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Conservation Agriculture, Crop Intensification and Cultivation of Mustard in the Northeastern Bangladesh

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Abstract— *Deteriorating soil quality and lower crop yields due to continuous monocropping in the small-scale farmers' fields have led to a quest for sustainable production practice with greater resource use efficiency in Bangladesh. Conservation agriculture is one such good practice that can successfully address soil quality improvements and crop productivity using locally available resources. Therefore, the objective of the study was to determine the effect of conservation agriculture practices on mustard productivity and soil quality in the northeastern region of Bangladesh. The study also cultivated mustard crops as a part of crop intensification of existing two cropping patterns into four crops. The study was conducted at two locations following Randomized Complete Block Design (RCBD) in the farmers' fields of Netrokona and Sunamganj Districts of Bangladesh during the period from November 2021 to January 2022. The results revealed that the conservation agriculture practice had significantly improved mustard seed yield and the trial variety Bangladesh Agriculture Research Institute (BARI-14) mustard produced the highest yield of 1035 kg/ha in the Dharmapasha area. In conservation agriculture practice, 50% of less fertilization, 12 t/ha organic manuring, minimum tillage, permanent crop residues and crop rotation had substantially improved the soil organic matter content, total nitrogen, phosphorous, potassium and also neutralize pH for crop cultivation. So, improvements in mustard productivity, overall economic gain and soil quality have made the conservation agriculture practice an attractive system for small-scale farmers in the northeastern region and other areas with similar conditions in Bangladesh. Thus, the present study concluded that in the next decade, agriculture will have to sustainably produce more food using less and through the more efficient use of natural resources, creating a minimum impact on soil and environment, in order to meet the demands of the growing population.*

Keywords— ***Minimum tillage, Cover crops, Organic manuring, Soil quality, Mustard.***

I. INTRODUCTION

Achieving the Sustainable Development Goals (SDGs) will be challenging in developing countries like Bangladesh where a majority of the population depends on agriculture for their daily living. The GDP contribution of the agriculture sector is 12.65% but the majority (87%) of rural people are depending on agriculture for their livelihoods in Bangladesh (World Bank, 2020; BBS, 2019). Arable land (ha/person) area in Bangladesh is only 0.05 and there is a limited scope to expand agricultural production due to an increase in population growth (World Bank, 2018). Therefore, the efficiency of crop productivity forms a vital element in improving food security.

Moreover, the persistent use of conventional farming practices based on extensive tillage has exaggerated soil erosion and soil resources have been steadily degraded (Montgomery, 2007; Ahmed and Kashem, 2017). Conventional tillage is commonly practiced all over

Bangladesh that has reduced soil organic matter and soil become caped and less porous, losing its ability to absorb and retain water (Hobbs et al., 2008; Thierfelder and Wall, 2010). So, the loss of soil organic matter leads to a loss in crop nutrients as well as soil structure and biological life; and these degradation processes are common and faster in the tropical region due to higher temperature and rainfall intensity (Ngwira et al., 2014; Giller et al., 2009). In addition, the lack of crop rotation and crop cover causes severe soil degradation in Bangladesh. The scenario is more intense in the resource-poor northeastern border region of Bangladesh, the farmers of that region have commonly faced water scarcity in the dry season and flash floods in the early rainy season to cultivate their main crops. These challenges would affect the crop production and livelihood of the farmers living in the India-Bangladesh border (northeastern) areas of Netrokona and Sunamgonj districts of Bangladesh.

