantly different (P<0.05) to the control (sole cropping of bread wheat). Among the treatments, in the 2021 cropping year the highest available Phosphorus was obtained from 100% NPS+Tree lucerne(*Chamaecytisus palmensis*) alleys (6.11mg/kg) and 75% NPS+Tree lucerne alleys (5.65 mg/kg) and the lowest was recorded from control treatment (2.22 mg/kg).

Similarly, in the 2022 cropping season the amount of available Phosphorus increased progressively more in Tree lucerne (*Chamaecytisus palmensis*) alleys than in sole cropping of bread wheat (Table3). The main reason for higher available Phosphorus in Tree lucerne (Chamaecytisus palmensis) alleys than in the control plots

Table 4: Post-harvesting soil properties of experimental site along study years (2021-2022)

	CEC		Av.K		Ca		Mg	
Treatments	2021	2022	2021	2022	2021	2022	2021	2022
25% NPS + Tree lucerne alleys	11.97[ab]	12.87[C]	91.14[ab]	91.49[c]	7.53[cd]	8.40[b]	5.56[c]	5.73[b]
50% NPS + Tree lucerne alleys	13.17[a]	13.17[bC]	90.82[ab]	98.9[b]	8.50[bc]	8.53[b]	5.95[bc]	5.94[b]
75% NPS + Tree lucerne alleys	13.31[a]	14.01[b]	103.43[a]	106.44[a]	9.60[ab]	10.16[a]	6.62[ab]	6.78[a]
100% NPS + Tree lucerne alleys	13.39[a]	15.06[a]	107.06[a]	108.36[a]	10.26[a]	10.60[a]	7.12[a]	7.26[a]
Sole cropping of wheat	10.9[b]	10.63[c]	69.75[b]	73.08[d]	6.83[d]	6.86[c]	5.36[c]	5.43[b]
Mean	12.55	4.1	92.4	95.7	8.5	8.91	6.12	6.23
LSD(5%)	1.37	1.24	24.87	7.33	1.35	1.03	0.88	0.71
CV(%)	5.4	4.1	14.3	4.1	8.4	8.9	7.7	6.2

**Mean values in the same column with the same superscript are not significantly different, Mean values in the same column with different superscript are significantly different, LSD- Least significance difference, CV-Coefficient of variance*

might be attributable due to above-ground litter fall deposition and decomposition of the pruning materials of the hedgerow/alley tree and changes in the soil pH. Similar to this study's findings, Okonkwo *et al.* [27] indicated that increments of available Phosphorus in the alley cropping agroforestry system could be attributed to Phosphorus from the pruning and changes in the soil pH.

Therefore, the maximum 6.23mg/kg and 5.69mg/kg levels of available Phosphorus were recorded in 100%NPS+Tree lucerne (Chamaecytisus palmensis) alleys and 75% NPS+Tree lucerne(Chamaecytisus palmensis) alleys respectively. However, in the control plot (bread wheat + recommended fertilizer rate) the amount of available Phosphorus decreased from 2.24mg/kg(in 2021) to 2.21mg/kg (in 2022 cropping year).

Cation Exchange Capacity (CEC): The CEC of alley crop treatments were significantly ($P<0.05$) higher than the control plot (sole cropping of bread wheat) (Table 4). However, in the 2021 cropping year of the study time there were no significant differences between the 25% NPS + Tree lucerne (*Chamaecytisus palmensis*) alleys and the control treatment. The variations of CEC of the soil among the Tree lucerne (*Chamaecytisus palmensis*) alley crop treatments were observed in the 2022 cropping season. The maximum CEC of 15.06cmol/kg and 14.01 cmol/kg were recorded from 100% NPS + Tree lucerne (*Chamaecytisus palmensis*) alleys and 75% NPS + Tree lucerne (*Chamaecytisus palmensis*) alley treatments.

