Ann. Bangladesh Agric. (2020) 24 (1) : 77-87
www.doi.org/10.3329/aba.v24i1.51937

ISSN 1025-482X (Print)
2521-5477 (Online)

APPLICATION OF *GLIRICIDIA SEPIUM* TREE LEAVES AND NITROGEN FERTILIZER TO IMPROVE TOMATO PRODUCTION AND SOIL PROPERTIES

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Abstract

Excess use of agrochemicals for intensive cultivation affects crop quality and destroys agro-ecosystems, and eventually creates health hazards. The study aims to investigate the effect of *Gliricidia sepium* (GS) tree leaf as suitable green manures for supplementing nutrient supply along with nitrogen (N) fertilizer to produce quality tomato and soil fertility improvement. A field experiment was conducted at the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh, from November 2016 to March 2017. The experiment was laid out in a randomized complete block design (two factors) with three replications. There were nine treatment combinations with three levels of GS tree leaves (5, 10 and 15 t ha^{-1}) and three doses of N (0, 50 and 100% of the recommended dose of fertilizer). The highest tomato yield was recorded in $GS_{15}\times N_{100}$ treatment combination, which was 41.68% higher compared to the control treatment. Decreasing C: N ratio in increasing dose of GS and N treated plot indicated the quality of tree leaves that ensures faster decomposition and high nutrient release pattern of this species. Increasing rate of soil pH and cation exchange capacity (CEC) in different treatments as compared to initial soil showed soil fertility improvement. Overall, the results indicated that quality tomato could be grown successfully by the application of *G. sepium* tree leaves along with an appropriate amount of N fertilizer.

Keywords: Green leaf manure, *Gliricidia sepium*, organic matter, soil fertility, tomato.

Introduction

World population is predicted to be enhanced to 9.7 billion and to feed these huge population, food production will be required to enhance about 70% between 2007 and 2050 (Bruinsma, 2011; FAO, 2016). Nevertheless, at present, Bangladesh positioned eighth most populous country in the world, whilst the predicted population will be 220 million by 2050 (Hossain, 2012). Higher population growth rate, rapid industrialization and infrastructural development provoke shrinking of per capita land from 0.13 to 0.04 ha between the years of 1960 and 2016 (Islam *et al*., 2016; Lal, 2016). Furthermore, extensive use of chemical fertilizers and pesticides for a long time, aggravate the deterioration of soil fertility and productivity through the alternation of soil physico-chemical properties, like texture, structure, pH, and organic matter (OM) as well

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as threatened the biodiversity composition (Kafiluddin and Islam, 2008; Lupatini *et al*., 2017). Undeniably, soils polluted by the appliance of chemical substances not merely destroying the soil ecology but also affecting the quality and safety of products by entering the food chain, resultant human health problems. Furthermore, increasing price of agricultural inputs upsurges the cost of production, which gradually makes agriculture as a non-profitable enterprise (Rasul and Thapa, 2004). To make the agricultural production systems environmentally friendly, socially fair and economically beneficial; agricultural scientists, environmentalists, and policymakers are now advocating the introduction of climate-smart organic agriculture (Wezel *et al*., 2014). Organic farming (OF) is one of the holistic approaches in agricultural systems, utilizing both traditional and scientific knowledge to improve the agro-ecosystem health by emphasizing ecosystem management rather than reliance on external agricultural inputs (Reddy, 2017; Garibaldi *et al.,* 2017). This farming mainly concentrates on enhancing soil fertility by using organic fertilizers, improve water storage of soil, and the biological control of crop pests and diseases via using organic pesticides, and traditionally associated with low-input, small-scale, diversified farms (Reganold and Wachter, 2016; FAO, 2016). Nevertheless, green manuring as a form of OF have been recognized as one of the propitious option due to its low price, availability and environment friendly nature, since time immemorial. It is worth to mention that green leaf manure (GLM) is capable of supplying the required plant nutrients as well as maintaining very good soil health as like as organic manure. Incorporation of nutrient rich tree leaves, especially leaves of leguminous plants like *Gliricidia sepium* (*G. sepium*), has come into limelight as a solution towards improving soil fertility due to its profuse growth, deciduous nature, rapid decomposition rate and higher nutrient content properties (Frankenberger and Abdelmagid, 1985; Makumba *et al.,* 2006; Rahman, 2008). It has been reported that application of *Gliricidia* leaf manure at the rate of 1 t ha^{-1} provides 21 kg N, 2.5 kg P, 18 kg K, 85 g Zn, 164 g Mn, 365 g Cu, 728 g Fe besides adding considerable quantities of S, Ca, Mg, B, Mo (Srinivasarao *et al*., 2011).

