Soil Chemical Properties Changes under Alley Cropping in Terrace Ecosystem of Bangladesh

A. S. M. J. Alam¹, S. R. Saha¹*, M. G. Miah¹, M. M. Rahman², M. R. Islam³ and A. K. Das¹

¹Department of Agroforestry and Environment, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706, Bangladesh.
²Department of Soil Science, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706, Bangladesh.
³Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706, Bangladesh.

Authors’ contributions

This work was carried out in collaboration among all authors. Author ASMJA designed the study, conducted research and analyzed soil samples, performed the statistical analysis, and prepared the first draft of the manuscript. Authors SRS, MGM, MMR, and MRI supervised the student in planning and designing the experiment, and editing the manuscript. Authors AKD helped ASMJA to analyze soil samples in the laboratory. All authors read and approved the final manuscript.

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ABSTRACT

Soil health needs to be improved for the sustenance of a productive agriculture and sound environment where alley cropping system might play a vital role. The study was composed of two factors viz. three alley widths of Gliricidia sepium (3.0, 4.5 and 6.0 m), and five nitrogen levels (0, 25, 50, 75 and 100% of the recommended dose) along with pruned materials in a split-plot design with three replications. The soil chemical properties were examined in alleys of Gliricidia sepium tree over two consecutive seasons. Results displayed that pruned materials (PM) of G. sepium increased the soil pH, organic carbon (OC), total nitrogen (N), available phosphorus (P) and sulfur (S), exchangeable calcium (Ca), magnesium (Mg), potassium (K), and cation exchange capacity (CEC) of soil in different alley widths compared to the control. However, alley width 3.0 m and
1. INTRODUCTION

Sustainable crop cultivation depends on good health of soil. Appropriate and well-adjusted nutrient availability influence the suitable crop growth and production. In Bangladesh, the fertility status of soil has been declining gradually. The soil under intensive cultivation is seriously degraded and appeared as a threat to sustainable agriculture [1]. Practically all upland soils of Bangladesh have inadequate nitrogen with low organic matter content. Organic matter content in the 60% of the arable land of Bangladesh is only 1% [2], while N, P and K contents are inadequate [3]. Around the world, from the last several decades’ soil health has been threatened and nonetheless there has been a renewed interest in defending and enhancing this most vital resource for the generations to come [4]. Therefore, it is an utmost task to keep soil alive and maintain its productive capacity. Environment friendly, demand oriented and climate smart agricultural technologies are to be adopted for sustainable crop production [5]. Fortunately, agroforestry practices offer a great opportunity to rebuild the soil fertility for sustainable crop production. It has multifunctional land use practices that generated considerable interest in recent years in response to its potentiality to diminish poverty level, ensure food security, alleviate climate change and decrease land degradation. However, agroforestry is known as a diversified land use system that improves soil health and greatly recognized as a climate smart agriculture practice since its inception [6,7,8]. Both poplar and guava-based agroforestry systems increased SOC than under the sole crop system [9]. Tree species growing on farmlands may help improve soil physical conditions and chemical properties [10].

Alley cropping is a type of agroforestry system which is considered as an ideal technology for sustainable crop production. In this system, agricultural crops are grown in the inter spaces between rows of planted shrubs and or tree species, preferably legumes, which are periodically pruned to minimize tree-crop competition for growth resources such as water, nutrient and light [11]. Pruned material is applied to the soil which upon decomposition releases nutrients and improves soil health. Increased nutrient supply and improved soil health ultimately contribute to the growth and development of associated crops [12]. Alley cropping enhances soil carbon (C) sequestration and helps to mitigate global warming [13,14,15]. In addition, fast growing leguminous tree/shrubs species are grown because they usually recycle nutrients, contribute to biological nitrogen fixation [16]. Soil organic matter could increase by 4-7% in alley-cropping systems with red alder (Alnus rubra) and maize in comparison with maize monoculture following 4 years of cropping [17]. Addition of pruned materials significantly increased enzyme activity and microbial diversity in agroforestry alley cropping systems as compared with monocrop agriculture [18,19,20]. Gliricidia sepium tree is known as a fertilizer tree that has greater capacity to improve and rejuvenate soil health, and sustain agricultural production [21]. In view of the current national and international interest in organic farming for safe environment, it is necessary to assess the suitability of alley cropping as organic farming. For proper management of hedges and increased production of cauliflower, a study was undertaken and executed over two consecutive seasons to examine the changes in soil chemical properties in alleys of G. sepium tree.