The cropping pattern in the northeastern region of Bangladesh is dominated by rain fade rice that includes Transplanted Aus and Aman rice mainly (Khatun et al., 2017; Islam et al., 2021). So, the cropping pattern with only two rice crops has severely affected the soil conservation, crop rotation and cover approaches in the northeastern region. Mustard (*Brassica sp*.) is one of the most important oilseed crops in Bangladesh and the annual production is over 312,000 tons (BBS, 2019). Mustard seeds contain 40-50% oil and 20-25% protein and it contains a rich amount of fat-soluble vitamins like A, D, E and K (Ahmed and Kashem, 2017). However, the mustard production is low compared to our national demands, as a result, the country needs to import a higher amount of mustard from abroad. The production of mustard in particularly the short-duration variety can be increased by bringing more lands of fallow and resource-poor areas under mustard cultivation. However, given the challenges that arise from the conventional tillage and lack of crop rotation and cover crop approach in the northeastern region of Bangladesh, a key policy intervention for conservation soil resources and maintaining crop productivity is the conservation agriculture (CA) practice. Therefore, the objective of the study was to determine the effect of conservation agriculture Achieving the Sustainable Development Goals (SDGs) will be challenging in developing countries like Bangladesh where a majority of the population depends on agriculture for their daily living. The GDP contribution of the agriculture sector is 12.65% but the majority (87%) of rural people are depending on agriculture for their livelihoods in Bangladesh (World Bank, 2020; BBS, 2019). Arable land (ha/person) area in Bangladesh is only 0.05 and there is a limited scope to expand agricultural production due to an increase in population growth (World Bank, 2018). Therefore, the efficiency of crop productivity forms a vital element in improving food security.

Theoretical framework: The study introduced short-duration mustard crops using conservation agriculture (CA) technology in the resource-poor northeastern region of Bangladesh. CA technology utilize soils for the production of crops with the aim of reducing to a minimum the excessive mixing of the soil that is characteristics of tillage-based farming, maintaining crop residues on the soil surface to minimize damage to the environment and deploying crop diversity and associations for increasing soil and crop health, for producing more biomass of higher quality and crop productivity (Giller et al., 2011). Therefore, CA is featured by three principles that are linked to each other, viz. minimal soil disturbance, soil cover by crop residues and cover crops, and crop rotation (Figure 1). In addition, the study implies a crop intensification program so as to ensure soil permanent cover throughout the whole year. That means the study area's two rice-based cropping patterns would be extended to four cropping patterns and also confirmed the addition of all crop residues to the respective fields.

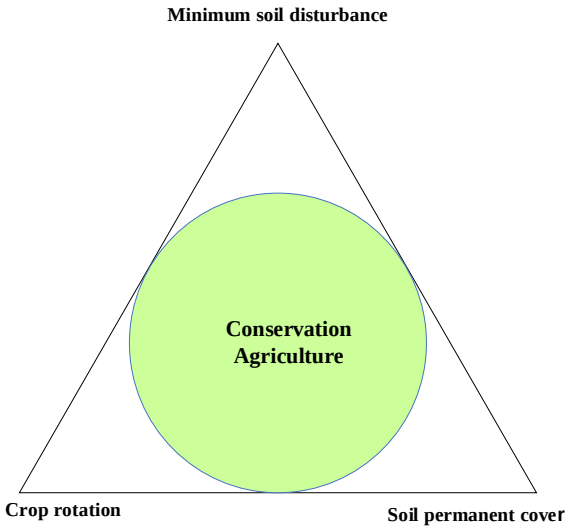

Figure 1: Conservation Agriculture Practice

II. METHODOLOGY

2.1 Study Area

The study was conducted in the farmers' field of Kalmakanda and Dharmapasha Unions of Netrokona and Sunamganj districts of Bangladesh (Figure 2) under the agroecological zone of AEZ-22 (northern and eastern piedmont plains). This region is situated in the Bangladesh-India border occurring as a narrow strip of land at the foot of the northern and eastern hills. The soil of this area is characterized by the grey piedmont and non-

calcareous grey floodplains, also loam to dry, slightly acidic to strong acidic in reaction and lower fertility status. The study area's soil pH ranges from 5.48 to 6.06 (acidic) and has lower organic matter content (2.16 to 2.69%) (soil tested in BAU laboratory). The field research was set up from November to January (Rabi season) of 2021. Rabi season is featured by low temperature and medium to the low moisture content in the soil. Usually, farmers do not cultivate any crops at this time due to a shortage of water after December and the soil becomes dry. In some cases, Boro rice has been cultivated within irrigation facilities. Moreover, the study farmers were poor and cannot manage irrigation facilities and thus, short-duration mustard is a suitable crop for these areas.

