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# Production of Summer Vegetables Using Conservation Agriculture Techniques: Experiences from Northern Bangladesh

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**Abstract:** Poor soil quality and decreasing crop yields brought on by ongoing monocropping in the fields of small-scale farmers in Bangladesh have demanded a search for sustainable production methods that are more resource efficient and environmentally friendly. Conservation agriculture is such a beneficial approach that effectively addresses crop productivity and soil quality enhancements using locally available resources. Therefore, the objective of the study was to determine the impacts of conservation agricultural practices on the growth and yield of summer vegetables cultivated in the northern region of Bangladesh. The study was carried out at farmers field situated in the Chilmari upazila of Kurigram district using the Randomized Complete Block Design (RCBD) with three replications during July to September 2020. The trial vegetables, i.e., Red amaranth, Kangkong and Indian spinach had showed the better yield of 4.95 t/ha, 14.5 t/ha and 19.5 t/ha in compared with traditionally cultivated vegetable cultivated methods in the farmers field, according the conservation agriculture method had enhanced vegetable yield. As part of conservation agriculture practices, soil organic matter content, total nitrogen, phosphorus, and potassium levels, as well as $p^H$ for better crop production, were all positively increase with the implications of conservation techniques like, adding organic manure, minimal tillage, permanent crop residues and crop rotation. Therefore, the study came to the conclusion that traditional agriculture would need to adopt conservation agriculture methods in order to produce more food while using fewer resources and doing so in a more efficient manner while having the least possible negative effects on the environment.

**Keywords:** Summer vegetables; Tillage; Soil fertility; Productivity; Conservation.

## INTRODUCTION

Continuous and excessive uses of agrochemicals with traditional agriculture practices have been steadily degraded soil and causes of environmental hazards (Montgomery 2007; Islam *et al.* 2021; Islam *et al.* 2022). On the contrary, the global demand for agricultural products would be double in the next decade (Godfray *et al.* 2010; Thierfelder *et al*. 2015). The major share of those agricultural products is coming from the developing countries including Asia (Theirfelder *et al*. 2015). While the soil degradation has invariably declined the agricultural production in the developing countries (Wall *et al*. 2013; Winterbottom *et al.* 2013; Morris 2007; Sanginga and Woomer 2009; Thierfelder *et al.* 2015). Therefore, many small-scale farmers are facing lower farm productivity and trapped by poverty as well (Kumwenda *et al*. 1998; Sachs *et al*. 2004; Tittonell and Giller 2013; Thierfelder *et al*. 2015).

Soil degradation is also a core problem in Bangladesh so as to feed its 160 million people with a limited cultivable land resource (BBS 2019; Ahmed and Kashem, 2017). Traditional agriculture practices have used local agricultural implements and tractor draw disc plows and harrows for land preparation, which caused soil inverted and pulverized and made soil compaction. The traditional agriculture cultivation process thus affected soil physical properties, provoke biological degradation, loss of soil organic matter and finally decline crop yields (Ngwira *et al*. 2014; Giller *et al.* 2009; Govaerts and Vaghi 2010). The situation is worse in the disaster-prone northern region of

Bangladesh, the farmers of that region have commonly faced soil degradation and sudden floods in the rainy season to cultivate their main crops. Chilmari Upazilla of Kurigram district in northern Bangladesh has faced early and regular flood during the rainy season and thus, small-scale farmers are suffering climatic catastrophic event and the degradation of soil. Given the challenges arises from the soil degradation, conventional agricultural practices plus catastrophic climatic event in crop cultivation in northern Bangladesh, a key policy intervention for sustainable crop production is to encourage the adoption of technologies that rely on local renewable resources. Conservation agriculture technologies is one such noble technology that can use local resources and reduce the harmful use of agrochemical and conserve the soil for sustainable crop production in the long term.

