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Gliricidia Tree Leaf Incorporation into Soil and Use of Companion Plants for Safe Tomato Production

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Bangladeshi soils are generally low in fertility and enhanced crop yield is only possible through using of a combination of organic and inorganic fertilizers. Continuous use of agrochemicals in crop production and processing not only affecting the food quality, environment and humans but also increasing cost of production. A field study was conducted to investigate the effectiveness of companion plant (basil, nira and coriander) as an alternative pest management strategy along with application of organic matter (gliricidia tree leaf and cow dung) for safe tomato production, insect abundance and soil properties changes. Tomato yields were 59 and 61% higher when grown in gliricidia+basil plot compared to no-companion plant and no-organic matter treatment, respectively. Insect infestation was significantly lower in companion plant treatments. Soil pH and organic carbon were higher in cow dung than gliricidia leaf applied treatment. Results revealed that tomato in association with companion plants had potential effect on reducing insect pests as well as attracting pollinators and predators. However, the degree of potentiality of companion plants can be ranked as basil>coriander>nira. Therefore, tomato can be grown successfully in association with Basil as companion plant and by incorporating gliricidia tree leaf into soil as green manure.

Key words: Abundance, cow dung, diversity, insect, richness, soil properties.

INTRODUCTION

Among economically important vegetables, tomato (*Solanum lycopersicum* L.) is one of the world's most cultivated vegetables with a worldwide production of 177,042,359 tons (FAO, 2018). It is consumed throughout the world and has been demonstrated to possess health benefits due to its high content of phytonutrients (Hsu *et al.*, 2008). It is also important as a good source of vitamins, minerals and fiber in human diets. Due to adaptability to wide range of soil and climatic conditions, it is cultivated throughout the Bangladesh. Currently, the tomato growing area is around 27, 114 hectares, with annual production of 368,000 metric tons (Bangladesh Bureau of Statistics [BBS], 2017). The average yield is 13.46 mt ha⁻¹ in Bangladesh (BBS, 2017) which is low compared to other countries like India (21.96 mt ha⁻¹), Japan (55.72 mt ha⁻¹), USA (81.91 mt ha⁻¹), China (50.97 mt ha⁻¹), Egypt (36.08 mt ha⁻¹) and Turkey (60.71 mt ha⁻¹) (FAO, 2018). Among the different reasons of such a low yield, the depletion of soil organic matter and vis-à-vis soil fertility is of prime importance.

Soil organic matter is a key factor in maintaining long-term soil fertility since it is the reservoir of metabolic energy, which drives soil biological processes

involved in nutrient availability. A good soil should have at least 2.5% organic matter but in Bangladesh, most of the soils have less than 1.5%, and some soils even less than 1% organic matter (FRG, 2012). Further, the use of mineral fertilizers alone has been associated with increased soil acidity, nutrient imbalance and soil degradation. A comparable level of productivity can be achieved with the use of low level of mineral fertilizer combined with manures (Akande *et al.*, 2010). Therefore, mixing organic and inorganic fertilizers could be a sound soil fertility management strategy. Cow dung is known to be effective in maintenance of adequate supply of organic matter in soil, with improvement in soil physical and chemical properties and enhanced crop performance. Meanwhile, the benefits of gliricidia leaf incorporation into the soil are well known, which results in increase of soil organic matter and nitrogen; improvement of soil physical characteristics, aeration and drainage. Furthermore, when the leaves are initially applied as a surface mulch used to control weeds, reduces surface soil erosion and soil temperature, and help conserve soil moisture (Kang *et al.*, 1990). Gliricidia is native to the seasonally dry parts of Mexico and Central America and is now cultivated throughout the world as a result of domestication over many centuries. Gliricidia fresh leaf may be used as an alternative to cow dung.

Public anxiety has been growing, nowadays, about pesticides non-target effects on humans and other organisms. Many pests have devolved resistance to some of the most commonly-used pesticides. Since the tomato is eaten raw as salad, the quality of the fruits in terms of agrochemicals use is important to avoid health and environmental hazards. One pest-management alternative is the diversification of agricultural fields by

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establishing “polycultures” that include one or more different crop varieties or species within the same field, to more closely match the higher species richness typical of natural systems (Vandermeer, 1989).