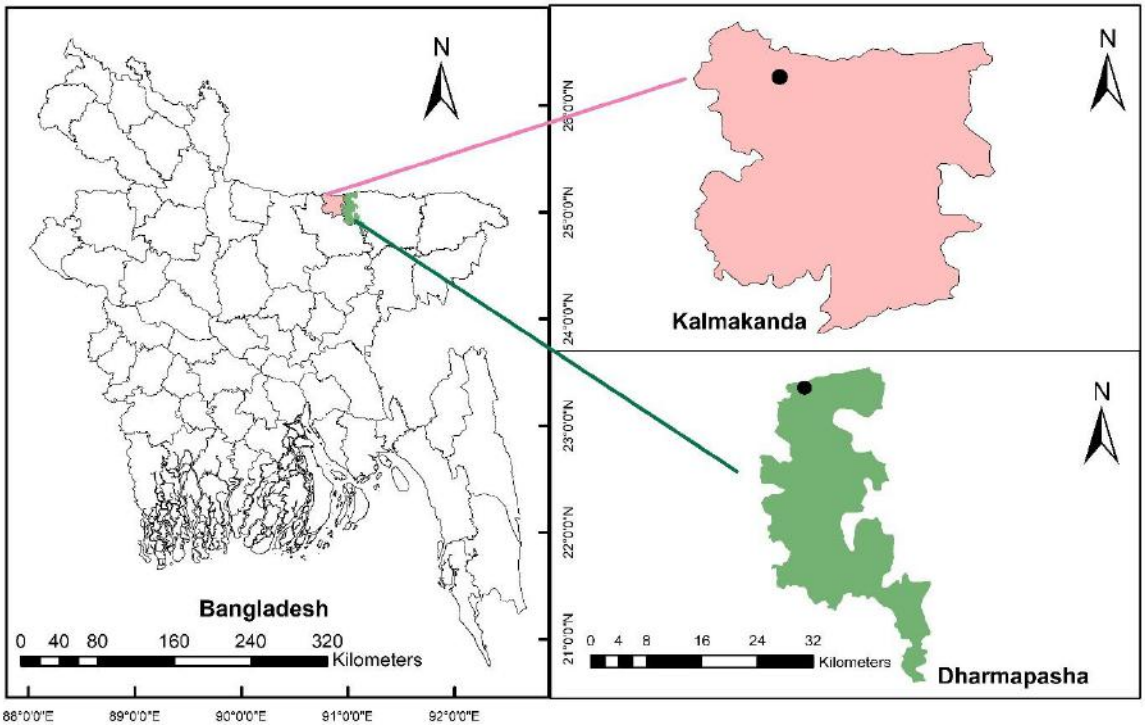

Figure 2. Study area map showing Kalmakanda and Dharmapasha Unions of Bangladesh.

2.2 Mustard Variety

The study used the high-yielding and short-duration tested mustard varieties in the study area. The two varieties in Bangladesh namely, BARI Mustard-14 and BINA Mustard-9 have been performed good results in field trials (Ahmed and Kashem, 2017). Bangladesh Agriculture Research Institute (BARI-14) variety is the medium plant structure, photo insensitive and resistant to major diseases. The seed is brownish in color and contains a higher oil percentage. Crop duration is about 75 days and seed yield around 1.7 ton/ha and also recommended for entire Bangladesh. While the Bangladesh Institute of Nuclear Agriculture (BINA-9) variety is good for the winter season and widely adoptable all over the country. BINA-9 mustard duration is about 80 days and the average seed yield is 1.7 t/ha. Seed is bigger in size with blackish to brown color, contains 43% oil, plants are resistant to mosaic virus and suitable for all over Bangladesh (Ahmed and Hashem, 2017; BINA, 2022).

2.3 Experimental Design and Land Preparation

Two experiments were conducted in the Randomized Complete Block Design (RCBD) with four treatments (T1=BARI-14 CA, T2=BARI-14 Traditional, T3=BINA-9 CA and T4=BINA-9 Traditional) and three replications in two different locations (Kalmakanda and Dharmapasha). Each plot size has a 5m × 4m size, therefore, 12 plots in Kalmakhanda and another 12 plots in Dharmopasha Upazilla were used for the study. The conservation agriculture technology followed organic manuring plus 50% less recommended doses of fertilizers, minimum tillage, line seed sowing, no insecticides/pesticides and use mustard crop residues as green biomass for the next crop. While the traditional technology uses conventional chemical-based producing technologies in both locations. To ensure crop rotation and cover crops pillar of CA, the study cultivated Mungbean-Aus Rice-Aman Rice and Mustard and allowed all crop residues (cut crops above 6 inches to ground level) to the cultivated mustard field.