The tomato (*Solanum lycopersicum*) is the second most widely consumed vegetable after the potato because of its availability and nutritional values (Lugasi *et al.,* 2003; Ilić *et al.,* 2014). In the human diet, it is an important source of micronutrients, certain minerals (especially potassium), carboxylic acids and carotenoids (Suárez *et al.,* 2007; Ilić *et al.,* 2014). Most importantly, tomato consumption has been shown to reduce the risks of cardiovascular disease and certain types of cancer, such as prostate, lung, and stomach (Canene-Adams *et al.,* 2005; Ilić *et al.,* 2014). Despite impressive nutritional properties, tomato production in Bangladesh is quite low (14.85 t ha^{-1}) compared with many other countries like India (25.67 t ha^{-1}), Japan (52.82 t ha^{-1}), USA (65.22 t ha^{-1}), China (30.39 t ha^{-1}), Egypt (34.00 t ha^{-1}) and Turkey (41.77 t ha^{-1}). The low yield potentiality of this crop is mostly attributable to unavailability of improved varieties and quality seeds, improper management of fertilizers, irrigation, and disease control measures. In addition, OM content of Bangladesh's soils is less than 1% (BARC, 2012) and ranging between 0.05

and 0.9%, which are mostly responsible for low yield, since, OM act as a key reservoir of metabolic energy to driven soil biological processes that involved in nutrient availability of plants (Pandey and Chandra, 2013; Huq and Shoaib, 2013). Therefore, other than varietal advancement, improvement of soil properties would be a best solution to boost the tomato yield. In this aspect, the present research work was undertaken to investigate the effects of *G. sepium* tree leaves inclusion as partial supplement of chemical fertilizers as well as different dosage of N fertilizer on soil properties, tomato yield and quality of tomato.

Materials and Methods

Plant materials, treatments and growth conditions

A field experiment was conducted at the research field of the Department of Agroforestry and Environment, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh during November 2016 to March 2017. BARI Tomato-15 was used as the test crop for this study. *Gliricidia* leaves were incorporated into the soil at the rate of 5 (GS_5), 10 (GS_{10}) and 15 (GS_{15}) ton per hectare, which were considered as factor A. Simultaneously, three doses of N fertilizer i.e. 0, 50 and 100% of the recommended rate were also applied and considered as factor B. Therefore, the total treatment combinations were nine. Afterwards, all treatment combinations were compared with control plot denoted as farmer's practice, which was fertilized by the recommended doses of fertilizers. *Gliricidia* tree leaves were incorporated into the soils as treatments fifteen days before tomato seedling transplanting for better decomposition. The size of the plot was 2.5×4 m^2. Each plot was also fertilized by triple super phosphate (200 kg ha^{-1}) and mutate of potash (220 kg ha^{-1}). Thirty-six (36) day old healthy and uniform tomato seedlings were transplanted maintaining 50 cm× 60 cm spacing.

