Effects of tillage and nutrient management on yield of okra (*Abelmoschus esculentus* (L.) Moench)

M. Akter[1], N.C. Shil[2,*] and S. Ahmad[1]

[1] Department of Botany, Jagannath University, Dhaka–1100, Bangladesh

[2] Division of Soil Science, Bangladesh Agricultural Research Institute, Gazipur–1701, Bangladesh

* Corresponding author: nirmal_shil@yahoo.com

Submission: 17 January 2018 Revised: 12 June 2020 Accepted: 17 June 2020

ABSTRACT

A field experiment of okra (*Abelmoschus esculentus* (L.) Moench) was conducted in Gazipur under Agro–ecological Zone 28 during kharif 2015. The objectives of the study were to observe the effects of tillage depth and nutrient management on growth and yield of okra and to find out the suitable fertilizer dose for maximizing the yield of okra. The treatments comprised of three different tillage options viz., minimum tillage (0–4 cm; T_1), conventional tillage (10–12 cm; T_2) and deep tillage (20–22 cm; T_3) in combination with four nutrient management packages viz., 100% STB ($N_{100}P_{18}K_{49}S_{12}Zn_{1.75}B_{0.60}$ kg ha^{-1}) all from chemical fertilizer (M_1), 125% STB ($N_{125}P_{22.5}K_{61}S_{15}Zn_{2.19}B_{0.75}$ kg ha^{-1}) all from chemical fertilizer (M_2), 100% STB by using chemical fertilizer 75% ($N_{75}P_{13.5}K_{37}S_9Zn_{1.31}B_{0.45}$ kg ha^{-1}) and rest 25% from compost (4.3 t ha^{-1}) as integrated plant nutrition system (IPNS; M_3) and native fertility (M_4). The experiment was set up in 2 factors Randomized Completely Block Design having 12 treatment combinations with 3 replications. There were no significant effects of tillage on the yield and yield components of okra although deep tillage produced the highest yield (12.69 t ha^{-1}) followed by conventional tillage. Irrespective of tillage, a highly significant variation was observed for fruit yield due to different fertilizer management packages. The highest green edible fruit yield (14.96 t ha^{-1}) was recorded from M_2 where 125% STB fertilizer dose was applied, which was statistically identical to M_3 (IPNS based dose) but significantly higher over rest of the treatments. The lowest fruit yield (7.83 t ha^{-1}) was obtained from M_4, which was significantly lower than all other treatments. The yield benefit over M_4 was 51.7, 91.1 and 87.6% for M_1, M_2 and M_3, respectively. An almost similar trend of results was observed for yield parameters as growth factors. The interaction effect between tillage depth and nutrient management on the fruit yield of okra appeared to be statistically non–significant, but $T_3 \times M_3$ package gave the highest yield (15.21 t ha^{-1}), which was 30.56% higher over conventional practice ($T_2 \times M_1$). Highly significant positive linear relationships ($R^2 > 0.87$; $P < 0.01$) were observed between fruit yield with plant height, fruits plant^{-1}, fruit length and branch plant^{-1}. Present fertilizer recommendations for okra should be updated by increasing 25% more nutrients. Organic manure as compost at 4.3 t ha^{-1} in combination with 75% STB chemical fertilizer dose employing medium depth tillage appeared to be remunerative in augmenting the yield and economic return. For eco–friendly agriculture, IPNS package (M_3) with medium depth tillage may be the best option. Thus, the said package may be recommended for maximizing the yield of okra and sustaining the soil health.

Keywords: Okra, tillage depth, nutrient management, compost, yield

Thai J. Agric. Sci. (2020) Vol. 53(2): 97−108

INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench) is one of the important summer vegetable crops in South Asian region although it could be grown almost all over the world. As per botanical classification, okra belongs to the order Malvales, family Malvaceae, genus *Abelmoschus* and species *A. esculentus*. It can be cultivated throughout the year in Bangladesh but of course, cultivated widely in summer. Okra is a deep rooted crop and it could have a great impact on soil physical as well as chemical properties. Integrated nutrient management approach coupled with conservation tillage practice may play an important role in improving fertilizer and water use efficiency, physical conditions of soil and enhanced crop productivity. But nutrient turnover and mobilization require a congenial physical environment of soil, which could be achieved through proper tillage practices and optimum nutrient management.