The farmer's field was prepared with minimum plowing for CA and three times plowing followed by laddering in traditional plots. The traditional plot was mixed by the recommended doses of fertilizers- Urea, TSP, MoP at the

rate of 80, 70, 45 kg/ha (BINA, 2022); however, the CA plots were mixed with 50% recommended doses of fertilizers with 12 ton/ha tree leaf/ cow dung at the time of land preparation. The mustard seeds were sown 2.8-3.0kg/ha rate in the traditional plot with hand broadcasting methods and line sowing methods on November 9, 2021. In line sowing methods, about 30% less seed was required compared to the broadcasting method and other intercultural operation was done accordingly.

2.4 Growth and Yield Parameters of Mustard

Data on plant height (cm), number of branches per plant, number of capsules per plant, capsule length (cm), number of seeds per capsule, 1000 seeds weight (gm) and seed yield (kg/ha) were recorded. Ten mature plants from each plot were collected to measure those parameters and for total yield, we converted each plot yield to a hectare basis. The mean value of those parameters was recorded and seed weight was collected after proper sundry, both mustard varieties were harvested after 75 days of sowing.

2.5 Soil and Data Analysis

The study also collected and analyzed the Soil p^H, Organic Matter (OM), total N, P, and K of field soil before starting the experiment on December 2020 and after mustard harvested on January 2022. The soil samples were collated using Augur and analyzed in the Soil Science department of Bangladesh Agricultural University. The collected data were analyzed using the statistical package of Web Agri Stat Package (WASP) and the mean difference was measured at a 5% level of significance.

III. RESULTS AND DISCUSSIONS

3.1 Growth and Performance of Mustard

On field evaluation of conservation agriculture (CA) practice and traditional practices exhibited differing trends in mustard growth and performance in the two districts of northeastern region of Bangladesh. The growth data of the BARI and BINA mustard varieties in CA and traditional technologies showed that plant height (cm), number of branches per plant, capsule length (cm), no of seeds per capsules, no of branches per plant and 1000 seed weight (gm) were statistically significant at 5% level of significance. That means there was significant variation among the two varieties in both CA and traditional cultivation technologies (Table 1). However, the BARI-14 mustard variety in conservation agriculture technology showed the best results among the other treatments (Table1).

In case of two locations, the Dharmapasha are showed better performance of all studied growth parameters of mustard compare to Kolmakanda region. The highest number of branches per plant (6.33 cm) was observed in Dharmapasha BARI-14 CA treatment (Table 1) while the lowest (4.33) was found in BINA-Traditional mustard treatment in Kolmakanda area. The mustard capsule length was not varied significantly in Dharmapasha area and all other studied parameters had significant variation in CA agriculture practice. That means the CA practice have had a positive effect on growth and performance of mustard in both locations (Table 1).

3.2 Yield of Mustard

The results indicated that the mustard yield was better in CA practice compare to traditional cultivation methods and the total yield of BARI-14 mustard variety performed well both in Kalmakanda and Dharmapasha areas. It was mentioned here that the CA practice used 50% less fertilizers and in addition, 12 ton/ha available organic manures (cow dung/tree leaf) were added to the CA plot. These two mustard varieties have already proved to be the best production ability in Bangladesh, and the present study found that the BARI-14 variety performed better compared to BINA-9 variety in the northeastern resource poor area of Bangladesh. The results found that the highest seed yield of 1.3 ton/ha mustard was found in BAR-14 variety in Dharmapasha area while the lowest (0.97 ton/ha) yield was observed in BINA-9 variety at Kolmakanda region (Figure 3). The study also revealed that the mustard average yield in both study area was fewer than the average national mustard production of 1.7 ton/ha (BINA, 2022). It was due to fact that the soil of the study area was very poor in terms of nutrients and organic matter content and there is an essential task to improve the soil quality for the better crop production in the resource-poor northeastern regions of Bangladesh.

