Journal of Agroforestry and Environment

Volume 16, Issue 1, 2023

Journal DOI: https://doi.org/10.55706/jae
Journal homepage: www.jagroforenviron.com

Moving to conservation agriculture: (*1*) evidence of rhizome crops performance in existing agroforestry practices of Madhupur Garh, Bangladesh

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Received: 12/04/2023

Accepted: 23/06/2023

Available online: 30/06/2023

Abstract: The continuous practice of mono-cropping by small-scale farmers in Bangladesh has resulted in poor soil quality and declining crop yields. As a result, there is a growing need to explore sustainable production methods that are resource-efficient and environmentally friendly. Conservation agriculture has emerged as a beneficial approach that effectively addresses these challenges by utilizing locally available resources to enhance crop productivity and soil quality. With this in mind, the objective of this study was to assess the impacts of conservation agricultural practices on the growth and yield of ginger and turmeric in the Madhupur Garh of Bangladesh. The study was conducted in the Auronkhola, Gaira, Makontonagar in Madhupur district, using a Randomized Complete Block Design (RCBD) with three replications from July to September 2022. Ginger and turmeric were selected for the trial. The results showed that these spices exhibited significantly higher yields (6090 kg/ha and 11370 kg/ha, respectively) compared to traditionally cultivated vegetables in the farmers' fields. The implementation of conservation agriculture practices contributed to the improved yields. As part of conservation agriculture practices, various factors crucial for crop production, such as soil organic matter content, total nitrogen, phosphorus, potassium levels, and pH, were positively influenced. This was achieved through the use of organic manure, minimal tillage, the retention of permanent crop residues, and crop rotation. Based on the findings, the study concludes that traditional agriculture must transition to conservation agriculture methods in order to achieve increased food production while utilizing fewer resources and minimizing negative environmental impacts. This shift towards conservation agriculture offers a more efficient and sustainable approach to farming.

Keywords: Ginger; Turmeric; Tillage; Soil fertility; Productivity; Conservation.

INTRODUCTION

The consistent and excessive utilization of agrochemicals in conjunction with conventional agricultural methods has progressively deteriorated the soil and given rise to environmental risks (Montgomery 2007; Islam et al. 2021; Islam et al. 2022). Contrarily, there is an expected twofold increase in the global demand for agricultural products over the next decade (Godfray et al. 2010; Thierfelder et al. 2015). The majority of these agricultural products originate from developing nations, particularly in Asia (Theirfelder et al. 2015). Bangladesh faces a significant challenge of soil degradation due to the necessity of feeding its population of 160 million people with limited arable land resources (BBS 2019; Ahmed and Kashem, 2017). The utilization of local agricultural tools and tractor-drawn disc plows and harrows for land preparation in traditional farming practices has resulted in soil inversion, pulverization, and compaction. As a consequence, the physical properties of the soil have been adversely affected, leading to biological degradation, the depletion of soil organic matter, and ultimately reduced crop yields (Ngwira et al., 2014; Giller et al., 2009; Govaerts and Vaghi 2010). Conservation agriculture technologies are a valuable approach that utilizes local resources, minimizes the harmful use of agrochemicals, and promotes the long-term preservation of soil for sustainable crop production. The primary objective of conservation agriculture is to protect natural resources through the sustainable management of soil, water, and air environments. Its main focus is on enhancing and maintaining agricultural production while prioritizing resource efficiency and environmental considerations, hence earning the name "resource-efficient agriculture" (FAO 2019; Govaerts and Vaghi 2010). Conservation agriculture has emerged as a solution to address soil degradation and enhance productivity, especially considering the rising costs of inputs that burden small-scale farmers. By utilizing soils for crop production, conservation agriculture technologies aim to minimize excessive soil mixing associated with conventional tillage-based farming. The approach involves retaining crop residues on the soil surface to mitigate environmental harm and promoting crop diversity and associations to enhance soil and crop health. This strategy also aims to generate a greater quantity of higher-quality biomass, ultimately leading to increased crop productivity (Giller et al., 2011).