Determination of growth and yield parameters

Height of plants were taken from the selected five plants at 15, 30, 45, 60, 75 and 90 days after transplanting (DAT). Fruits were harvested from five selected plants when they attained to edible size in order to collect the yield-related attributes, including fruit length (mm), fruit diameter (mm) and fruit weight (g). Fruits were harvested in several times and recorded the same yield-contributing features. Furthermore, number of clusters per plant and number of fruits per plant were also recorded to appraise the yield of plant. Harvesting duration was determined by counting the days from first harvest to last harvest. Fresh yield of tomato was determined by cumulating the weight of representative fruits from each harvest then made average and afterwards multiplied by the number of fruits.

Changes in soil properties

Top soils (0-15 cm) were collected from each plot after two weeks of *Gliricidia* leaf incorporation and continue till to harvesting at one-week interval. Collected soil samples were then air-dried, ground and sieved in order to determine chemical properties of soils, including pH, organic carbon, total nitrogen and cation exchange capacity (CEC) following the procedure of McLean (1982), Walkley and Black (1934), Jackson (1958) and Black *et al*. (1965), respectively. Organic carbon and nitrogen content ratio (C: N) were determined by dividing the value of organic carbon content in soils by total nitrogen content in soils.

Statistical analysis

Data recorded for different parameters of plant and soils were statistically analyzed by using Statistix 10 program following randomized complete block design with three replications and means were compared by LSD at 5% level of significance.

Results and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized into two sections, including (i) performance of tomato, and (ii) changes in soil properties.

Performance of tomato

Plant height: Plant height of tomato increased gradually with time and at the final measuring date, the highest plant height (103.07 cm) was recorded in $GS_{15}\times N_{50}$ treatment combination, which was 10.21% higher compared to control plot (Table 1). In contrast, the lowest plant height (85.67 cm) was recorded in $GS_{10}\times N_0$ treatment combination, which was 8.39% lower relative to that of control plots (Table 1). Besides, 50% of applied nitrogen, faster decomposition rate and better nutrient release from *Gliricidia* tree leaves might be associated with improved soil fertility that helps to improve plant growth in terms of plant height. Winarni *et al.* (2016) demonstrated that the rice plant height was better in *Gliricidia* leaves-treated pots compared to that of cowdung-treated pots, which considered as control treatment.

Table 1. Effect of *Gliricidia* leaf incorporation and different nitrogen levels on the height of tomato plant

Treatment combinations	15DAT	30DAT	45DAT	60DAT	75DAT	90DAT
$GS_5\times N_0$	42.40 ^{c}	71.40^{b}	78.77 ^{b}	83.80 ^{bc}	88.53 ^{bc}	90.8 ^{bc}
$GS_5\times N_{50}$	50.08^{a}	81.13 ^{a}	90.80 ^{a}	91.67 ^{ab}	95.70 ^{ab}	97.73 ^{ab}
$GS_5\times N_{100}$	48.33 ^{ab}	80.40 ^{a}	86.03 ^{ab}	90.33 ^{abc}	94.97 ^{ab}	97.13 ^{ab}
$GS_{10}\times N_0$	43.13 ^{c}	71.47 ^{b}	82 .00 ^{ab}	80.00 ^{c}	83.73 ^{c}	85.67 ^{c}
$GS_{10}\times N_{50}$	43.80 ^{bc}	78.93 ^{ab}	91.94 ^{a}	92.07 ^{ab}	96.63 ^{ab}	98.82 ^{ab}
$GS_{10}\times N_{100}$	47.33 ^{abc}	79.73 ^{a}	89.00 ^{ab}	93.35 ^{ab}	97.60 ^{ab}	99.80 ^{ab}
$GS_{15}\times N_0$	43.33 ^{bc}	73.60 ^{ab}	83.67 ^{ab}	87.67 ^{abc}	91.90 ^{abc}	94.10 ^{abc}
$GS_{15}\times N_{50}$	42.40 ^{c}	80.27 ^{a}	84.07 ^{ab}	95.47 ^{a}	100.57 ^{a}	103.07 ^{a}
$GS_{15}\times N_{100}$	46.70 ^{abc}	81.13 ^{a}	87.60 ^{ab}	90.60 ^{abc}	95.57 ^{ab}	98.42 ^{ab}
Control (FP)	37.33	62.45	71.47	81.67	88.90	93.52
CV	6.48	5.69	6.94	7.30	6.52	6.10