Tillage improves the physical properties of soil and favors the rooting behavior of plants, which lead to enhanced nutrient uptake and better yield of crops. The choice of appropriate tillage system is crucial for sustainable farming in sub–tropical ecosystems. With high levels of organic matter decomposition and nutrient leaching in the tropics, conservation tillage with balanced fertilizer management becomes an effective option to consider for environmental conservation. Zugec (1986) reported that the highest and the most stable maize grain yields were obtained with conventional tillage.

Moreover, tillage is the most important practice in croplands having a major effect on the C pool, either negative with conventional plowing or positive when conservation tillage is applied. Conservation tillage practices can minimize the rapid breakdown of plant residues. Reduced tillage is helpful in reducing organic carbon loss from soils, which may result in improved physical, chemical and biological properties of soil as well as improved crop productivity.

Conservation tillage could benefit agricultural production by controlling topsoil loss from wind erosion and conserving soil moisture as a reserve against common summer droughts. Being a short duration crop, the growth and yield parameters of okra are largely influenced by appropriate nutrient management practices (Singh *et al*., 2000). Sole application of chemical fertilizers to meet the crop nutrient demand is deleterious for both soil and environmental health. Integrated nutrient management is found to be very effective for improving yield of many vegetable crops as well as in maintaining soil health (Noor *et al.,* 2007).

On the other hand, the nutrient application should be made based on plant demand. Plant demand is a function of growth rate, growth stage, climatic conditions and cultivar (Lang *et al*., 1999). The amount of nutrients required by a crop is also related to a realistic yield potential for the selected cultivar and land farmed. Thus, the amount of fertilizer applied to crop should depend on the supplying power of the soil, the potential for nutrient loss and the growth potential of the cultivar (Dean, 1994). Because of present socio–economic conditions and farming situation–mechanized agriculture instead of draught power and handy alternate use of cowdung resulted in its severe scarcity to be applied in the crop fields as organic manure. Under such circumstances, the use of compost to the crop field could be a better option in maintaining soil health and increasing yield. Because conventional compost as prepared from organic/agricultural wastes is rapidly assimilated in soil with minimal disruption of processes and maximum benefit in maintaining or improving soil fertility. It is widely believed that Bangladesh is now self-sufficient in cereal production but lagging far behind to meet the demand for vegetables and fruits. In these contexts, due attention is necessary to increase the productivity of vegetables and improve soil health through an integrated nutrient management system using conventional compost as the source of organic manure. Under the above perspectives, the objectives of the present study were (i) to observe the effects of different tillage depth and nutrient management on growth and yield of okra and (ii) to find out the suitable fertilizer dose for maximizing the yield of okra

MATERIALS AND METHODS

Study Area

The field trial was conducted at Bangladesh Agricultural Research Institute (BARI), Gazipur during kharif 2015 (March-July). The research site was at Gazipur, which is about 35 kilometers north from Dhaka. It is located at 23° 59' N latitudes and 90° 24' E longitudes. The study area represents Modhupur Tract (Agro-ecological zone; AEZ–28), which belongs to the *Chhiata* series of the Grey Terrace Soils (*Aeric Albaquept*) under the order Inceptisol.

Climate

The climate of the experimental area is sub-tropical, wet and humid. Heavy rainfall occurs in the monsoon and scanty in the other times. The experiment was conducted in kharif 1 (summer) season, which starts in March and ends in May, followed by a monsoon (kharif 2) season June to August. Rainfall of crop growing period ranged between 55 and 389 mm where variation in relative humidity was 65–79%. The average temperature varied from 32°C in March to 34°C in May.