On the other hand, the lowest CEC of 10.63 cmol/kg was recorded from the control treatment plots (Table 4). This could be mainly due to higher organic matter accumulation under the alley crop treatments than the control plots implying the release of more cations to the soil through mineralization resulting in increased negative charges in the soil. Similarly, Brady and weil [17] indicated that the cation exchange capacity of a soil is strongly related to its organic matter content. Because, as the amount of organic matter in the soil increases the total negative charge in the soil increases which in turn increases the CEC of the soil. In line with this study, Ahmed *et al.* [29] indicated that cation exchange capacity in the alley cropping plots was higher than that of the control plot and initial level. Similarly,in their earlier studies, Agboola *et al.* [30] and Atta-Krah and Sumberg [31] also confirmed that higher CEC was recorded in alley cropping treatment than in the control plot.

Available Potassium: Based on the findings of this study, the available K was significantly ($P<0.05$) different among the experimental treatments. In both cropping years, the highest amount of available Potassium was recorded from100% NPS+ Tree lucerne (*Chamaecytisus palmensis*) alleys and 75% NPS + Tree lucerne (*Chamaecytisus palmensis*) alley treatments(Table 4).While, in the 2022 cropping season of the study time the minimum available Potassium of 73.08ppm and 91.49ppm were recorded from the control plot (wheat grown alone) and 25% NPS +Tree lucerne (*Chamaecytisus palmensis*) alley treatments. The findings of this study are supported by the study results of Jannatul Ferdush *et al.* [32]. In their study results showed that the value of potassium content was lower in control treatment compared to agroforestry treatments. Because, crop removal and losses through runoff may be attributed to the lowest value of K in the control plot. Similarly, in their earlier study results [33] indicated that no K was added to the control plot through pruned materials, whereas, the increase in available K in plots with tree species was probably due to the return of K via tree pruning and leaf litter fall to the soil surface.

Exchangeable Ca: The exchangeable Ca contents of soil showed an increasing trend in all Tree lucerne (*Chamaecytisus palmensis*) alleys treatments (Table 4). Among the treatments, in the 2022 cropping year the highest amount of exchangeable Ca was found in 100%

NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys (10.6 meq/100g) and 75% NPS +Tree lucerne (*Chamaecytisus palmensis*) alleys (10.16 meq/100g.) However,the lowest exchangeable Ca was recorded from the control plot(6.8 meq/100g). From this study observed that over time the overall exchangeable Ca value was higher in Tree lucerne (*Chamaecytisus palmensis*) alleys than in the control plots. This might be due to,an increased addition of soil organic matter through incorporated pruned materials of Tree lucerne (*Chamaecytisus palmensis*) alleys and probably the root decay of the tree species amount of exchangeable Ca increased in alley cropping agroforestry system. Similar to this study results, Aihou *et al.* [34] and Jones *et al.* [35] have reported an increase of exchangeable Ca in alley cropping agroforestry systems in the moist savanna of West Africa and in Malawi respectively.

Exchangeable Mg: In 2021 and 2022 cropping seasons significant differences in exchangeable Mg were not observed between 25% NPS + Tree lucerne (*Chamaecytisus palmensis*) alleys, 50% NPS + Tree lucerne (*Chamaecytisus palmensis*) alleys and sole cropping of bread wheat used as a control(Table 4). However, in both cropping season 100% NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys and 75% NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys were significantly (P<0.05) higher than the other experimental treatments. Among the treatments, the highest and the lowest exchangeable Mg content were recorded in 100% NPS+Tree lucerne alleys and sole cropping of bread wheat with recommended fertilizer rate. In favour of this study, Hauser [36] on his former study results reported that in alley cropping agroforestry system with *Leucaena leucocephala* legume tree species higher concentrations of exchangeable Mg were recorded in the surface soil under the hedgerows.