Conservation agriculture main goal is to conserve natural resources through sustainable management of soil, water and air environment. It mainly attributes to the environment towards increased and sustain agricultural production, and therefore, term as resource-efficient agriculture (FAO 2019; Govaerts and Vaghi 2010). Conservation agriculture has emerged to combat soil degradation and to enhance productivity and also increasing cost of inputs, which are inflicting tremendous burden of the small-scale farmers. Utilizing soils for crop production, conservation agriculture technologies seek to reduce to a minimum the excessive soil mixing typical of tillage-based farming, maintain crop residues on the soil surface to minimize environmental damage, and use crop diversity and associations to improve soil and crop health and produce more biomass of higher quality and increase crop productivity (Giller *et al*. 2011). As a result, conservation agriculture is defined by three interconnected principles: crop rotation, low soil disturbance, and soil cover by crop residues and cover crops (Figure 1).

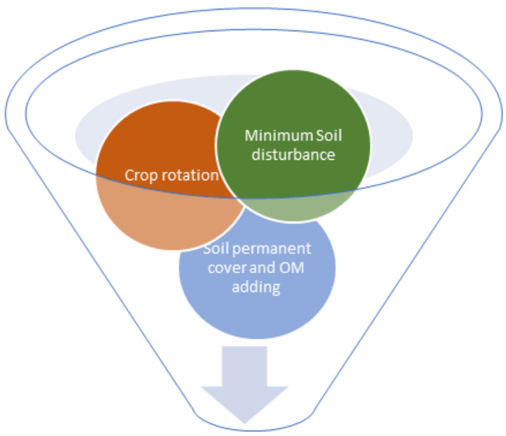


**Fig. 1.** Conservation agriculture

Summer vegetables are very popular and widely cultivate in Bangladesh, India, Africa and other tropical and subtropical region of the world. In Bangladesh, summer vegetables such as, Indian spinach, Red amaranth and Kangkong are very popular and cultivated throughout the country. Vegetable growing with excessive inorganic fertilizers and inappropriate application of pesticides is now a common practice in Bangladesh to achieve higher yield. However, judicious combination of soil organic and inorganic fertilizers, and proper management might improve soil physical properties and nutrient towards enhance crop yield (Habib *et al*. 2012; Afrin *et al.* 2019; Biswas *et al.* 2020; Farjana *et al.* 2019). Sustainable management of soil and vegetable production are now getting enormous importance in Bangladesh in order to main soil environment. Thus, cultivation of summer vegetables with conservation agriculture techniques in the resources poor northern Bangladesh would be a valuable contribution for the development of science and small-scale farmers of the country. So, the objective of the study was to determine the growth and yield performance of summer vegetables grown in conservation agricultural methods in the northern Bangladesh.

## MATERIALS AND METHODS

### Study Area

The study was executed in the farmers' field of Hazipara village of Chilmari Upazilla of Kurigram district, a northern district of Bangladesh (25.5810$^0$ N and 89.6616$^0$ E) under the agroecological zone of AEZ-2 (active Tista plains). This region is close to the Bangladesh-India border. The soil of this area contains irregular patterns of grey stratified, sands and silts. They are moderately acidic throughout and parent alluvium is enriched in minerals. Organic matter content is low and CEC is moderate. Generally, the soil fertility level is low to medium.

### Design of Experiment and Land Preparation

The experiment was conducted in the Randomized Complete Block Design (RCBD) with two treatments (T1= Conservation agriculture, T2= Traditional agriculture) and three replications in Chilmari upazila. Each plot size consists of a 3m × 4m size, therefore, 18 plots were cultivated in three farmers field at Chilmari for the field experiments. The experimental plots were prepared using spade with minimum tillage for seed sowing. The technology of conservation agriculture followed organic manuring along with 50% less recommended fertilizer doses, line seed sowing of three vegetables, and no application of insecticides/pesticides. In opposition to this, traditional technology used conventional chemical-based and traditional tillage based producing technologies in the experimental site. The farmer's field was prepared with minimum plowing for CA and three times plowing followed by laddering in traditional plots. The traditional plot (farmers own methods) was mixed with the recommended doses of fertilizers; however, the CA plots were mixed with 50% recommended doses of fertilizers (urea, MoP and TSP) with 12 t/ha tree leaf/cow dung at the land preparation time. In line sowing methods, relatively less seed was required compared to the broadcasting method, other intercultural operation was also carried out accordingly.