Soil Sampling and Analysis

Initial soil samples of the experimental plot were collected maintaining a depth of 0–20 cm. Samples were then processed and analyzed in Soil Science Laboratory, BARI, Gazipur following standard methods as below. Mechanical analysis of initial soil was done by hydrometer method (Bouyoucos, 1962). Bulk density was measured by core sampler method while particle density was determined by Pycnometer method (Tan, 1996). For the determination of field capacity pressure plate apparatus was used. A glass electrode pH meter was used for measuring soil pH (Mc Lean, 1982) maintaining 1:1 for soil: water ratio. Organic carbon was determined by wet oxidation method (Nelson and Sommers, 1996). The total N content of soil was determined following micro Kjeldahl method (Bremner and Mulvaney, 1982). Bray 1 method was used for the measurement of available P (Bray and Kurtz, 1945). Exchangeable bases (K, Ca and Mg) were extracted with 1M NH_4OAc (Thomas, 1982 as described by Tan, 1996). Available S was determined by turbidimetric method (Tabatabai, 1982). Available Zn was determined by DTPA extraction method while available B was measured by hot water extraction method as described by Tan (1996).

Filed Work and Crop Management

The treatments comprised of three tillage options viz., minimum tillage (4–6 cm; T_1), conventional tillage (10–12 cm; T_2) and deep tillage (20–22 cm; T_3) in combination with four types of nutrient management package viz., 100% STB ($N_{100}P_{18}K_{49}S_{12}Zn_{1.75}B_{0.60}$ kg ha^{-1}) based on (FRG, 2012) all from chemical fertilizer (M_1), 125% STB ($N_{125}P_{22.5}K_{61}S_{15}Zn_{2.19}B_{0.75}$ kg ha^{-1}) all from chemical fertilizer (M_2), 100% STB (75% from chemical fertilizer $N_{75}P_{13.5}K_{37}S_9Zn_{1.31}B_{0.45}$ kg ha^{-1} + 25% from compost (4.3 t ha^{-1}) as integrated plant nutrition system (IPNS; M_3) and native fertility (without fertilizer and manure; M_4). Thus there were 12 treatment combinations. The plot size was 4m × 3m. The experiment was set up in a 2 factor Randomized Completely Block Design with 3 replications. As per treatment, the entire amount of compost, TSP, muriate of potash, gypsum, boric acid and one-fourth of urea were applied during final land preparation. The rest urea was applied as top dress at 20, 40 and 60 days after sowing followed by a light irrigation. The seeds of okra (cv. Green King) were sown on 20 March 2015. The spacing was row to row 50 cm and plant to plant 40 cm. Two seeds were sown in each pit. After that, the seeds were covered with loose soil gently and irrigation was applied for proper germination. After seven days of germination, one healthy seedling was allowed to grow in each pit uprooting other seedlings. For controlling insect pest, Ripcord @ 2 ml L^{-1} water was spread twice. Irrigation was done immediately after top dressing.

Data Collection

Fruits were harvested at every alternate day at edible stage. Harvesting was started from 17 May 2015 and ended on 03 July 2015. Data on yield and components like plant height, fruit length, fruit breadth, individual fruit weight and number of fruits per plant were recorded.

Statistical Analyses

The mean data with replicate observations were analyzed statistically following Statistics 10 Software. The treatment means were separated by the Least Significant Difference (LSD) test. Regression analysis was done using Microsoft Excel Version 7.

Cost and Return Analysis

Cost and return for okra cultivation were analyzed following the procedure as described by Dillon and Hardaker (1993). Cost of seed, irrigation, pesticide and labour wages were considered as fixed cost. Variable cost is the sum of fertilizer cost, manure cost and tillage cost. Total cost is derived from the sum of variable cost and fixed cost. Gross return is the product of edible fruit yield and its market price. Gross margin or net benefit is calculated subtracting total cost from gross return. Benefit cost ratio (BCR) is the ratio between gross return and total cost.

RESULTS AND DISCUSSION

Physicochemical Properties of Soil

The textural class is clay loam. The bulk density and particle density of the soil were 1.52 and 2.55 g cm^{-3}, respectively having porosity 40.4%. The field capacity of the studied soil was 28.63%. The pH of the soil was 5.7. Total N content was very low (0.06%) while exchangeable K and available S and zinc content were low. The content of available P and B were medium (Table 1).