Effect of Tree lucerne (*Chamaecytisus palmensis*) Alley Cropping on bread wheat *(Triticum aestivum)* Productivity

Plant Height: In both cropping seasons (2021 and 2022), the mean plant height of bread wheat *(Triticum aestivum)* in Tree lucerne (*Chamaecytisus palmensis*) alleys was significantly (P<0.05) higher than sole cropping of bread wheat. In the 2022 cropping year the highest plant height of 93.71cm and 91.69cm were recorded from 75% NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys and 100% NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys respectively (Table 5). The present study results were in line with the former findings of Chamshama *et al.* [37] which was conducted in Morogoro, Tanzania. In their study findings reported that, alley cropping of *Faidherbia albida* with cereal crop increased plant height of the crop by 19.7% as compared to cropping alone. In support of this study, Grime *et al.* [28] also reported that crop height increased more in legume-planted alley cropping system than in control plots,while leguminous tree pruning resulted in higher food crop height and yield than in plots lacking leguminous tree species. However, the findings of this study contradicted with the findings of Chamshama *et al.* [37] who reported that the average height of cereal crop plants interplanted with *Luecaena leucocephala* trees decreased by 42.9% as compared to the height of cereal crop plants grown alone.

Number of Total Tillers: The effects of Tree lucerne (*Chamaecytisus palmensis*) alleys on a number of total tillers of bread wheat (*Triticum aestivum*) were significant. However, there is no significant difference in a number of total tillers between 25%NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys and sole cropping of bread wheat (Table 5). The highest number of total tillers recorded in Tree lucerne (*Chamaecytisus palmensis*) plot might be due to pruned materials of tree lucerne (*Chamaecytisus palmensis*) incorporated in to alley plots increased number of total tillers of bread wheat. In all cropping season the highest number of total tillers were observed in 50%,75% and 100% NPS +Tree lucerne (*Chamaecytisus palmensis*) alleys. Whereas, the lowest number of total tillers were recorded in 25% NPS +Tree lucerne (*Chamaecytisus palmensis*) alleys and bread wheat grown alone (Table 5). In line with this study, Okigbo and Greenland [38] reported that favorable climatic circumstances enhanced soil nutrient levels. Prunings from legume tree species contribute to soil organic matter and have shown promise in boosting the growth rate of food crops in agroforestry systems.

Number of Productive Tillers: In 2021 cropping season, number of productive tillers of 75% NPS+Tree lucerne (*Chamaecytisus palmensis*) alley and 100% NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys were significantly (P<0.05) higher than 25%NPS + Tree lucerne (*Chamaecytisus palmensis*) alleys, 50% NPS +Tree lucerne (*Chamaecytisus palmensis*) alleys and sole cropping of bread wheat. However, significant differences in the number of productive tillers were not recorded between bread wheat grown alone, 25% NPS+Tree lucerne (*Chamaecytisus palmensis*) alley and

Table 5: Mean value of yield component parameters of Wheat Alley cropping at Bore District during 2021 and 2022 cropping season

	Yield component parameters of wheat alley cropping							
	PH(cm)		NTT		NPT		SL(cm)	
Treatments	2221	2022	2021	2022	2021	2022	2021	2022
25% NPS + Tree lucerne alleys	85.65^{b}	90.31^{b}	2.20^{C}	2.36^{b}	2.03^{b}	2.11^{b}	6.66^{a}	6.18^{d}
50% NPS + Tree lucerne alleys	90.33^{a}	90.37^{b}	2.65^{ab}	2.70^{a}	2.14^{b}	2.40^{a}	6.94^{a}	7.38^{b}
75% NPS + Tree lucerne alleys	94.05^{a}	93.71^{a}	2.84^{a}	2.76^{a}	2.50^{a}	2.53^{a}	6.77^{a}	7.83a
100% NPS + Tree lucerne alleys	92.71^{a}	91.69^{ab}	2.81^{a}	2.74^{a}	2.46^{a}	2.53^{a}	6.16^{a}	7.64^{a}
Sole cropping of wheat	78.45^{c}	79.61^{c}	2.42^{bc}	2.41^{b}	2.14^{b}	2.14^{b}	6.64^{a}	6.61^{c}
Mean	87.84	89.14	2.58	2.59	2.25	2.34	6.64	7.13
LSD(5%)	5.3	3.6	0.23	0.25	0.18	0.23	NS	0.29
CV(%)	8.3	6.6	4.8	5.1	4.5	5.2	7.9	2.7