2. MATERIALS AND METHODS

2.1 Description of the Study Site

The experiment was conducted at the alley cropping field (24°09’ N latitude and 90°26’ E longitude with an elevation of 8.5 meters from Sea level) of the Department of Agroforestry and Environment, BSMRAU, Bangladesh from October to February during 2016-2017 and 2017-2018 in winter seasons. The land of the experimental field was characterized by terrace
landscape. The soil of the experimental site belongs to the agro-ecological zone 28 (Madhupur Tract) and is classified as shallow red brown terrace under the Salna series [22]. The texture of the soil has been changed to loamy by manual deposits of alluvial soils [23]. However, the available phosphorus content of the soil was low and other elements were almost at satisfactory level [24].

The experimental area has subtropical climate characterized by three distinct seasons, the monsoon or rainy season (May to October), the winter or dry season (November to February) and the pre monsoon or hot season (March to April). Heavy rainfall occurred during the months from May to September and scanty rainfall during rest of the year. The detailed meteorological data during experimentation periods of cauliflower in both the seasons has been envisaged in Table 1 and Table 2.

2.2 Experimental Design and Treatments

The experiment was laid out in a Split-plot design with three replications. The two factors were (Factor A); three different alley widths of *Gliricidia sepium* viz. 3.0 m, 4.5 m and 6.0 m which were designated as W₃.₀, W₄.₅ and W₆.₀, respectively, along with control (CC). Factor B comprised of five different nitrogen levels along with pruned materials (PM) namely; N₀+PM, N₂₅+PM, N₅₀+PM, N₇₅+PM and N₁₀₀+PM and there were twenty different treatment combinations in the present study. For the control treatment, the crop was grown in an open field without incorporation of *Gliricidia sepium* pruned materials.

### 2.3 Experimental Details

To evaluate the changes in soil properties in alley cropping system where *Gliricidia sepium* was used as the hedgerow crop; a hybrid cauliflower variety (Snow White) was grown in different alleys of the alley cropping with different levels of nitrogen fertilizer and the PM were added to the soil and left to decompose properly before planting the crop in both seasons. The seedling was transplanted in the field on 14 October in 2016-2017 and 20 October in 2017-2018 growing seasons following 60 × 60 cm spacing. The crop was fertilized by following the fertilizer recommendation guide (FRG, 2012). There were different doses of nitrogen namely N₀ (no nitrogen), N₂₅ (25% of the recommended dose), N₅₀ (50% of the recommended dose),

| Month       | Temperature (°C) | Relative Humidity (%) | Rainfall (mm) |
|-------------|------------------|-----------------------|---------------|
|             | Max. | Min. | Avg. | Max. | Min. | Avg. |
| October 2016 | 32.4 | 24.2 | 28.3 | 96.61 | 64.19 | 80.40 | 1.03 |
| November 2016 | 29.5 | 18.1 | 23.8 | 97.58 | 53.61 | 75.60 | 0.03 |
| December 2016 | 27.6 | 14.6 | 21.1 | 97.38 | 48.94 | 73.17 | 0.00 |
| January 2017 | 25.9 | 12.8 | 19.4 | 94.90 | 44.13 | 69.52 | 0.00 |
| February 2017 | 28.3 | 15.8 | 22.1 | 95.69 | 41.45 | 68.57 | 0.00 |

Source: Meteorological Station of the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706, Bangladesh

| Month       | Temperature (°C) | Relative Humidity (%) | Rainfall (mm) |
|-------------|------------------|-----------------------|---------------|
|             | Max. | Min. | Avg. | Max. | Min. | Avg. |
| October 2016 | 31.5 | 24.1 | 27.8 | 96.94 | 68.52 | 82.73 | 11.00 |
| November 2016 | 29.9 | 18.4 | 24.1 | 97.13 | 53.39 | 75.26 | 0.83 |
| December 2016 | 26.8 | 15.9 | 21.3 | 98.45 | 57.06 | 77.76 | 1.10 |
| January 2017 | 22.8 | 10.8 | 16.8 | 93.26 | 51.81 | 72.54 | 0.00 |
| February 2017 | 27.3 | 16.0 | 21.6 | 95.90 | 48.23 | 72.07 | 0.36 |

Source: Meteorological Station of the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706, Bangladesh
N\textsubscript{75} (75% of the recommended dose) and N\textsubscript{100} (100% of the recommended dose). No blanching was needed as the variety was a self-blanching one. Weeding was done properly to control the degree of competition between the crop and weeds for nutrient and light absorption. Irrigation along with other inter cultural operations was done as and when needed. No plant protection measures were taken as it was not essential. The crop was harvested when the curd size became suitable for consumption.