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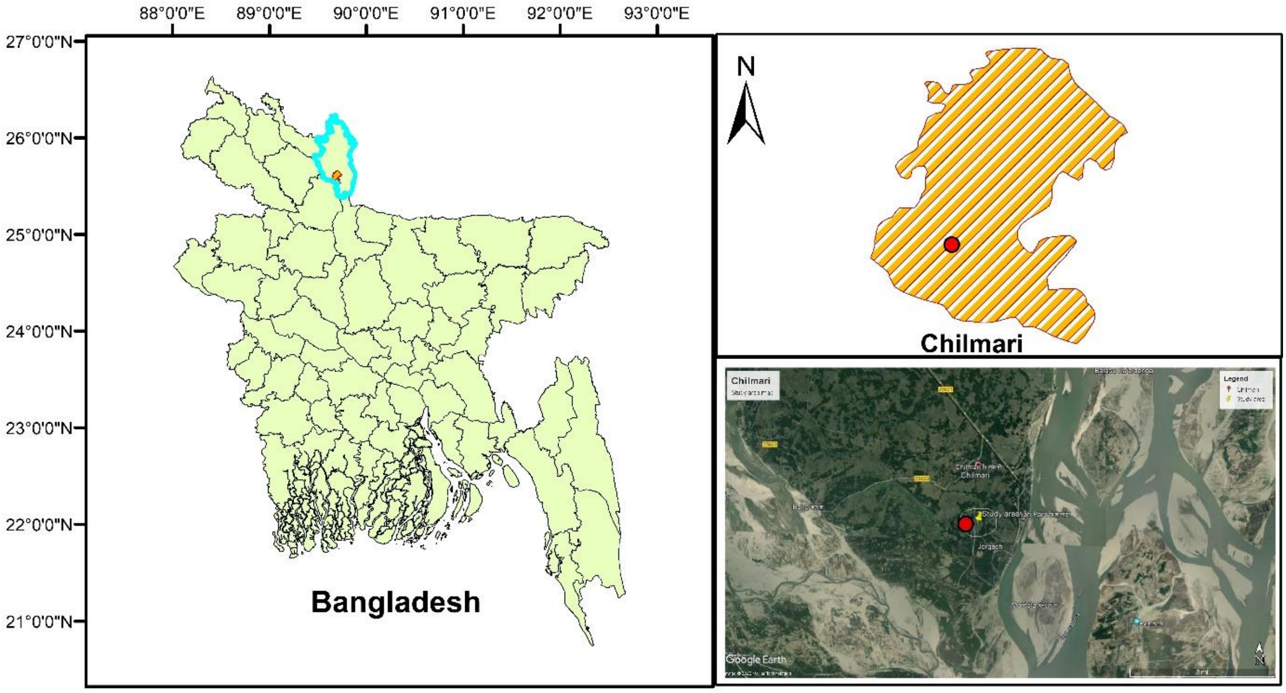


**Figure 2**. Study area map showing Bangladesh and Chilmari in google earth view (right-bottom).

### Growth and Yield Parameters of Summer vegetables

Data on plant height (cm), number of branches per plant, number of capsules per plant, plant height (cm), no of branches/ plant, no of leaves/ plant, leaves length (cm), leaves breadth (cm), fresh weight/plant (g), total yield (t/ha) plant residues (t/ha) were recorded. Ten mature plants from each plot were collected to measure those parameters and the total yield was converted each plot yield to a hectare basis. The mean value of those parameters was recorded. Red amaranth, Kangkong, and Indian spinach were harvested after 25, 35, and 35 days of seed sowing respectively. The mean value of those parameters was recorded.