Ginger (Zingiber officinale Roscoe) is a flowering plant with diverse applications as both a spice and a traditional remedy. It has been utilized worldwide since ancient times to address various unrelated conditions such as arthritis, cramps, rheumatism, sprains, sore throats, muscular discomfort, constipation, vomiting, hypertension, indigestion, dementia, fever, and infectious diseases (Ali, et. al. 2008). In Bangladesh, ginger is a commonly used spice, and the country's annual production amounts to approximately 49,405 metric tons. This production is achieved from cultivation on approximately 19,055 hectares of land (BBS, 2011). In Bangladesh, ginger cultivation primarily takes place as a rain-fed annual crop in upland areas and hill slopes. Key ginger-growing districts include Dinajpur, Rangpur, Tangail, Chittagong, and Rangamati. The successful growth of ginger relies on a warm and humid climate. Ginger can be cultivated in tropical regions ranging from sea-level to an altitude of 1500 meters, as long as the areas receive an annual rainfall of 1500 mm or more, with a brief dry season, and experience high temperatures for at least part of the year (Lim, 2016).

Turmeric (Curcuma longa) holds significant historical and cultural importance as a spice in the Indian subcontinent. It is a remarkable and versatile natural plant product known for its distinct flavoring and coloring properties (Shankaracharya and Natarajan, 1971). In Bangladesh, turmeric production covers an area of 56,203 hectares, resulting in a total production of 117,081 metric tons (BBS, 2010).

In Bangladesh, the significance of sustainable soil management and vegetable production has gained considerable attention to preserve the soil environment. Consequently, cultivating ginger and turmeric using conservation agriculture techniques in the resource-limited regions of Madhupur Garh holds great value for advancing both scientific knowledge and supporting small-scale farmers in the country. Therefore, the objective of this study was to assess the growth and yield outcomes of ginger and turmeric cultivated through conservation agricultural practices in the Madhupur Garh of Bangladesh.

MATERIALS AND METHODS

Study Area

The research was conducted in the farming fields of Auronkhola, Gaira, Makontonagar village, located in Madhupur district in northern Bangladesh (Figure 1). The soil in this area exhibits irregular patterns of red stratified sands and silts. It is moderately acidic throughout, and the parent alluvium is mineral-rich. The organic matter content is low, and the cation exchange capacity (CEC) is moderate. Generally, the soil fertility level in this area is categorized as low to medium.

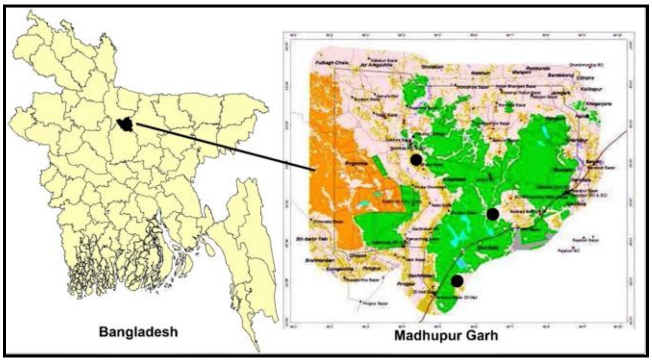

Figure 1. Study are map showing Magdupur Garh (1= Auronkhola, 2= Gaira, 3= Makontonagar)

Design of Experiment and Land Preparation

The experiment was carried out in Auronkhola, Gaira, Makontonagar village using a Randomized Complete Block Design (RCBD) consisting of two treatments: T1 (Conservation agriculture) and T2 (Traditional agriculture). Three replications of each treatment were established, resulting in a total of 18 plots across three farmers' fields. Each plot had dimensions of 3m × 4m.

For seed sowing, minimum tillage was employed, and the plots were prepared using a spade. In the conservation agriculture (CA) treatment, organic manure was utilized, along with a 50% reduction in recommended fertilizer doses. Line seed sowing was implemented for three different vegetable crops, and no insecticides/pesticides were applied.