### 2.4 Collection of Soil Samples and Analysis of Soil Chemical Properties

In each of the growing seasons, both before and after the experimentation soil samples were collected from 0-15 cm depth from each of the plots where the treatments were allocated. Soil samples were collected to determine soil pH, soil organic carbon, total nitrogen, available phosphorus and sulphur, exchangeable calcium, magnesium, potassium and cation exchange capacity (CEC). Soil pH was measured by Glass Electrode pH meter by maintaining soil water ratio of 1:2.5 [25]. Organic carbon (%) in soil sample was determined by wet oxidation method [26]. Total nitrogen content (%) of soil was determined following the method of Hesse [27]. Available phosphorus was estimated following the methods of Olsen and Page [28,27]. Available Sulphur was quantified as per method of Chesin and Yien [29]. Exchangeable calcium and magnesium were determined following the method of Hesse [30], whereas exchangeable potassium was estimated as per the method described by Page [27].

### 2.5 Statistical Analysis

All the data were analyzed by analysis of variance (ANOVA) using Statistix 10 software. Different alphabetical letters represent significant differences among the treatments at $P < 0.05$ following a least significant difference (LSD) test.

### 3. RESULTS AND DISCUSSION

#### 3.1 Effects of Pruned Materials Application on Soil Chemical Properties

The effects of different treatments on soil chemical properties after harvesting of cauliflower are presented and discussed under the following sub-headings.

#### 3.1.1 Soil pH

The soil pH varied from 5.13 (CC+N\textsubscript{0}) to 5.93 (W\textsubscript{3.0}N\textsubscript{75}+PM) among the treatments (Table 3). However, incorporation of the pruned materials of *G. sepium* slightly increased the pH of soil in different alley widths compared to the control where no pruned materials were added. The average pH of *G. sepium* pruned material added in plot W\textsubscript{3.0} was 5.82 while the values were 5.79 and 5.67 in W\textsubscript{4.5} and W\textsubscript{6.0} respectively. The control plot had pH value of 5.34 (Fig. 1a). Compared to control, the average increment of soil pH under different alley widths were 8.95%, 8.39% and 6.22% higher against W\textsubscript{3.0}, W\textsubscript{4.5} and W\textsubscript{6.0} treatments respectively.

The soil of the field where the study was conducted was slightly acidic and increment in soil pH of acidic soil is a good indication for better utilization of nutrients especially phosphorus. Acidic soil contains a high amount of Fe, Mn and Al, and these elements can react with phosphorus and ultimately phosphorus becomes insoluble. Thus, phosphorus either inherent or added through inorganic fertilizers becomes unavailable for plant uptake. The soil pH of PM added plots were found slightly higher over control treatment which indicated that due to application of PM, soil pH tends to increase. The increment in soil pH in *G. sepium* PM added plots in different alley widths may be due to the faster decomposition of PM and subsequent release of Ca into the soil. Similar increase in soil pH under *G. sepium* was observed by other researchers [12,31,32,33,34,35].

#### 3.1.2 Soil organic carbon

Soil organic carbon varied from 0.42% (CC+N\textsubscript{75}) to 0.94% (W\textsubscript{3.0}N\textsubscript{100}+PM) among the treatments (Table 3). Incorporation of the pruned materials of *G. sepium* slightly increased the organic carbon of soil in different alley widths compared to the control. The average organic carbon in *G. sepium* PM added plot was 0.82% in W\textsubscript{3.0}, while the values were 0.66% and 0.61% in W\textsubscript{4.5} and W\textsubscript{6.0} treatments while it was 0.44% in control plot. The organic carbon in soil of W\textsubscript{3.0}, W\textsubscript{4.5} and W\textsubscript{6.0} was found 40.83% higher over control plots respectively (Fig. 1a). Soil organic carbon content increased due to the incorporation of tree leaves and decreased slightly in control plots. Many researchers observed higher organic carbon content in soil under alley cropping system compared to the non-alley cropping system [36,37,35]. Alam et al.; AJSSPN, 7(4): 32-42, 2021; Article no.AJSSPN.71167
found 1.59% organic carbon in G. sepium added soil compared to 1.13% in the control soil [31]. Organic matter is known as a life of soil that governs all physical, chemical and biological characteristics. According to Fertilizer Recommendation Guide (FRG), the present level of soil organic carbon content in the study area is very low to medium [38]. Therefore, a regular supply of organic matter using different sources needs to be ensured for sustainable agriculture. Alley cropping might contribute to increase soil organic carbon and thus improve soil health. Furthermore, alley cropping fetches multiple benefits to make the production system economically viable and ecologically sustainable.