### Soil Analysis

Before the field experiment began in July 2022 and after the vegetable crops were harvested in October 2022, the study also collected and tested the soil's pH, organic matter (OM), total N, P, and K status. The soil samples were obtained using a hand Augur, and the Bangladesh Agricultural University's Soil Science department performed the soil analysis.

### Data Collection and Analysis

The field data of Red amaranth, Kangkong, and Indian spinach were collected and harvested after 25, 35, and 35 days of sowing respectively. Besides, the soil sample from every plot was collected through a augur using 0-30cm depth and bring it to the Bangladesh Agricultural University laboratories for analysis. The collected data were analyzed using Microsoft Excel software and duration of the study was July to October 2022.

## RESULTS AND DISCUSSIONS

### Growth and yield of Red Amaranth

The growth data of red amaranth in conservation agriculture (CA) and traditional technologies revealed that plant height (cm), number of branches per plant, number of leaves/ plant, leaves length (cm), leaves breadth (cm), fresh weight/plant (g), total yield (t/ha) and plant residues (t/ha) were statistically significant at 5% level of significance. This depicts that there was a significant variation between CA and traditional cultivation technologies (Table 1). However, the CA technology showed the best results in comparison to traditional methods (Table1). Plant height was recorded as maximum in CA (38.6 cm) while traditional showed a lower height (22.2 cm) (Table 1). The number of branches per plant (1) was observed similarly in both CA treatment and traditional treatment (Table 1). The number of leaves per plant was greater (14) in CA and lower (9) was observed in the traditional technology. Leaves length and breadth were recorded higher (11.5 cm and 9.6 cm respectively) in CA whereas relatively lower (8.8 cm and 6.5 cm respectively) was observed in traditional treatment (Table 1). Fresh plant weight in CA (9.60 t/ha) was found almost double of traditional treatment (4.85 t/ha) (Table 1) which shows the great positivity of CA over traditional technology regarding the production of plant residues. As for yield, it was found greater (4.95 t/ha) in CA and the lower (3.75 t/ha) was recorded in traditional treatment.

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**Table 1.** Growth and yield of red amaranth cultivated in conservation agriculture and traditional methods.

| Treatments | Red amaranth | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Plant height (cm) | No of branches/ plant | No of leaves/ plant | Leaves length (cm) | Leaves breadth (cm) | Fresh wt/plant (g) | Total yield (t/ha) | Plant residues (t/ha) |
| Conservation agriculture | 38.6 | 1 | 14 | 11.5 | 9.6 | 13.6 | 4.95 | 9.60 |
| Traditional | 22.2 | 1 | 9 | 8.8 | 6.5 | 7.2 | 3.75 | 4.85 |

**Growth and yield of Kangkong**

The growth data of Kangkong in CA and traditional technologies revealed that plant height (cm), number of branches per plant, number of leaves/ plants, leaves length (cm), leaves breadth (cm), fresh weight/plant (g), total yield (t/ha) and plant residues (t/ha) which were found significant at 5% level of significance. However, the CA technology showed the best results in comparison to traditional technologies (Table 2) (Figure 3). Plant height was recorded as maximum in CA (55 cm) while traditional showed a lower height (40 cm) (Table 2). The number of branches per plant (3) was observed similarly in both CA treatment and traditional treatment (Table 2).

**Table 2**. Growth and yield of Kangkong grown in conservation agriculture and traditional methods.

| **Treatments** | **Kangkong** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Plant height (cm)** | **No of branches/ plant** | **No of leaves/ plant** | **Leaves length (cm)** | **Leaves breadth (cm)** | **Fresh wt/plant (g)** | **Total yield (t/ha)** | **Plant residues (t/ha)** |
| Conservation agriculture | 55 | 3 | 33 | 22 | 5 | 9.5 | 14.5 | 20.8 |
| Traditional | 40 | 3 | 21 | 16 | 4 | 6.0 | 11.6 | 11.5 |