Companion planting is a kind of poly culture, under which two species of plants are grown together that are acquainted to promote one another's growth. In addition, it might have repelling and/or intercepting effects on pests and pathogens and attract natural enemies or provide food for natural enemies. In principle, pests have direct negative effects on the crop, whereas natural enemies have direct negative effects on the pests, and thus have indirect positive effects on the crop (Letourneau *et al.*, 2011). Both host-hiding and encouragement of natural enemies have the potential to depress pest populations and increase the abundance of beneficial insects (Schader *et al.*, 2005), reducing the need for pesticide applications and increasing crop yields (Van Emden and Williams, 1974). Currently, pollination is thought to be one of the key ecosystem services, provided that humans depend on its association for food production, what prepares it a process with inseparable economic value (Hanley *et al.*, 2015).

There are several plants, which are considered as excellent companions for tomato. Those plants may provide insecticidal properties to control and repel insect pests because of the pressure of rich source of bioactive chemicals. Among them, Basil (*Ocimum basilicum*), Nira (*Allium ramosum*) and Coriander (*Coriandrum sativum*) are beneficial for tomato. Culinary herbs have been reported to possess antioxidant activities that can deter insect pest (Yanishlieva *et al.*, 2006). An attempt has therefore been made to compare the suitability of companion plant along with organic sources for tomato production in terms of productivity and pest management aspects in Bangladesh and investing the soil properties changes due to incorporation of gliricidia leaf into soil over traditional farming system.

MATERIALS AND METHODS

Study site

The study was conducted at the Bangabandhu Sheikh Mujibur Rahman Agricultural University research farm which is located at 24.00° N latitude and 90.25° E longitude (Hawlder and Mian, 1997) during the period from October 2016 to March 2017. It has an altitude of 8.4 m above the sea level (Hawlder and Mian, 1997) with average monthly rainfall between 0-82.63 mm, average monthly temperature between 12.11-32.77°C and average monthly relative humidity between 80.56-90.62% during the experimentation (Meteorological Station, BSMRAU). The soil of the experimental field belongs to Orchrept suborder of USDA soil taxonomy locally termed as Salna series of Shallow Red-Brown Terrace soil (Haider, Marumoto and Azad, 1991) under the agro-ecological zone of Madhupur Tract (AEZ-28).

Experimental design and treatments

The experiment was arranged in a randomized com-

plete block design (RCBD) with eight treatments replicated three times. Tomato (test crop) was grown along with Basil, Nira, Coriander as companion plants and gliricidia leaf and cow dung as manure.

The treatments were Gliricidia+Basil, Gliricidia + Nira, Gliricidia + Coriander, Gliricidia only, Cow dung + Basil, Cow dung + Nira, Cow dung + Coriander, and Cow dung only (Conventional practice).

Planting materials

BARI Tomato-14 variety was used as test crop and the seeds of which were collected from the Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur. Locally cultivated Basil and Nira were purchased from Gazipur market. BARI dhania-1 was collected from Spices Research Centre (SRI), Bangladesh Agricultural Research Institute (BARI), Gazipur. The choice of Basil, Nira and Coriander as companion plants was made due to the characteristic strong smell of the essential oils that they contain.

Land preparation, crop establishment and maintenance

The site was disc ploughed as an initial step of land preparation. Land was then leveled using hand tools to provide a medium fine tilth for the better growth of tomato, basil, nira and coriander. The experimental area consisted of 24 plots having the plot size of 10 m². There were eight treatments of which four were treated by gliricidia fresh leaf into the soil at the rate of 1 kg m⁻² and another four treatments were applied with cow dung in soil at the rate of 1 kg m⁻². Cow dung was added as organic source in soil for improving the soil fertility and comparing the efficiency of gliricidia leaf in improvement of soil fertility. Organic manures were applied two weeks before transplanting. The experimental plots were fertilized at the rate of 600 kg urea, 500 kg TSP, 300 kg MP per hectare. Total TSP and one third each of urea and MP were applied during the final land preparation and the rest of urea and MP were applied in two equal installments at 20 and 40 days after transplanting (Hussain *et al.*, 2006). Each plot had four rows of tomato three each, with bordering companion plants but the control plot had four rows of tomato six each without any companion plants.

Tomato, basil and nira seedlings were raised in a seedbed at the beginning of the season at the nursery of the department of Agroforestry and Environment, BSMRAU. Thirty five (35) days old healthy, uniform tomato seedlings were planted at 60 cm × 50 cm spacing. Basil and nira were planted by maintaining distance at 50 and 10 cm, respectively. Transplanting was done at the afternoon. Coriander seeds were continuously sown in main field. Seedlings of coriander were thinned out at a distance of 5 cm. Companion plants were grown at the border of each tomato plot. All agronomic practices (weeding, irrigation and drainage) were done during the study period as and when needed. Insect pests of tomato crop were expected to be suppressed by com-

panion plants. Therefore, no insecticide was used throughout the study period for controlling the insect pests.