In contrast, the traditional agriculture treatment followed conventional chemical-based and traditional tillage-based practices. The farmer's field was prepared through plowing three times, followed by laddering. In the traditional plots, recommended fertilizer doses were applied, while in the CA plots, 50% of the recommended

DOI: https://doi.org/10.55706/jae1617

doses of urea, MoP, and TSP fertilizers were used, along with 12 t/ha of tree leaves or cow dung during land preparation.

The line sowing method required relatively less seed compared to the broadcasting method, and other intercultural operations were conducted accordingly.

Growth and Yield Parameters of Ginger and Turmeric

Measurements were taken for various parameters including plant height (cm), leaf length (cm), leaf breadth (cm), no. of tiller per plant, no. of mother rhiz per plant, no. of primary fing per rhiz, fresh rhize weight per clump (g). To obtain the data, ten mature plants were collected from each plot, and the measurements were recorded. The total yield of each plot was converted to a per-hectare basis. The mean values of these parameters were calculated. The crops, namely ginger and turmeric, were harvested 25, and 35 days after seed sowing, respectively. The mean values for the aforementioned parameters were recorded accordingly.

Soil Analysis

Soil samples were collected and tested for pH, organic matter (OM), total nitrogen (N), phosphorus (P), and potassium (K) status before the start of the field experiment in July 2022 and after the harvest of the vegetable crops in October 2022. The soil samples were collected using a hand auger, and the soil analysis was conducted by the Soil Science department of Bangladesh Agricultural University.

Data Collection and Analysis

The field data for ginger and turmeric was gathered and the crops were harvested 25, and 35 days after sowing, respectively. Additionally, soil samples were collected from each plot using an auger at a depth of 0-30cm. These samples were then taken to the laboratories of Bangladesh Agricultural University for analysis. The collected data was analyzed using Microsoft Excel software. The study duration encompassed the period from July to October 2022.

RESULTS AND DISCUSSION

Growth and yield of Ginger

The growth data analysis of ginger under conservation agriculture (CA) and traditional technologies indicated statistically significant differences at a 5% level of significance for various parameters. This suggests that there were notable variations between CA and traditional cultivation methods (Table 1). Notably, the CA technology demonstrated superior results compared to traditional methods (Table 1).

In terms of plant height, CA exhibited a maximum height of 69.2 cm, whereas traditional methods showed a lower height of 58.8 cm (Table 1). The number of tiller per plant was also higher in CA than traditional treatments (Table 1). However, CA and Traditional agriculture had similer number of rhizome per plant (4.8). Leaves length and breadth were also higher in CA, with measurements of 23.9 cm and 2.5 cm, respectively, whereas the traditional treatment had relatively lower measurements of 20.6 cm and 3.7 cm, respectively (Table 1).

Fresh rhizo weight in CA was higher that of the traditional treatment, with values of 505 g and 400 g, respectively (Table 1). This indicates the positive impact of CA on the production of plant residues.

Table 1. Yield and yield contributing characters of ginger grown in conservation and tradition agricultural systems.

Treatments	Plant height (cm)	Leaf length (cm)	Leaf breath (cm)	No of tiller/ Plant	No of rhizome/ plant	No of finger/ rhizome	Fresh rhizo wt/ plant (g)
Conservation Farmer-1	68.5	22.7	2.5	4.3	4.8	19.2	505
Conservation Farmer-1	61.9	23.9	2.3	4.1	4.7	20.0	500
Conservation Farmer-1	69.2	22.6	2.4	4.1	4.7	18.5	495
Traditional Farmer -1	62.5	21.2	2.2	4.0	4.8	18.5	490
Traditional Farmer -2	60.6	20.6	2.3	3.7	4.7	18.5	400
Traditional Farmer -3	58.8	22.9	2.2	3.8	4.3	19.0	420

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Growth and yield of Turmeric

The growth data analysis of turmeric under conservation agriculture (CA) and traditional technologies indicated significant differences at a 5% level of significance for various parameters. However, the CA technology demonstrated better results compared to traditional technologies (Table 2).