**Conservation Agriculture Plot** **Traditional Plot**

**Figure 3.** Growth and yield performance of CA and Traditionally cultivated vegetables

**Table 3.** Growth and yield of Kang Indian spinach cultivated in conservation agriculture and traditional methods.

| **Treatments** | **Indian spinach** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Plant height (cm)** | **No of branches/ plant** | **No of leaves/ plant** | **Leaves length (cm)** | **Leaves breadth (cm)** | **Fresh wt/plant (g)** | **Total yield (t/ha)** | **Plant residues (t/ha)** |
| Conservation agriculture | 23.5 | 7 | 12 | 13 | 10 | 188 | 19.5 | 25.5 |
| Traditional | 15.2 | 5 | 10 | 9 | 7 | 132 | 16.2 | 19.2 |

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The number of leaves per plant was greater (33) in CA and lower (21) was observed in traditional technology (Table 2). Leaves length and breadth were recorded higher (22 cm and 16 cm respectively) in CA whereas traditional treatment was found relatively lower (5 cm and 4 cm respectively) (Table 2). Fresh plant weight in CA (9.5 t/ha) was found higher in comparison to traditional treatment (6.0 t/ha) (Table 2). Moreover, the yield of Kang kong was found greater (20.8 t/ha) in CA and the lower (11.5 t/ha) was recorded in traditional treatment which reveals the great positivity of CA over traditional technology regarding the total yield (Table 2).

**Growth and yield of Indian spinach**

The growth data of Indian spinach in CA and traditional technologies disclosed that plant height (cm), number of branches per plant, number of leaves/plants, leaves length (cm), leaves breadth (cm), fresh weight/plant (g), total yield (t/ha) and plant residues (t/ha) all were found significant at 5% level of significance. However, the CA technology showed the best results in comparison to traditional technologies (Table 3). Plant height was recorded as maximum in CA (23.5 cm) while traditional treatment showed a lower height (15.2 cm) (Table 3). The number of branches per plant was found greater (7) in CA and a relatively lower (5) was observed in traditional technologies (Table 3). The number of leaves per plant was greater (12) in CA and lower (10) was observed in traditional technology (Table 3). Leaves length and breadth were recorded higher (13 cm and 10 cm respectively) in CA whereas traditional treatment was found relatively lower (9 cm and 7 cm respectively) to the former (Table 3). Fresh plant weight in CA (25.5 t/ha) was found higher in comparison to traditional treatment (19.2 t/ha) (Table 3). Moreover, the yield of Indian spinach was found greater (19.5 t/ha) in CA and the lower (16.2 t/ha) was recorded in traditional treatment which reveals the positive effect of CA over traditional technology regarding the total yield (Table 3).

**Yield Comparison of Summer Vegetables**

The results showed that Red amaranth, Kangkong, and Indian spinach all showed convenient growth and yield towards conservation agriculture (CA) technology. The CA practice used 50% fewer fertilizers and in addition, 12 ton/ha available organic manures (cow dung and tree leaf) were added to the CA plot. In the case of the yield of Red amaranth, CA technology (4.95 t/ha) superseded traditional technology (3.75 t/ha) (Figure 2). The yield of Kangkong also showed similar results to the former, here CA (14.5 t/ha) dominated over traditional treatment (11.6 t/ha) (Figure 2). As for the yield of Indian spinach, CA was found to be greater (19.5 t/ha) than traditional technology (16.2 t/ha) (Figure 2 & 3). In a word, CA will not only yield greater but also keep the environment safe. For a better future, CA turns out to be the best option.