3.1.3 Total nitrogen

The total nitrogen content in soils under different treatments in pruned material added plots was found to increase over the control (Fig. 1a). The average increment of total nitrogen in G. sepium pruned material added plots were 113.57% and 108.29% in W3.0 and W4.5 alley widths respectively. But at W6.0 treatment, it was found 103.77% over control. The average total nitrogen in G. sepium pruned material added plot was 0.08%, 0.17% in both W4.5 and W6.0 alley widths while it was 0.16% in W6.0 alley width. Among the treatment’s highest total nitrogen content (0.209%) was recorded in W3.0N100+PM followed by 0.201% in W4.5N100+PM treatments. While the lowest value (0.027%) was recorded in control treatments (Table 3). Results revealed that addition of G. sepium PM increased N content in soils and thereby increased soil fertility. Nitrogen loss from the soil environment is very high through different pathways like denitrification, ammonia volatilization, nitrate leaching etc. Therefore, enrichment of soil with nitrogen and store it for a long time is not possible. Nitrogen is one of the most limiting plant nutrients in the tropical and sub-tropical production environment and therefore, judicious and balanced application of nitrogen as per crop requirements is always advisable for better utilization of nitrogen in crop production. Leguminous crops can fix atmospheric nitrogen and increase soil fertility. The increment of soil nitrogen in the present study might be the contribution of alley cropping. Alley cropping along with inorganic fertilizer application and alley cropping alone have the potential to increase 70-100% soil nitrogen compared to the zero-input control [39].

3.1.4 Available P

Available phosphorus means the portion of the total soil phosphorus which can be utilized by plants and that can be extracted by dilute acid solution. In the present study, the available P varied remarkably among the treatments (Table 3). However, incorporation of the pruned materials of G. sepium increased the available P in soil compared to the control treatments (Fig. 1b). The average available P in G. sepium pruned material added plot was 13.97 ppm in both W3.0 and W4.5 alley widths while it was found 13.13 ppm in W6.0 alley width. On the other hand, control plot had 7.68 ppm P in soil. The average increment of available P in W3.0, W4.5 and W6.0 alley widths was 81.97 ppm, 81.87 ppm and 70.91 ppm respectively over control. Among the treatments, the highest available P was recorded in W3.0N100+PM (16.261 ppm) treatment, while the lowest value was recorded in CC + N75 (7.606 ppm) treatment. Inherent phosphorus content of agricultural soil is low and moreover, the applied P undergoes a rapid fixation either with calcium and magnesium in calcareous soil or with iron, aluminum and manganese in acidic soil. However, the adoption of different soil and crop management practices may improve phosphorus supply capacity of soils Addition of higher phosphorus in soil from G. sepium was also observed in alley cropping system by other scientists [40,35].

3.1.5 Available S

The available S varied slightly among the treatments (Table 3). However, incorporation of the pruned materials of G. sepium slightly increased the available S of soil compared to the control. The average available S in G. sepium pruned material added plots were 14.85 ppm, 14.84 ppm and 14.00 ppm in W3.0, W4.5 and W6.0 alley widths respectively whereas, the control plot showed 7.71 ppm S in soil. The average increment of S was 92.65% in W3.0 while the average increments were 92.54% and 81.63% in W4.5 and W6.0 over the control. Among the treatments, the highest available S was recorded in W6.0N100+PM (16.266 ppm) treatment and the lowest was recorded CC+N75 (7.650 ppm). Sulphur (S) is required for the formation of proteins, enzymes, vitamins, and chlorophyll in plants. It is essential for legume nodule development and efficient nitrogen fixation. However, alley cropping can be a good options for increasing organic matter content of soil as most of the available S comes from organic
matter. The Pertinent result was found in alley cropping plots when G. sepium and L. leucocephala were added as pruned materials [41].

### 3.1.6 Exchangeable Ca

The exchangeable Ca contents of soil showed an increasing trend in all the treatments except control (Table 3). Incorporation of the pruned materials of G. sepium increased the soil exchangeable Ca in all the alley widths compared to the control. The average exchangeable Ca in G. sepium pruned material added plot was 2.49 meq/100g soil in WE1.5 alley width whereas, 2.25 and 2.27 meq/100g soil of Ca were found in W4.5 and W6.0 alley widths and the control plot had 1.09 meq/100g soil of exchangeable Ca. The average increment of exchangeable Ca was maximum in W3.0 alley width (128.26%) whereas 106.61% and 108.07% of Ca were found in W4.5 and W6.0 treatments of alley widths over control. Among the treatments, the highest exchangeable Ca was recorded in W3.0N100+PM (2.54 meq/100g soil) and the lowest was recorded in CC+N25 (1.05 meq/100g soil) treatment (Table 3). The high availability of calcium in soil neutralizes soil acidity and thereby helps in increasing the solubility of phosphorus as well as improve the soil aggregate stability. Findings regarding the increase of soil Ca in alley-cropping system had been reported in different investigations [42,32,43].