Table 1 Chemical properties of initial soil in the experimental field

Chemical properties	Soil depth (0–15 cm)	
	Initial	Critical level
pH	5.70	–
OM (%)	1.26	–
Total N (%)	0.06	–
K (meq 100 g^{-1})	0.14	0.12
Ca (meq 100 g^{-1})	6.34	2.00
Mg (meq 100 g^{-1})	2.00	0.80
P (µg g^{-1})	11.80	7.00
S (µg g^{-1})	12.00	10.00
Zn (µg g^{-1})	0.56	0.60
B (µg g^{-1})	0.33	0.20

Yield and Yield Attributes

The green edible fruit yield of okra did not increase significantly due to the mean effect of tillage (Table 2). In spite of this, the fruit yield varied from 12.01–12.69 t ha^{-1} where the highest yield was obtained from deep tillage (T_3), which was followed (12.33 t ha^{-1}) by medium tillage (T_2) and the lowest yield from minimum tillage (T_1). Even though the yield variation was non–significant in terms of F–test by 5% probability level but deep tillage contributed 2.92% increased yield over medium depth tillage (T_2) while fruit yield was decreased by 2.60% for minimum tillage (T_1) over medium tillage (Table 2).

Table 2 Effect of tillage on the yield component and yield of okra

Tillage	Plant height (cm)	Fruits plant^{-1} (no.)	Branch plant^{-1} (no.)	Fruit length (cm)	Fruit yield (t ha^{-1})	Yield increase over conventional tillage (%)
T_1	93.6	18.53	1.92	14.04^{b}	12.01	–2.60
T_2	99.1	18.57	2.03	14.44^{ab}	12.33	–
T_3	99.7	19.50	2.09	14.67^{a}	12.69	2.92
CV (%)	9.64	10.91	10.15	3.51	12.00	
Significance level	NS	NS	NS	*	NS	

Note: T_1 = minimum tillage (0–4 cm), T_2 = conventional tillage (10–12 cm), T_3 = deep tillage (20–22 cm), CV = coefficient of variation, mean data in a column having same letter(s) do no differ significantly at 5% level of probability by LSD, NS = non-significant, * $P < 0.05$

However, irrespective of tillage, a highly significant variation was observed for fruit yield due to different fertilizer management packages (Table 3). The highest green edible fruit yield (14.96 t ha^{-1}) was recorded from M_2 where 125% STB fertilizer dose entirely from chemical source as per FRG–2012 was applied, which was statistically identical to M_3 (IPNS based dose) but significantly higher over rest of the treatments. The second highest fruit yield (14.69 t ha^{-1}) was derived from M_3 which was 100% STB formulated with 75% from chemical fertilizer and rest 25% from organic manure (conventional compost). The said treatment (M_3) was also significantly higher over M_1 and M_4. The present fertilizer dose (M_1 = 100% STB) gave 11.88 t ha^{-1} yield, which was significantly higher only over control (M_4). As such, the present fertilizer recommendation (FRG–2012) as per STB appeared to be insufficient in maximizing the fruit yield of okra. But such fertilizer dose when formulated with IPNS approach (75% chemical fertilizer + 25% compost) showed significantly higher yield as revealed from M_3 package. The beneficial effects of compost in improving physical and chemical properties of soil as well as its growth hormonal activities might have contributed to increase the yield. The lowest fruit yield (7.83 t ha^{-1}) was obtained from M_4, which was significantly lower than all other treatments. The yield benefit over native fertility (M_4) was 51.7, 91.1 and 87.6% for M_1, M_2 and M_3, respectively (Table 3), which also revealed the contribution of compost based IPNS package in augmenting the fruit yield of okra. Omotoso and Shittu (2007) reported that the fertilizer NPK significantly increase growth parameters (i.e., plant height, leaf area, root length and number of leaves) and yield of okra. Similarly, Sultana (2002) obtained the highest yield of okra due to the integrated use of chemical fertilizers ($N_{200}P_{35}K_{66}S_{20}B_{0.5}$ kg ha^{-1}) and cowdung 5 t ha^{-1}. The present findings also corroborate with such results. Naidu *et al*. (2000) reported a significant increase in microbes in soil with application manures. Mal *et al*. (2014) found that the application of the highest dose of NPK @100% in combination with vermicompost (5 t ha^{-1}) and bio–fertilizers with FYM increased the fruit yield of okra (cultivar Mahyco–10). Gayathri and Reddy (2013) observed the maximum number of fruits plant^{-1}, individual fruit weight and fruit yield due to application of recommended dose of $N_{100}P_{50}K_{50}$ kg ha^{-1}. The significantly higher yield of okra due to application of fertilizer may be due to early vegetative growth, earliness in flowering and fruiting as well as individual fruit weight. These results are in conformity with the findings of Chaterjee *et al*. (2005). Higher yield response due to organic manure (compost) is ascribed to improvement in physical and biological properties of soil resulting in better supply of nutrients, which leads to luxuriant crop growth and yield. These results are in line with the findings of Premsekhar and Rajashree (2009).