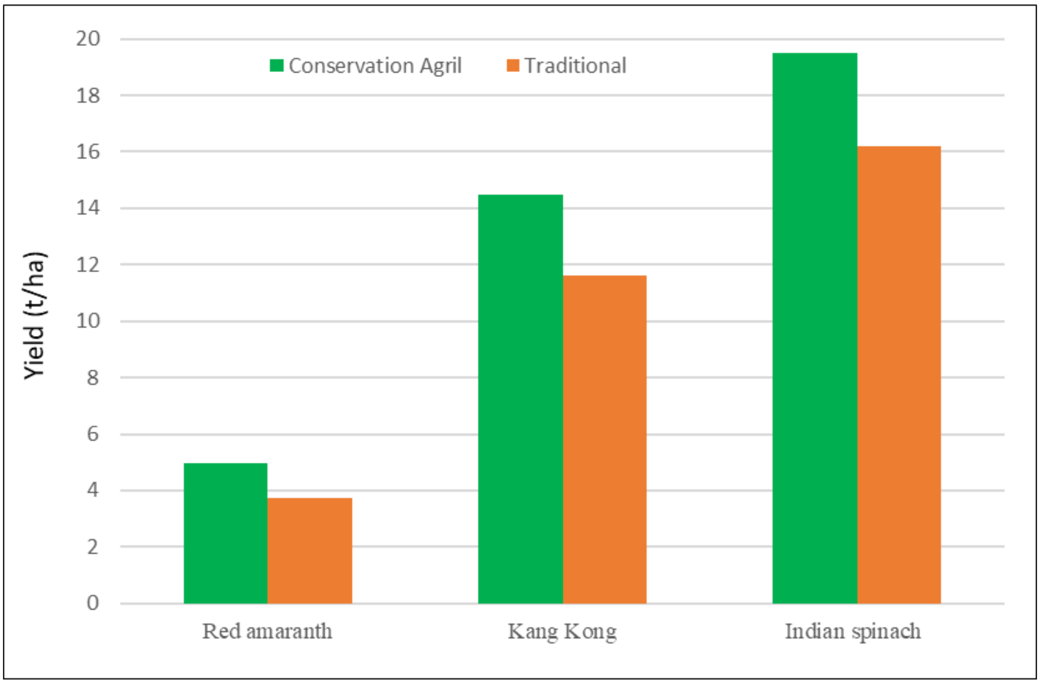


**Figure 3**. Yield comparison of summer vegetables cultivated in conservation agriculture and tradition methods.

**Conservation of Natural Resources**

Bangladeshi soils frequently have lower amount of organic matter (OM). Most soils have less than 2.5% OM content, while the soil in the northern region has less than 2.0%. A healthy soil should have 5.0% OM content. When the study initially collected soil samples, it was determined through soil analysis that the soil's nutritional quality was poor and its OM content was only 1.98% (Table 4). Cultivation of summer vegetables using organic manures have enhanced soil OM and NPK in the northern region of Bangladesh that indicated the positive impacts of conservation agriculture practices (Table 4).

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**Table 4.** Changes of soil quality in conservation agriculture practices

| Soil Samples | Soil $p^H$ | Soil OM (%) | Soil Total N (%) | Soil P (ppm) | Soil K (meg/100g) |
|---|---|---|---|---|---|
| Control/Before Exp. | 6.11 | 1.98 | 0.132 | 11.68 | 0.055 |
| CA Plots | 6.50 | 2.29 | 0.148 | 24.78 | 0.175 |
| Traditional Plots | 6.30 | 2.02 | 0.134 | 19.82 | 0.074 |

**Table 5.** Opportunities of conservation agriculture in northern Bangladesh**.**

| Issues | Parameters | Indicators |
|---|---|---|
| Productivity | Growth | Increase vegetables growth contributing parameters compare to traditionally producing vegetables |
| | Yield | Increase vegetables fresh yield in CA practice compare to traditional production systems |
| Soil Quality | OM | Uses 12 t/ha organic manure during land preparation, allow crop residues, alter soil at minimum rate and all of those increase soil organic matter |
| | $p^H$ | Soil $p^H$ did not vary in CA and traditional plots, however, the trend showed that CA improve soil $p^H$ and neutralize soil in conservation agricultural practices. |
| | N P K | Although the changes of N P K nutrients were not significant, the improvements trends of those essential nutrients were positive in conservation agriculture production techniques that facilitate vegetable production. |
| | Drought | Increase resilience to drought due to practice of much and efficient water utilization technique |
| | Erosion | Crop residues protected soil surface erosion and soil run-off |
| | Labor saving | Conservation agriculture techniques has decrease irrigation rate and require agricultural labor for vegetable production, thus, reduces the cost of production |
| | Crop rotation | Farmers cultivated rice and mustard in other seasons that ensure crop rotation |
| Adoption | Emission | Conservation agriculture practices reduced GHGs emission through lower tillage and fertilizations |
| | Carbon storage | Increase soil carbon through addition of organic matter in the soil and available soil carbon for vegetable cultivation. |