Plant height was recorded as the maximum in CA, measuring 111.5 cm, while traditional methods resulted in a lower height of 99 cm (Table 2). The number of tillers per plant was observed to be higher in the CA treatment than traditional treatment (Table 2). However, CA had a greater number of mothers rhizome per plant (4) compared to the traditional technology, which had only 3 leaves per plant. Leaves length and breadth were also higher in CA, with measurements of 17.5 cm and 5 cm, respectively, while the traditional treatment exhibited relatively lower measurements of90.2 cm and 14 cm, respectively (Table 2). Fresh rhizome weight in CA was higher at 590 g compared to the traditional treatment, which yielded 410 g (Table 2).

Table 2. Yield and yield contributing characters of turmeric grown in conservation and tradition agricultural systems.

Treatments	Plant height (cm)	Leaf length (cm)	Leaf breath (cm)	No of tiller/ Plant	No of mother rhiz/plant	No of primary fing/ rhiz	Fresh rhizo wt/ clump (g)
Conservation Farmer-1	111.5	94.6	17.5	4.8	4.0	13.5	590
Conservation Farmer-1	109.0	93.5	16.4	4.8	3.6	12.4	500
Conservation Farmer-1	108.0	91.0	16.5	5.0	3.5	12.6	450
Traditional Farmer -1	99.0	91.7	12.8	4.0	3.0	11.5	470
Traditional Farmer -2	99.5	90.5	14.0	4.0	3.5	9.0	410
Traditional Farmer -3	105.5	90.2	14.5	3.6	3.8	8.9	430

Yield Comparison of Ginger and Turmeric

The findings indicated that ginger and turmeric exhibited favorable growth and productivity when cultivated using conservation agriculture (CA) technology. The implementation of CA involved a 50% reduction in fertilizer usage, while incorporating 12 tons per hectare of organic manures such as cow dung and tree leaves into the CA plot. In terms of ginger yield, CA technology (6090 kg/ha) surpassed traditional methods (5420 kg/ha) (Figure 3). Similarly, turmeric demonstrated higher yields under CA (11370 kg/ha) compared to the traditional approach (9730 kg/ha) (Figure 4). For a brighter future, CA emerges as the most favorable choice.

Figure 2. Conservation and traditional agriculture practices in Madhupur Garh.

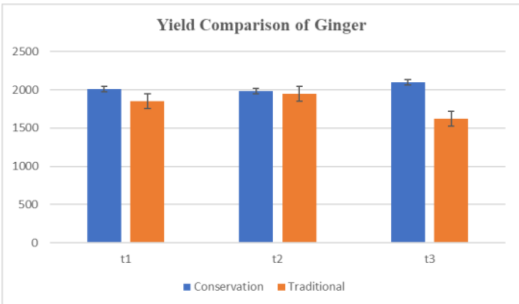

Figure 3. Yield comparison of ginger in conservation agriculture and tradition methods

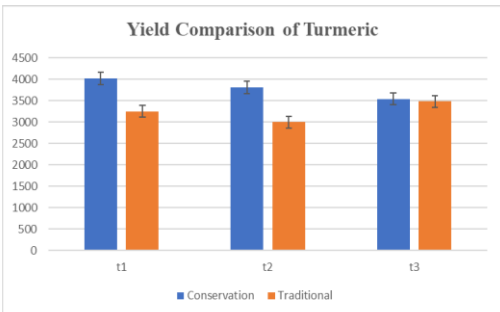

Figure 4. Yield comparison of turmeric in conservation agriculture and tradition methods

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Conservation of Natural Resources

In Bangladesh, the soils often exhibit lower levels of organic matter (OM). The majority of soils contain less than 2.5% OM, with the northern region's soil having less than 2.0% OM. Ideally, a healthy soil should contain 5.0% OM. During the initial phase of the study, soil samples were collected and analyzed, revealing poor nutritional quality and an OM content of only 1.98% (Table 3). However, the cultivation of ginger and turmeric utilizing organic manures in the northern region of Bangladesh has led to an improvement in soil OM and the presence of NPK nutrients. These outcomes highlight the positive effects of adopting conservation agriculture practices (Table 3).