### 3.1.7 Exchangeable Mg

The available Mg did not vary remarkably among the treatments (Table 3). But control treatments showed comparatively lesser quantities of exchangeable Mg. Incorporation of the pruned materials of G. sepium slightly increased the soil exchangeable Mg as compared to the control. The average exchangeable Mg in G. sepium pruned material added plot was 0.76 meq/100g soil in W3.0 alley width while the average values were 0.70 and 0.66 meq/100g soil for W4.5 and W6.0 alley widths respectively. The average increment of exchangeable Mg was 82.88% in W3.0 while the average increments were only 69.82% and 60.22% in the higher alley widths of W4.5 and W6.0 over the control respectively (Fig. 1b). Among the treatments, the highest exchangeable Mg was recorded in W3.0N100+PM (0.899 meq/100g soil) and the lowest was found in CC+N100 (0.390 meq/100g soil) treatment (Table 3). The addition of plant materials plays an important role in increasing soil Mg content. An increase of the concentration of available basic cations after the burn of plant litters. Another reason may be due to the accumulation of ashes rich in oxides and carbonates of basic ions [44] renders the higher Mg content in soil in alley cropping system.

### 3.1.8 Exchangeable K

The exchangeable K content in soil showed an irregular fashion. However, K was lower in control treatments as compared to alley cropping treatments (Table 3). Incorporation of the pruned materials of G. sepium slightly increased the soil exchangeable K as compared to the control. The average exchangeable K in G. sepium pruned material added plot was 0.09 meq/100g soil, while the average values were 0.16 and 0.15 meq/100g soil for W4.5 and W6.0 alley widths respectively. The average increment of exchangeable K was 86.36% in W3.0 alley width while the average increments were only 81.82% and 75.00% in the higher alley widths of W4.5 and W6.0 respectively over the control (Fig. 1b). Among the treatments, the highest exchangeable K was recorded in W4.5N100+PM (0.19 meq/100 g soil) and the lowest was found in both CC+N6 and CC+N25 (0.08 meq/100 g soil) treatments (Table 3). Crop removal and losses through runoff may be attributed to the lowest exchangeable K in the control plot, whereas, the increase in exchangeable K in plots under the three different alley widths might be due to the return of K via tree pruning and leaf litterfall to the soil surface [42] and an increased exchangeable K was observed under G. sepium [24].

### 3.1.9 Cation exchange capacity (CEC)

The cation exchange capacity (CEC) of soil varied among the treatments but the incorporation of the pruned materials of G. sepium slightly increased the soil CEC compared to the control (Table 3). The average CEC of G. sepium pruned material added plot was 14.67 meq/100g soil in W3.0 treatment while the average values were 15.64 and 14.26 meq/100g soil were found in W4.5 and W6.0 treatments respectively. The average increment of CEC was 12.34% in W3.0 whereas, the values were observed 19.77% and 9.22% in W4.5 and W6.0 treatments respectively over the control (Fig. 1b). Among the treatments, the highest CEC of soil was recorded in W4.5N100+PM (15.99 meq/100g soil) and the lowest was recorded in CC+N25 (12.74 meq/100g soil) treated plots (Table 3).
CEC of soil indicates the fertility status of soil and higher CEC indicates the more fertile condition of soil. The improvement of CEC was recorded due to the addition of pruned materials in alleys of alley cropping system at BSMRAU alley cropping field when cabbage was grown under five different nitrogen levels [41].

Table 3. Change in soil properties in alley cropping system as influenced by tree pruned materials of Gliricidia sepium along with different N doses after harvesting of Cauliflower (Average of two seasons)