Data collection for crop performance

Five tomato plants from each plot were selected randomly and tagged for data collection. Number of clusters per plant was counted when tomato attained edible size. Fruit length and diameter were measured by using digital vernier caliper at harvest. Tomato fruits from each treatment were harvested by hand picking at the breaker stage for five times throughout the study period. At each harvest, fruits from each treatment were separately counted and later on weighed using a digital weighing balance. Fresh yield of tomato was determined by cumulative weight of fruits from each harvest and then converted to kg plant⁻¹.

Insect sampling and identification

Collections of various insect groups were done fortnightly between November, 2016 and February, 2017 from the tomato plots. The insect sampling was carried out in the early hours of the day as insects are active and easily observed at early sunrise. The insects were collected by sweep nets and pitfall method depending on the type of insect. Each sample was consisted of 30 sweeps or 30 pitfalls encompassing each plot. The collected insects were brought from the experiment field to the Entomology Laboratory of BSMRAU for counting total abundance. The insects were killed by storage in a freezer for a few hours, then mounted on points and dried and morphotyped. Insects were identified and also grouped into pest, pollinator and predator. For identification, the specimens were compared with the specimens in a labeled collection and compared with pictures or descriptions.

To enlighten the pest management potentiality of basil, nira and coriander, it is necessary to evaluate abundance, richness and diversity. Abundance is usually measured as the number of individuals found per sample. Species Richness is the number of different species present in an area. Species diversity relates to the number of the different species and the number of individuals of each species within any one community. The formula for calculating Simpson's index is:

$$D = \frac{\sum n_i(n_i - 1)}{N(N - 1)}$$

Where, N = the total number of all insects, n_i = the total numbers of insects of each individual species.

Analysis of chemical properties of soil

A composite sample of soil was taken randomly (0-10 cm) using soil auger before the commencement and after the experiment to determine the soil fertility status before and after experimentation. The soil was air dried, crushed, sieved and analyzed for chemical properties. Soil pH was measured by Glass Electrode pH meter method with soil- water ratio being maintained at 1:2.5 (McLean, 1982). At first organic carbon (%) in soil sam-

ple was determined by wet oxidation method and then it was converted into organic matter (%) multiplying by 1.72 (Angers *et al.*, 1999). Total nitrogen content of soil was determined by Kjeldahl Method following concentrated sulfuric acid digestion and steam distillation with 40% NaOH. The ammonia evolved was collected in a beaker containing 4% boric acid with an indicator composed of 95% alcohol, methyl red and bromocresol green and was titrated against 0.02 N H₂SO₄ as described by Jackson (1973). The amount of N was calculated using the following formula:

$$\% N = 14.007 \times N \times f \times (T-B) \times (100/10) \times (100/Y)$$

Where,

1N H₂SO₄ standard solution (1 ml) = 14.007 g NH₄⁺ - N

T = Sample titration (ml) value of standard H₂SO₄

B = Blank titration (ml) value of standard H₂SO₄

N = Strength of H₂SO₄ = 0.02

Y = Sample weight in gram (1 g)

10 = Quantity of digested extract taken for distillation (ml)

100 = Total digest amount (ml)

100 = Conversion factor for percentage

F = Titration accuracy factor = 1.02

Statistical analysis

Data were subjected to Analysis of Variance (ANOVA) using Statistix 10 program following randomized complete block design. Treatment means that showed significant difference by F test were separated using least significant difference (LSD) test at $p \leq 0.05$.

RESULTS

Yield and yield contributing characteristics of tomato

The effect of organic manure and companion plants on the number of clusters per plant ($F_{7,14} = 21.97$, $p < 0.001$), number of fruits per plant ($F_{7,14} = 55.55$, $p < 0.001$) and fruit weight per plant ($F_{7,14} = 94.86$, $p < 0.001$) of tomato were significantly varied among the treatments except fruit length ($F_{7,14} = 4.60$, $p > 0.001$) and fruit diameter ($F_{7,14} = 2.20$, $p > 0.001$). (Table 1)

Insect pest

There had a significant variation among the treatments in terms of insect pest abundance ($F_{7,14} = 141.59$, $p < 0.001$), richness ($F_{7,14} = 28.84$, $p < 0.001$) and diversity ($F_{7,14} = 19.29$, $p < 0.001$). The abundance, richness and diversity of the insect pests in different treatments varied from 10.3 ± 0.88 to 26.3 ± 1.86 , 3.6 ± 0.19 to 8.0 ± 0.29 and 0.12 ± 0.02 to 0.24 ± 0.03 , respectively (Table 2).