Table 3 Effect of nutrient management on the yield component and yield of okra

Fertilizer Package	Plant height (cm)	Fruits $plant^{-1}$ (no.)	Branch $plant^{-1}$ (no.)	Fruit length (cm)	Fruit yield (t ha^{-1})	Yield increase over control (%)
M_1	100.90^a	17.60^b	2.00^b	14.04^c	11.88^b	51.70
M_2	105.60^a	21.76^a	2.28^a	14.94^b	14.96^a	91.10
M_3	107.20^a	22.60^a	2.38^a	15.52^a	14.69^a	87.60
M_4	76.10^b	13.51^c	1.40^c	13.03^d	7.83^c	–
CV (%)	9.64	10.91	10.15	3.51	12.00	
Significance level	**	**	**	**	**	

Note: M_1 = 100% STB ($N_{100}P_{18}K_{49}S_{12}Zn_{1.75}B_{0.60}$ kg ha^{-1}) all from chemical fertilizer, M_2 = 125% STB ($N_{125}P_{22.5}K_{61}S_{15}Zn_{2.19}B_{0.75}$ kg ha^{-1}) all from chemical fertilizer, M_3 = 100% STB (75% from chemical fertilizer $N_{75}P_{13.5}K_{37}S_9Zn_{1.31}B_{0.45}$ kg ha^{-1} + 25% from compost (4.3 t ha^{-1})), M_4 = native fertility (control), CV = coefficient of variation, mean data in a column having same letter(s) do no differ significantly at 5% level of probability by LSD, NS = non–significant, ** P < 0.01

However, the interaction effect between tillage and nutrient management on the fruit yield of okra appeared to be statistically non-significant, which revealed that both the factors acted independently in terms of F–test (Table 4). Nevertheless, fruit yield for different combinations varied from 7.45–15.21 t ha^{-1} where the highest result was recorded in $T_3 \times M_3$ followed by $T_3 \times M_2$, $T_2 \times M_2$ and $T_1 \times M_2$ and the lowest from $T_1 \times M_4$. Results showed that yield obtained from M_4 was poor irrespective of tillage depth and so yield was mostly governed by nutrient management and a little for the tillage, which might be the major reason for non–significant interaction effect. The yield benefit over the conventional method of cultivation ($T_2 \times M_1$) for various combinations was 30.56, 29.01, 28.50, 27.81, 26.18 and 21.63% for $T_3 \times M_3$, $T_3 \times M_2$, $T_2 \times M_2$, $T_1 \times M_2$, $T_2 \times M_3$ and $T_1 \times M_3$, respectively (Table 4). Native fertility treatment combinations showed a declining trend of yield where the highest decrease (36.05%) was recorded in $T_1 \times M_4$, followed by $T_2 \times M_4$ and $T_3 \times M_4$. A slight yield reduction was also observed in $T_1 \times M_1$ treatment. Thus, the effect of reduced tillage was not convincing for single crop cultivation even with higher fertilizer input and eco–friendly IPNS approach. The benefits of reduced tillage may be achieved if long term pattern based experiments with the integrated approach are practiced. Despite of up to certain yield benefit, deeper tillage may not be suitable for crop cultivation over the years because it may erode soils and ruins the physical environments threatening to sustainable agriculture and soil health. The effect of tillage on the yield and yield parameters of okra as mentioned earlier appeared to be statistically non–significant. Similar findings were also reported by Shil *et al*. (2015)

for potato. Thus, the mean effect of tillage was not remunerative as like the mean effect of nutrient management, but reduced tillage is helpful in sustaining the soil health and subsequently the crop yield in the long run.