| Treatment | pH | OC (%) | TN (ppm) | P (ppm) | S (ppm) | Ca (meq/100 g of soil) | Mg (meq/100 g of soil) | K (ppm) | CEC (meq/100 g of soil) |
|-----------|----|--------|----------|---------|---------|------------------------|------------------------|---------|------------------------|
| W 3.0 N0 + PM | 5.79 | 0.71 | 0.140 | 12.40 | 13.28 | 2.42 | 0.62 | 0.14 | 14.02 |
| W 3.0 N25 + PM | 5.84 | 0.77 | 0.149 | 12.89 | 13.76 | 2.48 | 0.71 | 0.14 | 14.43 |
| W 3.0 N50 + PM | 5.84 | 0.82 | 0.166 | 13.81 | 14.68 | 2.51 | 0.76 | 0.16 | 14.72 |
| W 3.0 N75 + PM | 5.81 | 0.88 | 0.186 | 14.50 | 15.37 | 2.49 | 0.80 | 0.18 | 14.90 |
| W 3.0 N100 + PM | 5.80 | 0.94 | 0.209 | 16.26 | 17.13 | 2.54 | 0.89 | 0.20 | 15.28 |
| W 4.5 N0 + PM | 5.75 | 0.59 | 0.139 | 12.40 | 13.28 | 2.30 | 0.62 | 0.14 | 15.35 |
| W 4.5 N25 + PM | 5.69 | 0.63 | 0.147 | 12.88 | 13.76 | 2.38 | 0.69 | 0.14 | 15.38 |
| W 4.5 N50 + PM | 5.87 | 0.65 | 0.162 | 13.80 | 14.68 | 2.32 | 0.73 | 0.16 | 15.70 |
| W 4.5 N75 + PM | 5.90 | 0.68 | 0.180 | 14.49 | 15.36 | 2.08 | 0.74 | 0.17 | 15.78 |
| W 4.5 N100 + PM | 5.72 | 0.73 | 0.201 | 16.24 | 17.11 | 2.18 | 0.74 | 0.19 | 15.99 |
| W 6.0 N0 + PM | 5.75 | 0.56 | 0.139 | 11.52 | 12.40 | 2.13 | 0.61 | 0.14 | 13.83 |
| W 6.0 N25 + PM | 5.52 | 0.62 | 0.145 | 12.05 | 12.93 | 2.34 | 0.67 | 0.14 | 14.20 |
| W 6.0 N50 + PM | 5.80 | 0.60 | 0.159 | 12.94 | 13.82 | 2.18 | 0.69 | 0.15 | 14.30 |
| W 6.0 N75 + PM | 5.93 | 0.63 | 0.174 | 13.69 | 14.56 | 2.34 | 0.68 | 0.16 | 14.43 |
| W 6.0 N100 + PM | 5.35 | 0.66 | 0.194 | 15.40 | 16.26 | 2.35 | 0.66 | 0.18 | 14.55 |
| CC + N0 | 5.13 | 0.45 | 0.072 | 7.68 | 7.68 | 1.07 | 0.42 | 0.08 | 12.99 |
| CC + N25 | 5.39 | 0.44 | 0.081 | 7.65 | 7.66 | 1.05 | 0.43 | 0.08 | 13.14 |
| CC + N50 | 5.54 | 0.44 | 0.081 | 7.67 | 7.69 | 1.08 | 0.44 | 0.09 | 13.25 |
| CC + N75 | 5.47 | 0.42 | 0.081 | 7.60 | 7.65 | 1.08 | 0.39 | 0.09 | 12.74 |
| CC + N100 | 5.16 | 0.43 | 0.083 | 7.77 | 7.84 | 1.17 | 0.39 | 0.10 | 13.17 |
| SE (±) | 0.68 | 0.02 | 0.02 | 1.45 | 0.78 | 0.09 | 0.03 | 0.20 | 1.55 |
| CV | 2.06 | 3.54 | 3.10 | 0.60 | 0.66 | 1.52 | 1.06 | 0.14 | 1.57 |

GS: Gliricidia sepium; N0 = 0%; N25 = 25%; N50 = 50%; N75 = 75%
AW 3.0 = 3 m, AW 4.5 = 4.5 m, AW 6.0 = 6 m

Fig. 1a. Performance of pruned materials application in three different alley widths when cauliflower was grown for improving soil fertility. Data presented are means and standard errors of three replications (n = 3). Different alphabetical letters above the error bars indicate significant differences among various treatments (P < 0.05, least significant difference test). Organic C, organic carbon; N, Nitrogen
Fig. 1b. Performance of pruned materials application in three different alley widths when cauliflower was grown for improving soil fertility. Data presented are means and standard errors of three replications ($n = 3$). Different alphabetical letters above the error bars indicate significant differences among various treatments ($P < 0.05$, least significant difference test). P, phosphorus; S, sulphur; Ca, Calcium; Mg, magnesium; K, potassium; CEC, cation exchange capacity.

4. CONCLUSIONS

The findings of the study revealed that $G$. sepium as a fertilizer tree in the alley cropping system potentially improved the soil chemical properties than the mono-cropping system. Our results indicated that $G$. sepium based alley cropping system could be a viable option in response to
restore the soil health for noteworthy crop production.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Khan MS, Shil NC and Noor S. Integrated nutrient management for sustainable yield of major vegetable crops in Bangladesh. Bangladesh Journal of Agriculture and Environment. 2008;4(Special Issue):81-94.