**Mean values in the same column with the same superscript are not significantly different, Mean values in the same column with different superscript are significantly different, NS-Non-Significant, PH= Plant height, NTT=Number of total tiller, NPT=Number of productive tiller,SL=Spike length*

Table 6: Mean value of yield and yield component parameters of Wheat Alley cropping at Bore District during 2021 and 2022 cropping season

	Yield and yield related parameters					
	NSPS		TKW(gm)		TGY/Ha (kg)	
Treatments	2021	2022	2021	2022	2021	2022
25% NPS + Tree lucerne alleys	20.94^{d}	23.61^{b}	46.55^{c}	47.32^{d}	1100^{c}	1132^{d}
50% NPS + Tree lucerne alleys	29.68^{b}	31.02^{a}	50.83^{b}	54.83^{b}	2864^{b}	3425^{b}
75% NPS + Tree lucerne alleys	31.97^{a}	32.58^{a}	60.15^{a}	60.63^{a}	3100^{a}	3650^{a}
100% NPS + Tree lucerne alleys	32.55^{a}	31.94^{a}	60.22^{a}	60.92^{a}	3107^{a}	3645^{a}
Sole cropping of wheat	22.28^{c}	25.28^{b}	50.02^{b}	49.94^{c}	2829^{b}	3022^{c}
Mean	28.08	28.88	53.55	55.34	2600	2975
LSD(5%)	2.4	2.3	2.04	0.93	113.3	86.7
CV(%)	4.1	4.2	2	1.9	2.3	1.5

**Mean values in the same column with the same superscript are not significantly different, Mean values in the same column with different superscript are significantly different, NSPS= Number of Seed per spike, TKW=Thousand Kernel Weight, TGY/Ha=Total Grain Yield per Hectare*

50% NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys treatments (Table 5). The findings of this study showed that, in 2022 cropping season number of productive tillers of 50%,75% and 100% NPS +Tree lucerne (*Chamaecytisus palmensis*) alleys were significantly ($P<0.05$) higher than 25% NPS +Tree lucerne (*Chamaecytisus palmensis*) alleys and sole cropping of bread wheat used as a control (Table 5).

Spike Length: In terms of spike length, significant differences were not recorded among the treatments in 2021 cropping season. However, in the 2022 cropping year 75% NPS+Tree lucerne (*Chamaecytisus palmensis*) alley and 100% NPS +Tree lucerne (*Chamaecytisus palmensis*) alleys were significantly ($P<0.05$) higher than the others (Table 5). In line with this study, Jannatul Ferdush *et al.* [40] reported that interaction effect of *Gliricidia sepium* and *Leucaena leucocephala* tree species and fertilizer rate showed a significant effect on spike length of wheat. The findings of the present study showed that, significantly the highest spike length of bread wheat,7.83cm and 7.64cm were found in 75% NPS+ Tree lucerne (*Chamaecytisus palmensis*) alleys and 100% NPS+ Tree lucerne (*Chamaecytisus palmensis*) alleys respectively. However, the lowest spike length of bread wheat, 6.18cm and 6.61cm were recorded in 25% NPS +Tree lucerne (*Chamaecytisus palmensis*) alleys and sole cropping of bread wheat respectively (Table 5).