Effective soil improvement program could enhance the physical, chemical, and biological characteristics of the soil, which also serves as a major source of plant nutrients. The findings of the soil study showed that study's soil OM content had increased, even though the trends of improvement were slow. This clearly demonstrates that the CA techniques had been successful in raising the soil quality and soil nutrient status (Table 4). In comparison to the initial soil analysis results, the soil phosphorus in the Chilmari area has improved (24.78 ppm) (Table 4).

Conservation agriculture is always credited with lowering production costs, increasing yield, and improving water usage efficiency (Ernstein *et al*. 2008; Ngwira *et al*. 2012; Islam *et al*. 2021). The year-round retention of crop residues and tree leaf as surface mulch is a significant addition for conservation agriculture adoption. The summer vegetables were cultivated in July 2022 and harvested at a height of 2/3 cm or higher, and we left as much vegetable's residue on the soil as possible for the next crops (Table 5). Additionally, we used compost or cow dung and, in some case, vermicompost as organic manures to grow vegetables crops. The study also made farmers aware of the importance of agricultural residues in slowing down soil erosion, as well as the social implications of other conventional competing uses for residues.

Farmers and rural people are now recognized that agriculture should not only produce large yields but also be sustainable and capable of protecting natural resources (Reynolds and Borlaug 2006). As a result, the current study used action research to maintain all year-round crop intensifications to show the technical performance of CA at the farmers' level. It has been suggested that conservation agriculture is a widely adapted set of management practices that can guarantee more sustainably produced agriculture. Through the integrated management of soil, water, crops, and other biological resources, it aims to improve, preserve, and make better use of natural resources. In order to protect soil structure, soil fauna, and soil organic matter, the study used the CA technique to ensure minimal soil disturbance (minimal tillage) (Table 5). Finally, diverse crop rotation (vegetables, cereals and pulse crops) might boost soil-microorganism and disturb plant pests, weeds, and illnesses as well. The study also ensured permanent soil cover (cover crops, crop leftovers) to protect soil and help suppress weeds.

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## CONCLUSION

The soil quality of Bangladesh is gradually declining due to traditional farming techniques, a lack of crop rotation and crop coverings, an uneven use of fertilizers, and poor management techniques applied nationwide. The worst cropping situation occurs in Bangladesh's northern region, where there are few resources and only Transplanted Aman rice are grown. Conservation agriculture is a key technique for maintaining and boosting crop output and soil fertility. Trials conducted on farms in the Chilmari upazila of Kurigram district revealed that conservation agriculture practice improved soil quality, net return, and vegetables fresh yield when compared to conventional cultivation methods. Application of three CA principles, i.e., minimal tillage, crop residue retention as surface mulch, and crop association seemed to be essential for these advantages. Therefore, the conservation field trial demonstrated that if farmers implement the proper CA principles, vegetables yield as well as soil fertility would increase. Strengthening the CA approach would anticipate to boost soil fertility, crop yield, and overall resilience to guard against unfavorable climatic conditions. Therefore, the study would advise focusing on farmers attitude shifts, adaptive research and demonstration efforts, governmental and institutional support, networks of farmers, and assuring availability and access to agricultural implements as the main challenges to be addressed to promote conservation agriculture in Bangladesh.

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**Conflicts of Interest**

The authors declared there were no conflict of interests.

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