Table 1. Mustard yield and yield contributing parameters in CA and traditional cultivation technologies

Location	Treatments	Plant ht. (cm)	No of branch/ plant	No of capsule/ plant	Capsule length (cm)	No of seeds/ capsule	1000 seeds wt. (gm)	Seed yield (kg/ha)
Kalmakanda	T_1 BARI-CA	92.67b	6.33a	88.67a	5.03a	22.67a	3.18a	10058a
	T_2 BARI-Trad	89.67c	4.67b	83.33 b	4.71a	16.33c	2.62c	9303c
	T_3 BINA-CA	96.83a	5.33bc	84.33 c	4.92b	21.33b	2.98b	9717b
	T_4 BINA-Trad	94.50b	4.33c	80.67 d	4.53b	15.33c	2.48c	9000d
	CV (%)	1.142	9.677	0.523	1.895	3.412	2.766	1.072
	CD (0.05)	**	*	**	**	**	**	**
Dharmapasha	T_1 BARI-CA	94.33a	6.33a	91.00a	5.30	24.67a	3.57a	10325a
	T_2 BARI-Trad	89.00b	5.33ab	85.67ab	4.74	17.33b	2.67c	9387c
	T_3 BINA-CA	100.33a	4.67b	86.67a	5.07	22.00a	3.00b	9783b
	T_4 BINA-Trad	93.33	4.33b	80.00b	4.58	15.67	2.30d	9083d
	CV (%)	3.452	11.175	3.369	6.055	7.485	4.731	0.890
	CD (0.05)	*	*	*	NS	**	**	**

Note: NS=Non significance, CV= Coefficient of Variation, CD= Critical difference at 5% (*) and 1% (**) level of probability.

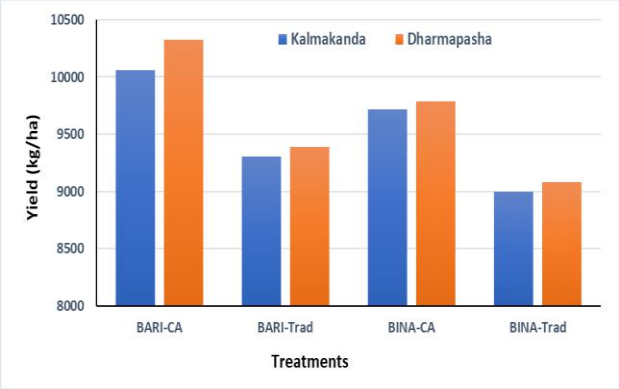

Figure 3. Mustard yield in CA and traditional cultivation techniques in study areas

3.3 Soil Quality Improvements

The soil of Bangladesh is commonly deficient in organic matter (OM) content. A good soil needs to have 5% OM content, whereas most soil have less than 2.5% and the soil of the northeastern region has less than 2.0%. The study initially collected the soil samples and soil analysis showed that the soil has poor in nutrient quality and the OM content was low (Table 2). Introduction of climate-smart and conservation agriculture practice in the northeastern region with Mungbean and Mustard crops has significantly improved soil OM and also NPK of the soils (Table 2).

Table 2. Changes of soil quality in conservation agriculture practices

Location	Treatments	Soil p^H	Soil OM (%)	Soil Total N (%)	Soil P (ppm)	Soil K (meg/100g)
Kalmakanda	Initial Stage (2020)	6.31	2.558	0.132	11.68	0.055
	CA Plots (Dec. 2021)	6.50	2.889	0.146	27.88	0.177
	Traditional Plots (Do)	6.38	2.593	0.134	11.82	0.074
Dharmapasha	Initial Stage (2020)	5.77	1.969	0.100	11.13	0.065
	CA Plots (Dec. 2021)	6.69	2.793	0.145	26.16	0.121
	Traditional Plots (Do)	5.77	2.034	0.106	12.38	0.111

Improving of soil OM can successfully improves soil physical, chemical, and biological properties and is the storehouse of almost all plant nutrients. The soil analysis results revealed that the OM content has improved in both sites, although the trends of improvement was slow but it clearly shows that the CA practices had successfully improves the soil quality (Table 2). The soil phosphorous has significantly improved (27.88 ppm) in Kalmakanda and also Dharmapasha (26.16 ppm) areas compare to the initial soil analysis results (Table 2).