Table 3. Changes of soil quality in conservation agriculture practices

Soil Samples	Soil pH	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

An efficient program aimed at improving soil quality can have a positive impact on the physical, chemical, and biological properties of the soil, which are vital for providing essential nutrients to plants. The results of the soil study indicated an increase in soil organic matter (OM) content, albeit with gradual progress. This provides clear evidence that the implementation of conservation agriculture (CA) techniques has successfully enhanced soil quality and nutrient status (Table 3). Notably, the analysis revealed an improvement in soil phosphorus levels, with a measurement of 24.78 ppm, as compared to the initial soil analysis results (Table 3).

Conservation agriculture is widely acknowledged for its ability to reduce production costs, increase yields, and enhance water usage efficiency, as supported by various studies (Ernstein et al., 2008; Ngwira et al., 2012; Islam et al., 2021). One key aspect of adopting conservation agriculture is the year-round retention of crop residues and tree leaves as surface mulch, which significantly contributes to its effectiveness. In July 2022, ginger and turmeric were cultivated and harvested at a height of 2/3 cm or higher, with a deliberate effort to leave as much residue on the soil as possible for subsequent crops (Table 4). Additionally, organic manures such as compost, cow dung, and occasionally vermicompost were utilized to nourish the crops. The study also aimed to raise awareness among farmers regarding the importance of agricultural residues in mitigating soil erosion and the social implications of alternative conventional uses for these residues.

Table 4. 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
	pH	Soil pH did not vary in CA and traditional plots, however, the trend showed that CA improve soil pH 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.

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Farmers and rural communities now recognize the importance of sustainable agriculture that not only yields abundant crops but also safeguards natural resources (Reynolds and Borlaug, 2006). Consequently, this study employed action research to demonstrate the practical implementation of conservation agriculture (CA) techniques at the farmers' level, maintaining intensified crop production throughout the year. Conservation agriculture is widely regarded as a set of management practices that can foster sustainable agricultural practices. By integrating the management of soil, water, crops, and other biological resources, CA aims to enhance, preserve, and optimize the utilization of natural resources. To safeguard soil structure, soil fauna, and soil organic matter, the study employed minimal soil disturbance through the adoption of CA techniques such as minimal tillage (Table 4). Furthermore, the incorporation of diverse crop rotations involving vegetables, cereals, and pulse crops can enhance soil microorganisms while disrupting plant pests, weeds, and diseases. The study also emphasized the importance of maintaining permanent soil cover using techniques such as cover crops and crop residues to protect the soil and suppress weed growth.

CONCLUSION

Traditional farming techniques, lack of crop rotation and coverings, uneven fertilizer use, and poor management practices have contributed to a gradual decline in soil quality in Bangladesh. The Madhupur Garh region of the country faces particularly challenging cropping conditions, with limited resources and a heavy reliance on Transplanted Aman rice cultivation. To address these issues and improve crop yields and soil fertility, conservation agriculture has emerged as a crucial technique. Field trials conducted in the Madhupur district demonstrated that conservation agriculture practices led to improvements in soil quality, net returns, and fresh vegetable yields compared to conventional cultivation methods. The application of three key principles of conservation agriculture—minimal tillage, retention of crop residues as surface mulch, and crop association—proved essential in achieving these benefits. The results of the conservation field trial underscored the potential increase in vegetable yields and soil fertility if farmers adopt proper conservation agriculture principles. Strengthening the implementation of conservation agriculture is expected to enhance soil fertility, crop yields, and overall resilience against adverse climatic conditions. The study highlights the need to address challenges such as shifting farmers' attitudes, promoting adaptive research and demonstration efforts, providing governmental and institutional support, fostering farmer networks, and ensuring the availability and access to agricultural implements. These measures are crucial for promoting the agenda to explore the role of conservation agriculture in widespread adoption of conservation agriculture in Bangladesh.

Author's contributions

All authors contributed to the conception and design of the study. Material preparation, data collection and analysis were performed by KKI and GMM. The first draft of the manuscript was written by SMK and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Acknowledgments

The research was supported by a special research grant from the ministry of science and technology (MoST), fiscal year 2022-23 (Grant Number SRG-221036).

Conflict of Interest

There is no conflict of interest to declare.

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