Means within a column followed by same letter(s) are not significantly different by LSD, $P \leq 0.05$. Subscript values in treatment column denotes different treatment amounts. GS-*Gliricidia sepium*; N-nitrogen; FP-farmers practice; CV-coefficient of variance; DAT-days after transplanting.

Number of cluster and fruits per plant: Results presented in Table 2 indicate that the maximum number of cluster per plant (7.00) was noted in $GS_{10}×N_{50}$ and $GS_{10}×N_{100}$ treatment combination, which was 16.66% higher compared to control plot. Whereas, minimum number of cluster (5.33) was recorded in $GS_5 × N_{100}$ treatment combination, which was 11.16% lower in comparison to that of control plot. On the other hand, the highest number of fruits per plant (25.00) was recorded in $GS_{15}×N_{100}$ treatment combination, which was 13.64% higher in contrasted to control plot (Table 2). While, the least number of fruits per plant was obtained in $GS_5×N_0$ (19.33) treatment combination, which was 12.14% lower compared to control plot (Table 2). Correspondence to our findings, Kendaragama (1999) also reported that tomato plants fertilized by *Gliricidia* tree leaves showed higher number of fruits per plant relative to that of coir dust, cowdung, and rice straw accompanied by chemical fertilizer application (N-90 kg ha^{-1}, P_2O_5-121.5 kg ha^{-1}, K_2O-80 kg ha^{-1}). Quee *et al.* (2017) noted that application of *G. sepium* leaves as mulch (at 0, 30, 60, 90, 120 kg ha^{-1}) positively influenced the number of cob m^{-2} in maize (10.0, 17.3, 24.0, 31.0, 38.3, respectively).

Fruit length and width: Treatment combinations of $GS_{15}×N_{50}$ and $GS_5×N_0$ showed the maximum (64.62 mm) and minimum fruit length (52.34 mm), which were 10.63% higher and 10.44% lower, respectively, in comparison to that of control plot (Table 2). The better fruit length of tomato might be associated with better nitrogen use efficiency as N released from *Gliricidia* tree leaves

Table 2. Effect of *Gliricidia* leaf incorporation and different nitrogen levels on the yield contributing characters of tomato

Treatments	Number of clusters/plant	Fruits/ plant	Fruit length (mm)	Fruit width (mm)
$GS_5×N_0$	6.33 ^{ab}	19.33 ^{f}	52.34 ^{e}	42.75 ^{d}
$GS_5×N_{50}$	6.33 ^{ab}	21.33 ^{d}	56.20 ^{de}	47.37 ^{c}
$GS_5×N_{100}$	5.33 ^{b}	22.00 ^{d}	62.03 ^{abc}	53.18 ^{ab}
$GS_{10}×N_0$	6.00 ^{ab}	20.33 ^{e}	57.74 ^{cd}	50.25 ^{bc}
$GS_{10}×N_{50}$	7.00 ^{a}	23.33 ^{c}	59.48 ^{bcd}	54.30 ^{ab}
$GS_{10}×N_{100}$	7.00 ^{a}	24.33 ^{ab}	63.40 ^{ab}	54.30 ^{ab}
$GS_{15}×N_0$	6.00 ^{ab}	21.33 ^{b}	62.94 ^{ab}	54.19 ^{ab}
$GS_{15}×N_{50}$	6.33 ^{ab}	24.00 ^{bc}	64.62 ^{a}	54.70 ^{a}
$GS_{15}×N_{100}$	6.00 ^{ab}	25.00 ^{a}	62.43 ^{abc}	56.84 ^{a}
Control (FP)	6.00	22.00	58.41	49.16
CV	12.44	2.50	4.16	4.51