Pollinator

Marked variation was found in the abundance ($F_{7,14} = 46.67$, $p < 0.001$), richness ($F_{7,14} = 74.69$, $p < 0.001$) and diversity ($F_{7,14} = 172.06$, $p < 0.001$) of the insect pollinators as influenced by different treatments. The abundance, richness and diversity of the pollinators varied from

Table 1. Effect of organic manure and companion plant on yield and yield contributing characteristics of tomato

Treatment	Number of clusters/ plant	Number of fruits/ plant	Fruit length (mm)	Fruit diameter (mm)	Fruit weight/ plant (kg)
Gliricidia + Basil	16.66 a	35.00 a	54.89 a	61.53 a	4.4 a
Gliricidia + Nira	11.33 bc	26.00 d	48.98 bc	57.70 ab	2.6 c
Gliricidia + Coriander	13.33 b	29.00 c	52.86 ab	57.46 ab	3.2 b
Gliricidia only	8.33 d	22.66 e	47.00 c	53.79 b	1.8 d
Cow dung + Basil	16.66 a	32.33 b	51.79 ab	57.49 ab	3.9 a
Cow dung + Nira	11.00 c	25.00 d	47.40 c	54.18 b	2.5 c
Cow dung + Coriander	13.33 b	28.33 c	50.20 bc	56.54 ab	2.9 bc
Cow dung only	8.66 d	21.00 e	46.53 c	52.05 b	1.7 d

Means with common letter (s) in column of the table do not differ significantly at 5% level by LSD.

Table 2. Average abundance, richness and diversity of insect pests in different treatments during the experimentation

Treatment	Abundance	Richness	Diversity
Gliricidia + Basil	10.3(±0.88) e	3.6(±0.19) d	0.12(±0.02) d
Gliricidia + Nira	15.0(±0.58) c	6.3(±0.44) b	0.19(±0.01) bc
Gliricidia + Coriander	13.0(±0.58) d	5.5(±0.32) c	0.17(±0.01) c
Gliricidia only	26.6(±1.20) a	7.2(±0.37) a	0.21(±0.03) ab
Cow dung + Basil	12.0(±0.58) d	4.2(±0.38) d	0.14(±0.01) d
Cow dung + Nira	17.0(±0.58) b	6.2(±0.27) bc	0.20(±0.02) b
Cow dung + Coriander	14.6(±0.33) c	6.0(±0.52) bc	0.19(±0.01) bc
Cow dung only	26.3(±1.86) a	8.0(±0.29) a	0.24(±0.03) a

Data expressed as mean (±SE). Means per insect group are taken from 30 sweeps or 30 pitfalls per total collection.

Means with common letter (s) in column of the table do not differ significantly at 5% level by LSD.

Table 3. Average abundance, richness and diversity of pollinators in different treatments during the experimentation

Treatment	Abundance	Richness	Diversity
Gliricidia + Basil	34.0(±2.08) a	7.5(±0.29) a	0.27(±0.012) a
Gliricidia + Nira	25.0(±1.73) de	5.7(±0.15) de	0.22(±0.012) d
Gliricidia + Coriander	29.0(±2.08) bc	6.4(±0.30) c	0.24(±0.012) c
Gliricidia only	13.0(±0.58) f	4.1(±0.09) f	0.17(±0.015) f
Cow dung + Basil	31.6(±1.86) ab	6.9(±0.10) b	0.25(±0.009) b
Cow dung + Nira	22.6(±1.76) e	5.3(±0.17) e	0.20(±0.012) e
Cow dung + Coriander	27.0(±2.08) cd	5.9(±0.07) d	0.22(±0.012) d
Cow dung only	14.0(±0.58) f	3.9(±0.03) f	0.15(±0.009) g

Data expressed as mean (±SE). Means per insect group are taken from 30 sweeps or 30 pitfalls per total collection.

Means with common letter (s) in column of the table do not differ significantly at 5% level by LSD.