Table 4 Interaction effect between tillage and nutrient management on the yield component and yield of okra

Treatment	Plant height (cm)	Fruits plant^{-1} (no.)	Branch plant^{-1} (no.)	Fruit length (cm)	Fruit yield (t ha^{-1})	Yield increase over conventional method (%)
$T_1 \times M_1$	100.8	17.23	1.97	14.00	11.51	–1.20
$T_1 \times M_2$	101.8	22.37	2.20	14.38	14.89	27.81
$T_1 \times M_3$	100.2	21.97	2.30	15.12	14.17	21.63
$T_1 \times M_4$	71.6	12.57	1.20	12.66	7.45	–36.05
$T_2 \times M_1$	98.1	17.60	2.03	13.92	11.65	–
$T_2 \times M_2$	109.1	21.53	2.27	15.17	14.97	28.50
$T_2 \times M_3$	114.4	22.30	2.43	15.62	14.70	26.18
$T_2 \times M_4$	75.0	12.83	1.40	13.06	7.99	–31.42
$T_3 \times M_1$	103.9	17.97	2.00	14.20	12.49	7.21
$T_3 \times M_2$	106.1	21.37	2.37	15.27	15.03	29.01
$T_3 \times M_3$	106.9	23.53	2.40	15.83	15.21	30.56
$T_3 \times M_4$	81.7	15.13	1.60	13.38	8.05	–30.90
CV (%)	9.64	10.91	10.15	3.51	12.00	
Significance level	NS	NS	NS	NS	NS	

Note: T_1 = minimum tillage (0–4 cm), T_2 = conventional tillage (10–12 cm), T_3 = deep tillage (20–22 cm), M_1 = 100% STB ($N_{100}P_{18}K_{49}S_{12}Zn_{1.75}B_{0.60}$ kg ha^{-1}) all from chemical fertilizer, M_2 = 125% STB ($N_{125}P_{22.5}K_{61}S_{15}Zn_{2.19}B_{0.75}$ kg ha^{-1}) all from chemical fertilizer, M_3 = 100% STB (75% from chemical fertilizer $N_{75}P_{13.5}K_{37}S_9Zn_{1.31}B_{0.45}$ kg ha^{-1} + 25% from compost (4.3 t ha^{-1})), M_4 = native fertility (control), CV = coefficient of variation, NS = non–significant

Functional Relationship

Yield components like plant height, fruits plant^{-1}, fruit length, branch plant^{-1} showed significant positive linear relationships with fruit yield of okra (Figure 1). A positive linear relationship was observed between plant heights with fruit yield (Figure 1A). The coefficient of determination (R^2) of the regression equation was 0.8939 ($P < 0.01$) indicating 89.39% variability in fruit yield could be explained by plant height. Similarly, fruits plant^{-1} showed a highly significant positive linear relationship ($R^2 = 0.9527$; $P < 0.01$) with yield, which revealed that fruit yield might be governed by fruits plant^{-1} by 95.27% (Figure 1B). Again, the relationship between length of fruit and fruit yield was highly significant ($R^2 = 0.8712$; $P < 0.01$). Thus, the contribution of fruit length to the fruit yield was attributable by 87.12% and implies its magnitude of strength in governing the fruit yield (Figure 1C). There was a positive linear relationship between branch plant^{-1} with fruit yield (Figure 1D).

This relationship suggests that with the increase of branch plant^{-1} the fruit yield increased linearly. The coefficient of determination of the regression equation, R^2 found to be 0.9407 which was highly significant. The result indicates that branch plant^{-1} might have governed the fruit yield by 94.07%. The magnitude of variability in fruit yield by the studied yield parameters followed the order of fruits plant^{-1}, branch plant^{-1}, plant height and fruit length. If there is a higher value of yield parameters there might be a better chance of getting a higher yield.