Means within a column followed by same letter(s) are not significantly different by LSD, $P \leq 0.05$. Subscript values in treatment column denotes different treatment amounts. GS-*Gliricidia sepium*; N-nitrogen; FP-farmers practice; CV-coefficient of variance.

together with adding from external nitrogen (50% of the recommended dosage) source, which is coincided with the result of enhanced fruit length of tomato with increasing dosage of N as reported by Pervin (2004). However, $GS_{15}×N_{100}$ treatment combination showed the maximum width of fruit (56.84 mm), which was 15.62% higher compared to control plots. Whereas, least fruit width (42.75 mm) was found in $GS_5×N_0$ treatment combination, which was 13.04% lower in contrasted to control plot.

Individual fruit weight and fruit yield: The maximum (115.61 g) and minimum weight (71.18 g) of individual fruit were found in $GS_{15}×N_{100}$ and $GS_5×N_0$ treatment combinations, respectively, which were 24.69% higher and 23.23% lower compared to control plot (Table 3). Augmented fruit weight of tomato might be associated with translocation of nitrogen to the fruits that exuberated the growth and thickness of the cell wall as well as increases the amount of solids, which perhaps responsible for increasing fruit weight (Pervin, 2004). Similar to our findings, Gaisie *et al*. (2016) also reported that incorporation of *Gliriciida* tree leaves in accordance with the recommended dose of supplemented nitrogen fertilizer might be contributed to achieve a profitable individual fruit weight in tomato. Significantly the maximum yield of tomato fruit in per plant (2.89 kg) was noted in $GS_{15}×N_{100}$ treatment combination, which provided 41.67% more yield compared to control plot. In contrast, minimum tomato yields in per plant (1.38 kg) was recorded in $GS_5×N_0$ treatment combination (Table 3). Similar to those results,

Table 3. Effect of *Gliricidia* leaf incorporation and different nitrogen levels on the yield of tomato

Treatment	Individual fruit weight per plant (g)	Total fruit yield per plant (kg)	Fruit yield (t ha^{-1})
$GS_5×N_0$	71.18 ^{h}	1.38 ^{f}	41.27 ^{f}
$GS_5×N_{50}$	79.15 ^{g}	1.69 ^{e}	50.64 ^{e}
$GS_5×N_{100}$	92.27 ^{e}	2.03 ^{d}	60.90 ^{d}
$GS_{10}×N_0$	87.36 ^{f}	1.78 ^{e}	53.29 ^{e}
$GS_{10}×N_{50}$	97.44 ^{d}	2.27 ^{c}	68.20 ^{c}
$GS_{10}×N_{100}$	110.28 ^{b}	2.68 ^{b}	80.52 ^{b}
$GS_{15}×N_0$	99.67 ^{c}	2.19 ^{c}	65.80 ^{c}
$GS_{15}×N_{50}$	109.90 ^{b}	2.64 ^{b}	79.13 ^{b}
$GS_{15}×N_{100}$	115.61 ^{a}	2.89 ^{a}	86.71 ^{a}
Control FP	92.72	2.04	61.20
CV	1.1	2.55	2.55

Means within a column followed by same letter(s) are not significantly different by LSD, $P \leq 0.05$. Subscript values in treatment column denotes different treatment amounts. GS-*Gliricidia sepium*; N-nitrogen; FP-farmers practice; CV-coefficient of variance.

maximum fruit yield in per hectare (86.71 t ha^{-1}) was also noted in GS$_{15}$×N$_{100}$ treatment combination, while minimum (41.27 t ha^{-1}) was found in GS$_5$×N$_0$ treatment aggregation. The capability of *Gliricidia* leaf manuring in enhancing the productivity, improving fertility and nutrient availability, and increasing crop yields were also observed in several research works (Kuntashula *et al*., 2004; Rahman, 2008; Srinivasarao *et al*., 2011; Quee *et al.,* 2017; Prakash *et al.,* 2017).