13.0±0.58 to 34.0±2.08, 3.9±0.03 to 7.5±0.29, 0.15±0.009 to 0.27±0.012, respectively (Table 3).

Predator

A significant difference was recorded among the treatments in terms of abundance ($F_{7,14}=38.04$, $p<0.001$), richness ($F_{7,14}=307.69$, $p<0.001$) and diversity ($F_{7,14}=97.43$, $p<0.001$) of the predator insects. The abundance, richness and diversity of the pests varied from 8.0±1.53 to 18.3±0.88, 2.7±0.08 to 6.7±0.15, 0.09±0.006 to 0.24±0.006, respectively (Table 4).

Soil chemical properties

Soil pH, organic carbon and total nitrogen were posi-

tively influenced due to incorporation of gliricidia leaf and cow dung, although the variation was not distinct. After application, soil pH, organic carbon and total nitrogen were increased by 6.27%, 5% and 10.87% in gliricidia leaf applied plots compared to cow dung applied treatment, respectively; while it was 7.71%, 10% and 6.52% higher over initial values for the corresponding parameters, respectively (Table 5).

DISCUSSION

As nitrogen level of gliricidia was higher than cow dung, length and diameter of tomato fruit were higher in gliricidia than cow dung treated plot with different com-

Table 4. Average abundance, richness and diversity of predators in different treatments during the experimentation

Treatment	Abundance	Richness	Diversity
Gliricidia + Basil	18.3(±0.88) a	6.7(±0.15) a	0.24 (±0.006) a
Gliricidia + Nira	12.6(±0.33) d	4.7(±0.15) e	0.17 (±0.003) d
Gliricidia + Coriander	16.0(±0.58) bc	5.8(±0.06) c	0.21 (±0.010) b
Gliricidia only	8.5(±0.29) f	2.9(±0.03) f	0.11 (±0.003) f
Cow dung + Basil	16.3(±0.88) b	6.0(±0.08) b	0.22 (±0.007) b
Cow dung + Nira	10.6(±0.33) e	4.5(±0.14) e	0.15 (±0.003) e
Cow dung + Coriander	14.3(±0.33) cd	5.4(±0.07) d	0.19 (±0.007) c
Cow dung only	8.0(±1.53) f	2.7(±0.08) f	0.099(±0.006) g

Data expressed as mean ±SE. Means per insect group are taken from 30 sweeps or 30 pitfalls per total collection. Means with common letter (s) in column of the table do not differ significantly at 5% level by LSD.

Table 5. Changing of soil chemical properties after harvesting of tomato in cow dung and gliricidia leaf applied plots compared to initial soil

Soil properties	Initial soil	After harvesting tomato	
		Cow dung	Gliricidia
pH	5.58	6.01 (7.7) ^a	5.93 (6.3)
% of Organic carbon	2.00	2.20 (10.0)	2.10 (5.0)
% of Total nitrogen	0.092	0.098 (6.52)	0.102 (10.9)

^a % of changing from initial soil to after harvesting tomato

panion plants. Pereira *et al.* (2015) showed that fruit length, basal circumference and apical circumference of bell peppers were higher in intercropping with basil than in single-cropping system. It was further stated that fruit length, basal circumference and apical circumference of bell peppers were higher in 'With bees' than 'Without bees' greenhouse compartment. Pollinator abundance in Gliricidia + Basil plot is higher than all other treatments. It may ensure the correspondence number of fruits per plant which is positively correlated with number of clusters per plant.

Due to higher fruit length and diameter of tomato, the fruit weight per plant was significantly higher in Gliricidia + Basil than other treatments. Pandey and Rai (2007) mentioned that gliricidia leaves decompose quickly and release maximum nitrogen within 15 days and the remaining part in two months in both surface applied as well as soil incorporated conditions. Nitrogen received quickly might increase in the amount of some cell structures such as- growth of the wall, thickness of the cell wall and amount of solids, which ultimately increased the fruit weight per plant. Pereira *et al.* (2015) showed that pulp weight of bell peppers was higher in intercropping with basil than in single-cropping system.

The weight, size of the fruits and the number of seeds has also been found to be correlated to the amount of pollen deposited on the stigma (Serrano and Guerra-Sanz, 2006). Auxin, which is produced in pollen and the endosperm and the embryo of developing seeds, are involved in the regulation of fruit development, in that it generates the initial stimulus for fruit growth (Taiz and Zeiger, 2010). Thus, flowers better pollinated by bees can develop fruits with characteristics different from those of fruits produced by self-pollination as well

as the width and weight of tomato were enhanced by the pollinators.