Conservation Agriculture practice is often reported to reduce the cost of production, increase yield and water use efficiency (Ernstein et al., 2008; Ngwira et al., 2012). Another important issue for adaptation of conservation agriculture is the year-round retention of crop residues as surface mulch. The study cultivated Mungbean in February 2021 followed by regular T. Aman and Rice cultivation and allowed crop residues for cultivating all crops. We harvested Mungbean and two rice crops above 6 inches from ground level and allow crop residues to the soil surface as much for the next crops (Table 3). In addition, we applied organic manures in the form of cow dung or compost to cultivate mustard crops. The study also created farmers' awareness on the role of crop residues in reversing soil degradation, the social aspect of other traditional competing uses of residues must be considered.

Table 3. Prospects of CA practices in northeastern region of Bangladesh

Items	Sub-items	Parameters
Productivity	Growth	Increase crop growth contributing parameters compare to traditional methods
	Yield	Increase mustard seed yield in CA practice compare to traditional cultivation systems
Soil Quality	OM	Uses 12 t/ha organic manure during land preparation, allow crop residues and all of those enhance soil OM
	p^H	Increasing of soil OM also neutralize soil p^H, it means soil become more neutral compare to initial acidic condition.
	N P K	Increase soil total N, P, K in CA practice and the soil become more favorable and available nutrients for growing crops.
	Drought	Increase resilience to drought due to practice of much and efficient water utilization technique
	Erosion	Crop residues protected soil surface erosion and run-off
	Labor saving	Decrease irrigation and overall labor requirement, reduce cost of production
	Soil cover	Crop intensification with four crops enhance soil cover and cultivation of Leguminosae crops ensure soil cover crop approach as well
	Crop rotation	Mungbean, Two Rice and Mustard ensure crop rotation and CA practices in the study areas
Resilience	Emission	Reduced GHG emission through lower tillage and fertilizations
	Carbon storage	Increase soil carbon sequestration and available soil carbon for crops

Nowadays, rural people and farmers have come to understand that agriculture should not only lead to high yields but also be sustainable and able to conserve natural resources (Reynolds and Borlaug 2006). Therefore, the

present study demonstrated the technical performance of CA at the field level by maintaining four crop-based intensifications through action research. In Bangladesh, as in other South Asian counterparts, the development of better markets for oilseeds and grain legumes is needed before farmers can invest in more balanced cereal-legume associations (one of the three pillars of CA is crop rotation or association) (Umar et al., 2011). Conservation agriculture has been proposed as a wide adapted set of management principles that can ensure more sustainable agriculture production. It seeks to conserve, improve, and make more efficient use of natural resources through integrated management of soil, water, crops and other biological resources. Through the CA practice, the study ensured minimal soil disturbance (minimum tillage) so as to preserve soil structure, soil fauna and soil organic matter (Table 3). The study also ensured permanent soil cover (cover crops, crop residues) to protect soil and contribute to the suppression of weeds and finally, diversified crop rotation (mungbean, two rice and mustard) could promote soil-microorganism and disrupt plant pests, weeds and diseases as well.

IV. CONCLUSION

Soil fertility of Bangladesh is decreasing gradually due to improper cropping practice, lack of crop rotation and crop covers, imbalanced use of fertilizers and faulty management practices all over the country. The scenario is worst in the northeastern resource-poor area of Bangladesh where the cropping pattern is limited to only Transplanted Aus and Aman rice only. So, Conservation Agriculture is an important method that can sustain and increase soil fertility and crop productivity. On-farm trials in Kalmakanda and Dharmapasha area found that CA practice increased mustard yield, net return and soil quality compared with traditional cultivation techniques. Application of three principles of CA, i.e., minimum tillage, retention of crop residue as surface mulch and crop association appeared to be vital for these benefits. So, the field trial on CA showed that the crop production together with soil fertility would be boosted if the appropriate measures of CA principles are taken by the farmers. It is expected that strengthening the CA program will help soil fertility and crop productivity to increases and overall, the resilience to protect the adverse climatic condition would be increased. Therefore, the study would recommend that the key issues to be addressed to promote conservation agriculture are changes in mindset, adaptive research and demonstration effort, policy and institutional support, networks of farmers and ensuring availability and access to agricultural implements.

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