Number of Seed per Spike: The effect of Tree lucerne (*Chamaecytisus palmensis*) alley cropping treatments on a number of seed per spike was significant. In the 2022 cropping season the highest number of seed per spike were recorded in 75% NPS + Tree lucerne (*Chamaecytisus palmensis*) alleys and 100% NPS + Tree lucerne (*Chamaecytisus palmensis*) alleys and 50% NPS + Tree lucerne (*Chamaecytisus palmensis*) alleys respectively (Table 6). However, in both cropping seasons the lowest seed per spike was found in 25% NPS + Tree lucerne

Fig. 2: Performance of wheat Alley cropping agroforestry system at maturity stage

(*Chamaecytisus palmensis*) alleys. The highest number of seed per spike observed under alley cropping system could be due to the adequate organic matter and nitrogen availability which might facilitate the tillering ability of the plants, resulting in a greater spike population. In line with this study, Jannatul Ferdush *et al.* [39] and Ayoub *et al.*[40] reported the highest number of grain per spike of wheat in alley cropping agroforestry system.

Thousand Kernel Weight: The findings of this study showed that, in 2021 and 2022 cropping seasons significant differences were observed between the experimental treatments. The maximum thousand kernel weight (60.92gm)was recorded in 75% NPS + Tree lucerne (*Chamaecytisus palmensis*) alleys followed by 100% NPS + Tree lucerne (*Chamaecytisus palmensis*) alleys (60.63gm). However, the lowest thousand kernel weight of 49.94gm and 47.32gm were recorded in sole cropping of bread wheat and 25% NPS + Tree lucerne (*Chamaecytisus palmensis*) alleys respectively (Table 6). The findings of this study supported with the study results of Grime *et al.* [28] who found that soil nutrient status increased in alley cropping agroforestry practice with nitrogen fixing tree species. It has been found that leguminous hedger trimming increases the growth and yields of a variety of food crops, owing to the nitrogen input. Leguminous tree prunings provide nitrogen and other soil nutrients, which enhance soil fertility and, as a result, boost food growth and production.

Total Grain Yield: Based on the findings of this study, a significant differences were observed among the experimental treatments in wheat grain yields at ($P< 0.05$). In the 2022 cropping seasons, the highest total grain yields were recorded in 75% NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys (3650kg/ha) and 100% NPS+Tree lucerne (*Chamaecytisus palmensis)* alleys (3645kg/ha). This could be due to wheat yield production being maintained in alley cropping practice, affected with different beneficial nutrients contributed by organic biomass of Tree lucerne (*Chamaecytisus palmensis)* alleys and the rate of NPS fertilizer applied in treatments. The findings of this study was in line with the study results of Naya *et al.* [41], who reported inclusion of appropriate nitrogen fixing tree/shrub legumes in farming systems usually reduces N loss through leaching thereby maximizing yield from croplands. In support of this study, Atta-Krah *et al.* [25] also reported that crop yields in *Gliricidia sepium* alley system were significantly higher than yields of the control plots.

Similar to this study, in South west Nigeria Atta-krah *et al*.[42] and in Zambia [43] have analyzed the use of *Gliricidia sepium* as green manure for horticultural crop production. In their study findings reported that higher crop yields were recorded in alley cropping than in unfertilized and full rate of fertilizer application. The findings of this study showed that, the lowest wheat grain yields of 1132kg/ha were recorded from 25% NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys (Table 6). In both cropping season total grain yields recorded in sole cropping of bread wheat with recommended fertilizer rate was significantly($P < 0.05$) higher than 25% NPS + Tree lucerne alleys (Table 6). That means, the yield increment depended on the soil micronutrients that crop gains from the soil due to alley shrubs biomass transfer to the soil/application of recommended fertilizer rate.