Quee *et al.* (2017) claimed that gliricidia leaves mulch has the possibility of conferring higher crop growth and yields as well as decreased weed growth in maize production. Application of gliricidia leaves in combination with chemical fertilizers has given tremendous yield improvements in both tomato and chili than coir dust, cow dung and rice straw (Kendaragama, 1999). Application of leguminous (e.g. gliricidia) green leaf manures and tree leaf extracts giving in the form of seed soaking and foliar sprays will increase the growth, yield, quality and economics of bhendi (Anbukkarasi and Sadasakthi, 2017).

Companion plants have great influence on pest abundance, richness and diversity. Beizhou *et al.* (2011) intercropped companion plant in Pear orchards with three aromatic plants: summer savory, ageratum, basil and got significantly lower population of major pests, especially *Aphis citricola*, as compared with natural grasses or clean tillage. Again, Basedow, Hua and Aggarwal (2006) reported that basil and summer savory intercropped with *Vicia faba* in a wind tunnel, greenhouse or field decreased the *Aphis fabae* population significantly. The strong aphid-repelling action of the *Allium* spp. (e.g. nira) is well established. It could be connected with the presence of high-sulfur compounds (94%). These compounds are known for their protective potential against storage insects (Ben-Issa *et al.*, 2017). Coriander repelled aphids, spider mites and potato beetles in potato (Kianmate and Ranamukhaarachchi, 2007).

Basil was found to attract a great richness and abundance of pollinators, which makes it suitable to enhance pollinator conservation and management in agricultural

environments. The floral resources provided by basil clearly benefited pollinator abundance and richness; however, while the primary objective of such practice was to favor pollinator and pollination. This strategy has the potential to provide secondary benefits to the farm and the surrounding landscape by enhancing overall biodiversity and ecosystem services (Wratten *et al.*, 2012). Majority of the hymenopteran pollinators were recorded on coriander, mustard and radish plants; whereas, more dipteran pollinators were observed on coriander, broad bean, lucerne and mustard (Ahmad, 2005).

Conserving of beneficial insects may be increased due to inclusion of floral resources where nectar and pollen is fed by functional groups including pest natural enemies (Balzan *et al.*, 2014). In a pear orchard ecosystem, Beizhou *et al.* (2011) used aromatic plants such as summer savory, ageratum and basil between pear tree rows enhanced the activity of the lady bird beetle and reduced the incidence of *Aphis citricola*. In New Zealand, for example, coriander as a companion plant intercropped with cabbage has been shown to attract adult hoverflies and decrease the aphid number only early in the season (Ben-Issa *et al.*, 2017).

The soil chemical properties were changed owing to chemical composition of cow dung and gliricidia. Cow dung consist of the following chemical composition 1.60% N, 0.70% P, 0.53% K, 0.91% Mg, 2.71% Ca, 0.50% Na and 56.8% organic matter (Onwudike, 2010). The chemical composition of gliricidia leaves are of 4.16% N, 0.40% P, 1.12% K, 0.58% Mg, 0.67% Ca, 29.73% organic carbon and 51.79% organic matter (Falana *et al.*, 2017). Calcium and organic matter were higher in cow dung than gliricidia. But nitrogen content was higher in gliricidia than cow dung. That is why, gliricidia treated plot showed higher nitrogen and cow dung showed higher pH, organic matter than cow dung and gliricidia, respectively.

CONCLUSIONS

Based on the findings of the study, it may be concluded that performance of tomato in association with three companion plants viz. basil, nira and coriander was better in all aspects as compared to monoculture. Tomato showed better performance in terms of fruit yield, soil chemical properties, insect pest suppression as well as pollinators and predators attraction when grown along with basil as companion plant followed by coriander and nira.

AUTHOR CONTRIBUTIONS

Mahfujul Islam BHUIYA, performed the research, collected data, analyzed the data and wrote the first draft of manuscript.

Md. Abiar RAHMAN, formulated and designed the idea of the study and supervised the research. Analysed the data and helped in preparing the manuscript.

Md. Ruhul AMIN, identified the insects and inspected final data. Analysed data related to insects.

Md. Main Uddin MIAH and Satya Ranjan SAHA – Helped in field data collection and manuscript check.

Ikuo MIYAJIMA provided suggestions in designing the research and comments on the manuscript.

However, all authors assisted in editing the manuscript and approved the final version.

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