Changes in soil properties

Soil properties, including pH and cation exchange capacity (CEC) were evaluated in order to assess the changes in soil quality after field experimentation. Moreover, C:N ratio was also determined regularly at weekly interval to get insights into the decomposition pattern of *G. sepium* tree leaves.

Soil pH and cation exchange capacity: In comparison to that of soils collected before field experimentation, an enhancement of soil pH was observed in all treatment combinations accompanied by *G. sepium* tree leaves. However, higher level of soil pH (6.23) was found under the treatment combination of GS$_{15}$×N$_{100}$, which was 9.68% higher compared to the soils before field experimentation (Table 4). These results clearly indicated that the soil pH increases with increasing amount of incorporated *G. sepium* tree leaves along with the amount of N fertilizer. Moreover, the increase in soil pH under *G. sepium* was explained by its faster leaf decomposition (Miah *et al*., 1997). Similar result of increasing soil pH under *G. sepium* was also observed by Makumba *et al.* (2006) and Ahmed *et al.* (2010). Similar to soil pH after field experimentation, cation exchange capacity of soils collected from all treatment

Table 4. Combined effect of incorporated *Gliricidia* leaf and different levels of nitrogen on the properties of soil after harvesting of tomato compared to initial soil

Soil samples/ Treatments	pH	% Change	CEC (meq 100^{-1}g)	% Change
Initial soil	5.68		19.98	
Soil after harvest (added amount of *G. sepium* leaves × added portion (%) of recommended nitrogen doses)				
GS$_5$×N$_0$	6.04	6.33	21.11	5.66
GS$_5$×N$_{50}$	6.04	6.33	21.73	8.76
GS$_5$×N$_{100}$	6.10	7.39	23.47	17.47
GS$_{10}$×N$_0$	6.15	8.27	23.20	16.16
GS$_{10}$×N$_{50}$	6.16	8.45	25.08	25.53
GS$_{10}$×N$_{100}$	6.18	8.80	27.35	36.88
GS$_{15}$×N$_0$	6.16	8.45	26.88	34.53
GS$_{15}$×N$_{50}$	6.18	8.80	28.51	42.69
GS$_{15}$×N$_{100}$	6.23	9.68	30.78	54.05

Subscript values in treatment column denotes different treatment amounts. GS-*Gliricidia sepium*; N-nitrogen.

plots showed enhanced value compared to that of soils before field experimentation. However, the maximum cation exchange capacity of soil was recorded in the treatment plot of $GS_{15}\times N_{100}$, which was 54.05% higher relative to that of soil collected before field experimentation. The biomass produced by green manures positively influences the chemical characteristics of the soils, enabling increase in organic matter content, which increases the cation exchange capacity, and therefore enhances the retention of nutrients in the soil particles (Ciotta *et al*., 2003; Zaccheo *et al*., 2016).

C: N ratio: The organic carbon and total nitrogen ratio (C: N) has great influence on the rate of decomposition of organic matter and the narrower the ratio, the rapid and better the decomposition of organic matter. The most efficient decomposition and/or composting occurs with an optimal C: N ratio of about 10:1 to 20:1 (Radovich *et al*., 2011). In this experiment, the organic carbon and total nitrogen content of soil showed an increasing trend from the very fast week after incorporation of *Gliricidia* tree leaves in the soil and continued till the end of the experiment, resulted a very low or narrow C: N ratio (Fig. 1). The ratio ranges from 13.29:1 in $GS_5\times N_0$ treatment combination to 9.07:1 in $GS_{15}\times N_{100}$ treatment combination at the final week, which was lower than the initial C: N ratio (16.88:1) of the soil. The result of this experiment implies that the incorporation of *Gliricidia* tree leaves had a great benefit due to its early decomposition and faster release of C and N, which ultimately activate the process of immobilization and mineralization of nutrients, and thus increases the availability of nutrients in the soil. From the results, it was also evident that the *Gliricidia* leaves incorporated into the soils at higher doses leads to lower the ratio