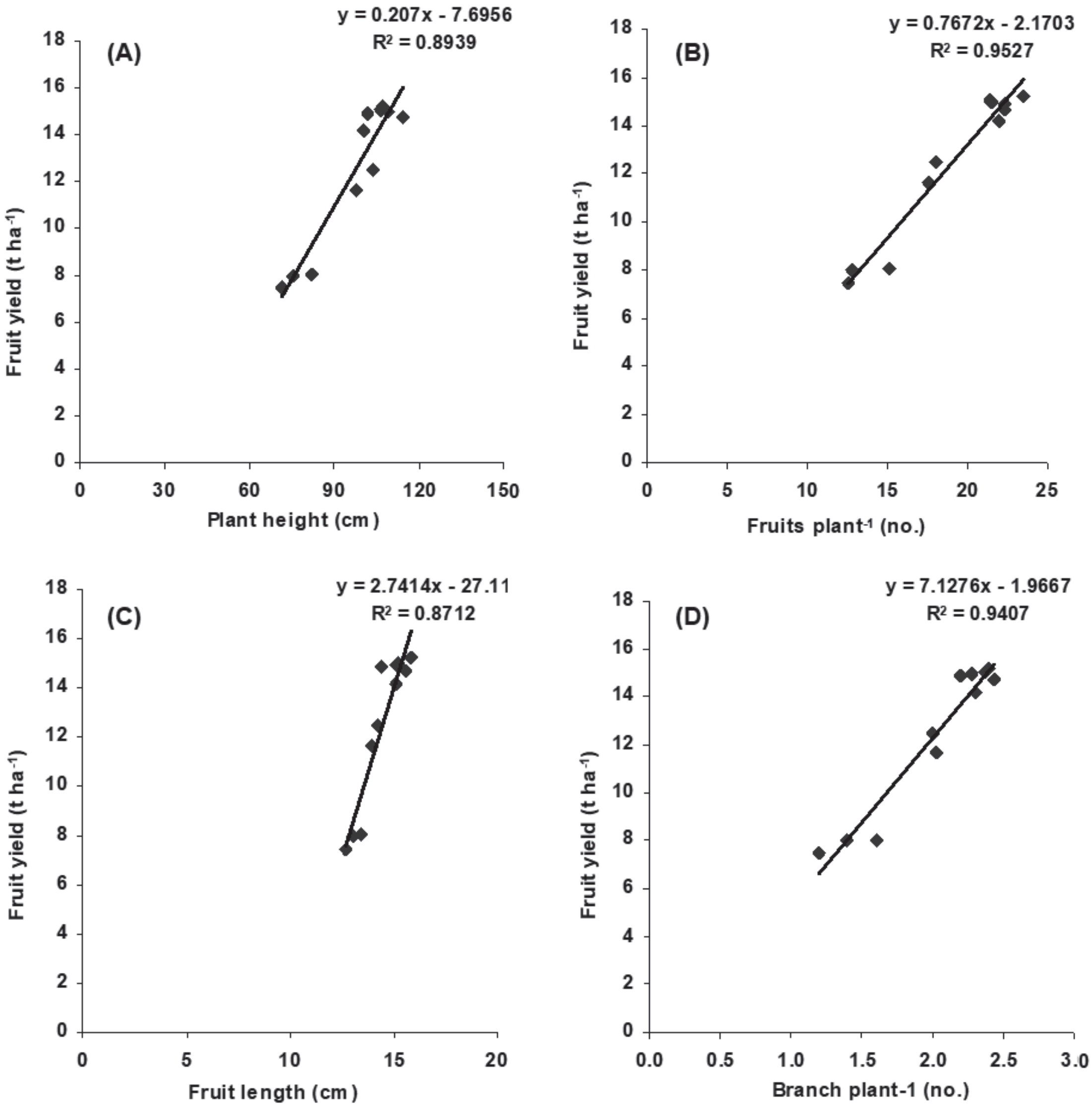

Figure 1 Relationship between fruit yield with plant height (A), fruits plant^{-1} (B), fruit length (C) and branch plant^{-1} (D) of okra

Cost and Return

The purpose of marginal analysis is to reveal how the net benefit from investment increases as the number of investment increases (Perrin *et al*., 1979). However, the cost and return analysis for okra cultivation are given in Table 5 and Table 6. The result showed that the gross return was highest (304,200 Taka ha^{-1}) for the treatment $T_3 \times M_3$ along with the highest gross margin (190,081 Taka ha^{-1}). The same treatment also showed the highest BCR (1.67) although which was equal to $T_1 \times M_2$ and almost similar to $T_2 \times M_2$ (1.64) and $T_2 \times M_3$ (1.65). Thus, the manure treated plot where 25% less chemical fertilizer was used gave better economic performance irrespective of tillage depth. Although deeper tillage showed slightly higher economic return when it matched with manure treated one, but in the long run, reduced tillage with integrated use of inorganic of fertilizer and organic manure may result in higher economic profitability and better soil health due to continuous IPNS based management practice over the years.