2. Hossain SMA, Kashem MA. Management combat declining soil fertility in Bangladesh. Keynote paper. Proc. of the 6th Biennial Conference of the Bangladesh Soc. Agron. 1997:22-39.

3. Miah MA, Saha PK, Islam A, Hasan MN and Nosov V. Potassium fertilization in rice-rice and rice-wheat cropping system in Bangladesh. Bangladesh Journal of Agriculture and Environment. 2008;4(Special Issue):51-67.

4. Dollinger J, Jose S. Agroforestry for soil health. Agroforestry System. 2018;92:213–219. Available:https://doi.org/10.1007/s10457-018-0223-9

5. Chowdhury MAH, Hassan MS. Hand book of agricultural technology. Bangladesh Agricultural Research Council, Farmgate, Dhaka. 2013:230.

6. Young A. Agroforestry for soil conservation. BPCC Wheatons Ltd, Exeter; 1989.

7. Nair PKR. Agroforestry systems and environmental quality: introduction. Journal of Environmental Quality. 2011;40:784–790. Available:https://doi.org/10.2134/jeq2011.0076

8. Das AK, Rahman MA, Keya SS, Saha SR, Rahman MM. Malta-based agroforestry system: An emerging option for improving productivity, profitability and land use efficiency. Environmental Sustainability; 2020. Available:https://doi.org/10.1007/s42398-020-00139-5

9. Dhaliwal J, Kukal SS, Sharma S. Soil organic carbon stock in relation to aggregate size and stability under tree-based cropping systems in Typic Ustochrepts. Agroforestry System; 2018. Available:https://doi.org/10.1007/s10457-017010-8

10. Nair PKR. Soil productivity aspects of agroforestry. International Council of Research in Agroforestry (ICRA), Nairobi. 1984;85.

11. Tossah BK, Zamba DK, Vanlauwe B, Sangina N, Lyasse O, Diels J, Merckx R. Alley cropping in the moist savanna of West Africa: Impact on soil productivity in a North to South transects in Togo. Agroforestry system. 1999;42(3):229-244.

12. Miah MG. Performance of selected multipurpose tree species and field crops growing in association as affected by branch pruning PhD. Dissertation, CLSU, Nueva Eeija, Philippines; 1993.

13. Rhoades CC, Nissen TM, Kettler JS. Soil nitrogen dynamics in alley cropping and no-till systems on ultisols of Georgia Piedmont, USA. Agroforestry Systems. 1998;39:31–44.

14. Peichl M, Thevathasan NV, Gordon AM, Huss J, Abihassan RA. Carbon sequestration potentials in temperate tree-based intercropping systems. Southern Ontario, Canada. Agroforestry Systems. 2006;66:243–257.

15. Udawattha RP, Jose S. Carbon sequestration potential of North American agroforestry practices. In Carbon sequestration in agroforestry systems, B.M. Kumar and P.K.R. Nair (eds.), The Netherlands: Springer. 2011;17–42.

16. Kang B T, Wilson GF, Lawson TL. Alley cropping, a stable alternative to shifting cultivation international institute for tropical agriculture, Ibadan, Nigeria, 1984;23.

17. Seiler S, William RD, Hibbs DE. Crop yield and tree-leaf production in three planting patterns of temperate-zone alley cropping in Oregon, USA. Agroforestry Systems. 1999;46:273–288.

18. Gomez E, Bisaro V, Conti M. Potential C-source utilization patterns of bacterial communities as influenced by clearing and land use in a vertic soil of Argentina. Applied Soil Ecology. 2000;15:273–281.
19. Myers RT, Zak DR, White DC, Peacock A. Landscape-level patterns of microbial community composition and substrate use in upland forest ecosystems. Soil Science Society of America Journal. 2001;65:359–367.

20. Munagai NW, Motavalli PP, Kremer RJ, Nelson KA. Spatial variation of soil enzyme activities and microbial functional diversity in temperate alley cropping systems. Biology and Fertility of Soils. 2005;42:129–136.

21. Rahman MA, Das AK, Saha SR, Uddin MM, Rahman MM. Morpho-physiological response of Gliricidia sepium to seawater-induced salt stress. The Agriculturist. 2019;17:66-75.

22. Brammer H. Rice soil of Bangladesh. In: Soil and Rice, IRRI, Manila, Philippines. 1978;35-45.

23. Rahman MB. Performance of cauliflower in aonla based multistoried agroforestry system. M. S. Thesis. Department of Agroforestry and Environment, BSMRAU, Gazipur, Bangladesh; 2014.