CONCLUSION AND RECOMMENDATION

Based on the findings of this study, Tree lucerne (*Chamaecytisus palmensis)*alley cropping plays an important role in enhancements of physical and chemical soil properties; as well, it increased wheat grain yield. Accordingly, as compared to sole cropping of bread wheat and pre-planting soil properties, in Tree lucerne (*Chamaecytisus palmensis)* alley cropping the recorded soil nutrients were significantly higher. This could be due to the pruning material of Tree lucerne (*Chamaecytisus palmensis*) incorporated into the soil and dead roots were built-up soil nutrients in alley cropping agroforestry practice. However, in terms of soil texture significance differences were not observed among the experimental treatments.

This study also showed that, Tree lucerne (*Chamaecytisus palmensis)* alley cropping agroforestry system had significantly affected wheat grain yield. Thus, a significant difference among arrangements of wheat alley cropping in grain yields were recorded. In 2022 cropping season wheat productivity was increased overtime and the highest total grain yields of wheat were recorded in 75% NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys (3650kg/ha), 100% NPS+Tree lucerne (*Chamaecytisus palmensis*) alleys (3645kg/ha) and 50% NPS+Tree lucerne (*Chamaecytisus palmensis)* alleys (3425kg/ha) respectively. This could be due to pruned materials of Tree lucerne (*Chamaecytisus palmensis)* incorporated into the soil under alley cropping agroforestry system increased crop productivity overtime through decomposition of pruned biomass and based on the rate of NPS fertilizer application. Therefore, based on the findings of this study Tree lucerne (*Chamaecytisus palmensis)* alley cropping agroforestry practices has high contribution in soil fertility enhancements and grown wheat with 75% NPS fertilizer application in between alleys of Tree lucerne(*Chamaecytisus palmensis*) legume multipurpose tree was recommended for the study area and similar agroecologies.

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REFERENCES

1. Leakey, R., 1996. Definition of Agroforestry Revisited. Agroforestry Today, (8)1: 5- 7, ISSN 1013-9591
2. Yin, R.S., 2004. Valuing the Impacts of Agroforestry in Northern China.Valuing Agroforestry Systems, 259-280. The Netherlands: Kluwer Academic Publishers.
3. Singh, H.P., R.K. Kohli and D.R. Batish, 2001. Allelophatic Interference of Populusdeltoides With Some Winter Season Crop. Agronomie, 21(2): 139-146, ISSN 0249-5627
4. Asadi, F., M. Calagari, R. Ghasemi and R. Bagheri, 2005. Investigation of Spacing Effect on Production of Poplar and Alfalfa in Intercropping. Iranian Journal of Forest and Poplar Research, 12(4): 455-480, ISSN 0883-1735
5. Otengi, S.B.B., C.J. Stigter, J.K. N'ganga and D.N. Mungai, 2000. Wind Protection in a Hedged Agroforestry System in Semi-Arid Kenya. AgroforestrySystems, 50(2): 137-156, ISSN 0167-4366
6. Workman, Sarah, W., Samuel C. Allen and Shibu Jose, 2001. Alley-Cropping Combinations for the South eastern USA.
7. Kang, B.T. and D.A. Shannon, 2001. Agroforestry with focus on alley cropping.Sustaining Soil Fertility in West Africa''. SSSA Special Publication No. 58. Soil Science Society of America and American Society of Agronomy, Madison, Wisconsin.
8. Kang, B.T. and R.C. Gutteridge, 1998. Forage tree legumes in alley cropping systems.
9. Anthony Young, A., 1989. Agroforestry for Soil Conservation. CA B International Council for Research in Agroforestry. Nairobi, August 1988.
10. Lai, R., 1989. Agroforestry systems and soil surface management of a tropical alfisol. Parts VI. Agroforestry Systems, 8(1): 1-6; 7-29.
11. Kang, B.T. and G. F. Wilson, 1987. The development of alley cropping as a promising agroforestry technology. In: Steppler, H.A. and P.K.R. Nair (eds.) Agroforestry.: A Decade of Development Nairobi, Kenya: ICRAF
12. Kang, B.T., Reynolds and A.N. Atta - krah, 1990. Alley farming. Adv. Agron., 43: 315-359.
13. Walkley, A. and C.A. Black, 1934. An examination of different methods for determining soil organic matter and the proposed modification by the chromic acid titration method. Soil Sci., 37: 29-38.