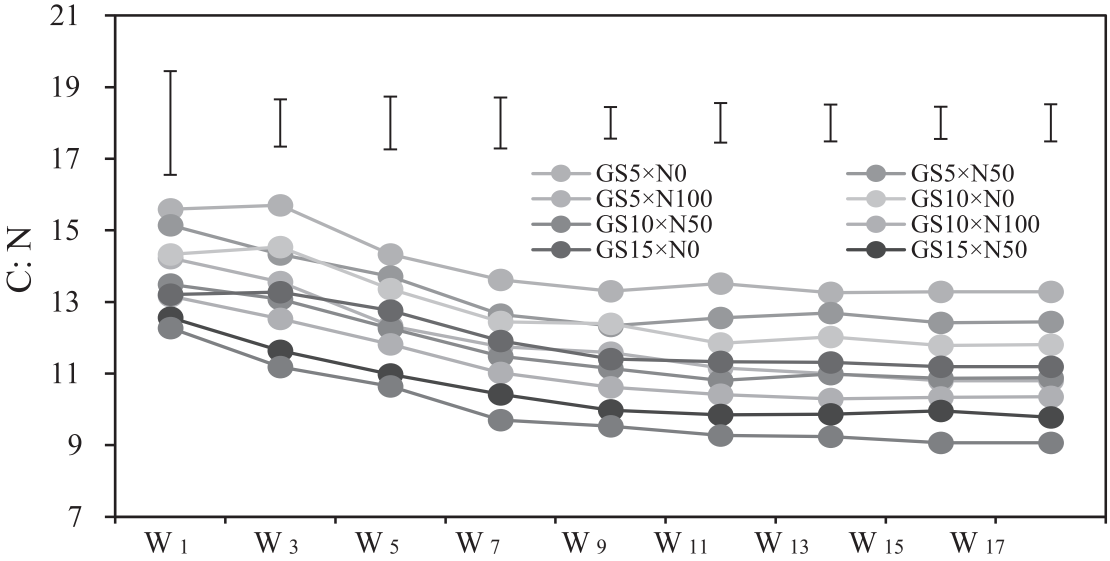

Fig. 1. Combined effect of *Gliricidia* leaf incorporation and different levels of N application on the C: N ratio of soil over the total cultivation period. Vertical bars indicate the LSD values at 5% level of significance. W- week; GS- *G. sepium*; N- nitrogen.

of C:N, which ensures higher availability of carbon and nitrogen throughout the cultivation period. Chowdhury (2000) and Makumba *et al.* (2006) also reported the increment of soil C and N, resultant lower C: N ratio after addition of *G. sepium* tree leaves in the fields.

Conclusions

On the basis of the results emerged out from the present investigation, it may be concluded that incorporated leaves of *G. sepium* along with nitrogenous (N) fertilizer in an optimum level positively influenced the yield of tomato. The higher yield (86.71 t ha^{-1}) was recorded in $GS_{15}\times N_{100}$ treatment combination, which was 41.68% increment compared to control. The chemical properties of the top soil (0-15 cm) showed positive changes indicating soil fertility. The C: N ration decreased over time indicating favorable soil environment by faster decomposition and nutrient release from *Gliricidia* tree leaf. The findings indicate that the enhancement of soil organic carbon, nitrogen, pH and CEC, may be due to incorporation of leaf litter of *Gliricidia* tree. This helps to enrich soil fertility and can maintain a good soil environment. Therefore, incorporation of *G. sepium* tree leaves along with suitable amount of N fertilizer can be a scope for profitable tomato production with sustainable soil fertility.

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