24. Ferdush J. Impact of alley cropping on wheat productivity and soil fertility. M. S. Thesis. Department of Agroforestry and Environment, BSMRAU, Gazipur; 2019.

25. Mclean EO. pH and lime requirement, methods of soil analysis. Part 2, 2nd ed. Chemical and microbial properties. Soil. 1982:199-224.

26. Jackson ML. Soil chemical analysis. Prentice Hall of India Pvt. Ltd. New Delhi. 1967:498.

27. Page AL, Miller RH, Keeney DR. Methods of analysis part 2, chemical and microbiological properties. Second edition, American Society of Agronomy, Inc., Soil Science Society of American Inc. Madison, Wisconsin, USA. 1982:403-430.

28. Olsen SR, Cale CV, Watanabe FS, Dean LA.. Estimation of available phosphorus in soils by extraction with sodium bicarbonate, USDA Circ. 939, Washington, USA; 1954.

29. Chesin L, Yien CH. Tribidimetric determination of available sulphates. Soil Science Society of America Journal. 1951;15:149-151.

30. Hesse PR. A text book of soil chemical analysis, John Murry Publ., London. 1971;106-234.

31. Attah-Krah AN, Sunberg JE. In: Withington, D. N; N. Glovar and J. L. Brewbaker (eds) “Gliricidia sepium (Jacq.) Walp manegment and improvement”. Nitrogen Fixing Tree Association, Waimanalo, Hawaii. 1987;31-43.

32. Onim JFM. Soil fertility changes and response of maize and beans to green manure of leucaena, sesbania and pigeonpea. Agroforestry system. 1990;12:197-215.

33. Rahman MA. Effect of alley cropping with different nitrogen levels on crop productivity and soil properties in upland ecosystem. M. S. Thesis. Department of Agroforestry and Environment, BSMRAU, Gazipur, Bangladesh; 2001.

34. Islam MH. Productivity of wheat, Tomato and cabbage in alley cropping system as affected by tree species and levels of nitrogen in upland ecosystem. M. S. Thesis. Department of Agroforestry and Environment, BSMRAU, Gazipur, Bangladesh; 2002.

35. Akhter SMM. Cabbage yield and change of soil chemical properties in response to tree levels and nitrogen application. M. S. Thesis. Department of Agroforestry and Environment, BSMRAU, Gazipur, Bangladesh; 2009.

36. Mazzarino MG, Szott L, Jemenez M. Dynamics of soil total C and N, microbial biomass and water-soluble C in tropical agro economics. Soil Biology and Biochemistry. 1993;25:205-214.

37. Jones RB, Wendt JW, Bunderson WT, Litmus OA. Leucaena+maize alley cropping in Malawi. Part 1: Effects on N, P and leaf application on maize yields and soil properties. Agroforestry systes. 1996;33:281-294.

38. FRG. Fertilizer recommendation guide, Bangladesh agricultural research council (BARC). Farmgate, Dhaka. 2012;1215:274.

39. Nwite J, Okonkwo C, Mbah C, Ekwe O, Uchewa E. Effect of alley cropping with Gliricidia sepium and NPK. fertilizer application on soil chemical properties and yield of Amaranthus cruentus. International Journal of Tropical Agriculture and Food Systems. 2008;2:2-3.

40. Agboola AA, Wilson GF, Gatahan A, Yamoah CF. Gliricidia sepium: A possible means to sustained cropping In: Maqc. Donald, L. H. (ed). Agroforestry in the African Humid Tropics. The United Nation University, Tokyo, Japan. As cited Attah-Krah and Sunberg; 1982.
41. Tonny KF. Impact of alley cropping on cabbage productivity and soil environment. M. S. Thesis. Department of Agroforestry and Environment, BSMRAU, Gazipur; 2017.

42. Miah MG, Garrity DP, Aragon ML. Effect of Legum trees on Soil chemical properties under Agroforestry system. Ann. Bangladesh Agric. 1997;7(2):95-103.

43. Soriano HM. Jr. Soil fertility and productivity aspects of alley cropping schemes using leguminous trees as hedgerows and corn. As an alley crop. A PhD dissertation, UPLB, Laguna; 1991.

44. Arévalo-Gardini E, Canto M, Alegre J, Loli O, Julca A, Baligar V. Changes in soil physical and chemical properties in long term improved natural and traditional agroforestry management systems of cacao genotypes in peruvian Amazon. PLoS ONE. 2015;10(7):e0132147. pmid:26181053