14. Bremner, J.M. and C.S. Mulvaney, 1982. Total Nitrogen. In: Page, A.L., Miller, R.H., Keeney, D.R. (eds). Methods of Soil Analysis. II. Chemical and Microbiological Properties. American Society of Agronomy, Soil Science Society of America, pp: 595-624.
15. Olsen, S.R., C.V. Cole, F.S. Watanable and L.A. Dean, 1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA Circular. 939(1): 19.
16. Chapman, H.D., 1965. Cation Exchange Capacity. In: Black, C.A., Ensminger, L.E., Clark, F.E. (eds). Methods of Soil Analysis, Agronomy Inc., Madison, Wisconsin. 9: 891-901. https:// doi.org/ 10.2134/ agronmonogr9.2.c6
17. Brady and weil, 2010. Elements of the nature and properties of soils.
18. Landon, J.R., 1991. Brooker Tropical Soil Manual. A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. John Wiley & Sons, Inc., New York, USA, pp: 474.
19. Ward Chesworth, 2008. Encyclopedia of soil science.ISBN: 978-1-4020-3994-2 Springer Dordrecht, Berlin, Heidelberg, New York
20. Sobulo, R.A. and O.A. Osiname, 1981. Soils and fertilizer use in Western Nigeria. Tech. Bull., 11: 8-9.
21. Enwezor, W.O., A.C. Oliri, E.E. Opubaribo and E.J. Udoh, 1989. A review of Soil Fertility Investigation in S.E. Nigeria. Vol. 11, F.D.A. Lagos, 30-39.
22. Balasubramanian, V. and L. Sekayange, 1991. Effect of tree legumes in hedgerows on soil fertility changes and crop performance in semi-arid highlands of Rwanda. Biol Agric Hort., 8: 17-32.
23. Matthews, R.B., S. Lungu, J. Volk, S.T. Holden, K. Solberg and K.H. Solberg, 1992. The potential of alley cropping in improvement of cultivation systems in the high rainfall areas of Zambia. II: Maize production. Agrofor Syst., 17: 241-261.
24. Dalland, A., P.I. Våje, R.B. Mathews and B.R. Singh, 1993. The potential of alley cropping in improvement of cultivation systems in the high rainfall areas of Zambia. III. Effects on soil chemical and physical properties. Agrofor Syst., 21: 117-132.
25. Atta-Krah, A.N., J.E. Sumberg and L. Reynolds, 1986. In potential of forage legume in farming systems of Sub-saharan Africa, Addis Ababa.
26. Taye, S. and S. Kelil, 2023. Evaluation of Alley Cropping with Selected Leguminous Multipurpose Tree Species on Maize Production and Soil Fertility at Abaya District, West Guji Zone, Southern Oromia, Ethiopia.East African Journal of Forestry and Agroforestry 6 (1), 174-185. https:// doi.org/ 10.37284/ eajfa.6.1.1302
27. Okonkwo, C.I., J.S.C. Mbagwu and S.O. Egwu, 2009. Changes in soil properties under alley cropping system of three leguminous crops. Journal of Tropical Agriculture, Food, Environment and Extension, 8(1): 60-65.
28. Grime, J.P., J.G. Hodgson and R. Hunt, 2014. Comparative Plant Ecology: A Fundamental Approach to Common British Species. London, Hyman Ltd., pp: 740-742.
29. Ahmed, S., S. Hasan, A.H.M.R.H. Chowdhury, A.K.M.M.A. Chowdhury and M.A. Hossain, 2010. Performance of growth and soil properties change by four multipurpose tree species in alley cropping system. Int. J. Sustain. Crop Prod., 5(2): 21-27.
30. Agboola, A.A., G.F. Wilson, A. Gatahan and C.F. Yamoah, 1982. Gliricidia sepium: A possible means to sustained cropping. In: Mac Donald, L.H. (ed). Agroforestry in the African Humid Tropics. The United Nations University, Tokyo, Japan.
31. Atta-Krah, A.N. and J.E. Sumberg, 1988. Studies with Gliricidia sepium for crop and livestock production systems in West Africa. In Gliricida sepium management and improvement proceedings of a workshop held at Catie Rica. NFTA Special Publication, pp: 31-43.
32. Jannatul Ferdush, Md. Meftahul Karim, Iffat Jahan Noor, Sadia Afrin Jui, Tofayel Ahamed and Sataya Ranjan Saha, 2019. Impact of alley cropping system on soil fertility. International Journal of Advanced Geosciences, 7(2): 173-178.
33. Miah, M.G., D.P. Garrity and M.L. Aragon, 1997. Effect of legume trees on soil chemical properties under agroforestry system. Ann. Bangladesh Agric., 7(2): 95-103.
34. Aihou, K., N. Sanginga, B. Vanlauwe, O. Lyasse, J. Diels and R. Merckx,1 999. Alley cropping in the moist Savanna of West Africa: I. Restoration and maintenance of soil fertility on 'terre de barre' soils in Southern Benin Republic. Agroforestry Systems, 42: 213-227.

35. Jones, R.B., J.W. Wendit, W.T. Bunderson and O.A. Itimu, 1996. Leucaena + maize alley cropping in Malawi. Part I: Effects on N, P and leaf application on maize yields and soil properties. Agrofor. Syst., 33: 281-294.
36. Hauser, S., 1990. Water and nutrient dynamics under alley cropping versus mono-cropping in the humid, sub-humid transition zone. In Transactions 14th International Soil Science Society Congress, pp: 204-209.
37. Chamshama, S.A.O., A.G. Mugasha, A. Klovstad, O. Haveraaen and S.M.S. Maliondo, 1998. Growth and yield of maize alley cropped with Leucaena leucocephala and Faidherbia albida in Morogoro, Tanzania. Agroforestry Systems, 40: 215-225. Kluwer Academic Publishers. Printed in the Netherlands.
38. Okigbo, B.N. and D.J. Greenland, 2006. Intercropping Systems in Tropical Africa. FAO Soil Bulletin 53, 1 - 100, FAO, Rome Italy.
39. Jannatul Ferdush1, Md. Meftahul Karim, Raihan Mujib Himel, Sataya Ranjan Saha and Tofayel Ahamed, 2018. Impact of Alley Cropping on Wheat Productivity. IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS), 11(2): 17-25.
40. Ayoub, M., S. Guertin, S. Lussier and D.L. Smith, 1993. Timing and levels of nitrogen fertility effects on spring wheat Yield in Eastern Canada. Crop Sci., 34(3): 748-756.
41. Naya, L., R. Ladrera, J. Ramos, E.M. González, C. Arrese-Igor, F.R. Minchin and M. Becana, 2007. The response of carbon metabolism and antioxidant defenses of alfalfa nodules to drought stress and to the subsequent recovery of plants. Plant Physiol., 144(2): 1104-1114. https:// doi.org/ 10.1104/ pp.107.099648
42. Atta-Krah, A.N., J.E. Sumberg and L. Reynolds, 1996. Leguminous fodder trees in the farming system. An over view of research in the humid tropical zone programme of ILCA in Southwest Nigeria. In Potential of Forage Legumes in Farming Systems of sub-Sahara Africa. Proceeding of a workshop held at ILCA Addis Ababa, Ethiopia.
43. Mafongoya, P.L. and O. Jiri, 2016. Nutrient dynamics in wetland organic vegetable production sys- tems in eastern Zambia. Sustainable Agriculture Research, 5: 78-85. DOI: 10.5539/ sar.v5n1p78