Table 5 Input and output price for okra cultivation

Input	Cost (Taka ha^{-1})	Output	Cost (Taka kg^{-1})
a) Variable cost			
Minimum tillage (T_1)	5,000	Edible fruit yield of okra	20
Conventional tillage (T_2)	7,000		
Deep tillage	10,000		
Fertilizer for M_1	9,282*		
Fertilizer for M_2	11,596		
Fertilizer for M_3	6,969		
Manure for M_3	2,150		
b) Fixed cost			
Labour wages	80,000**		
Irrigation	6,000		
Pesticide	4,000		
Seed	5,000		

Note: M_1 = 100% STB ($N_{100}P_{18}K_{49}S_{12}Zn_{1.75}B_{0.60}$ kg ha^{-1}) all from chemical fertilizer, M_2 = 125% STB ($N_{125}P_{22.5}K_{61}S_{15}Zn_{2.19}B_{0.75}$ kg ha^{-1}) all from chemical fertilizer, M_3 = 100% STB (75% from chemical fertilizer $N_{75}P_{13.5}K_{37}S_9Zn_{1.31}B_{0.45}$ kg ha^{-1} + 25% from compost (4.3 t ha^{-1})), * Fertilizer price (Taka kg^{-1}): urea = 17, TSP = 24, MoP = 16, gypsum = 10, zinc sulphate = 120, boric acid = 150, compost = 0.50, **Taka 400 $head^{-1}$ day^{-1}

Table 6 Cost and return for okra cultivation as influence by tillage and nutrient management interaction

Treatment	Fixed cost (Taka ha^{-1})	Variable cost (Taka ha^{-1})	Total cost (Taka ha^{-1})	Gross return (Taka ha^{-1})	Gross margin (Taka ha^{-1})	BCR
$T_1 \times M_1$	95,000	14,282	109,282	230,200	120,918	1.11
$T_1 \times M_2$	95,000	16,596	111,596	297,800	186,204	1.67
$T_1 \times M_3$	95,000	14,119	109,119	283,400	174,281	1.60
$T_1 \times M_4$	95,000	5,000	100,000	149,000	49,000	0.49
$T_2 \times M_1$	95,000	16,282	111,282	233,000	121,718	1.09
$T_2 \times M_2$	95,000	18,596	113,596	299,400	185,804	1.64
$T_2 \times M_3$	95,000	16,119	111,119	294,000	182,881	1.65
$T_2 \times M_4$	95,000	7,000	102,000	159,800	57,800	0.57
$T_3 \times M_1$	95,000	19,282	114,282	249,800	135,518	1.19
$T_3 \times M_2$	95,000	21,596	116,596	300,600	184,004	1.58
$T_3 \times M_3$	95,000	19,119	114,119	304,200	190,081	1.67
$T_3 \times M_4$	95,000	10,000	105,000	161,000	56,000	0.53

Note: T_1 = minimum tillage (0–4 cm), T_2 = conventional tillage (10–12 cm), T_3 = deep tillage (20–22 cm), M_1 = 100% STB ($N_{100}P_{18}K_{49}S_{12}Zn_{1.75}B_{0.60}$ kg ha^{-1}) all from chemical fertilizer, M_2 = 125% STB ($N_{125}P_{22.5}K_{61}S_{15}Zn_{2.19}B_{0.75}$ kg ha^{-1}) all from chemical fertilizer, M_3 = 100% STB (75% from chemical fertilizer $N_{75}P_{13.5}K_{37}S_9Zn_{1.31}B_{0.45}$ kg ha^{-1} + 25% from compost (4.3 t ha^{-1})), M_4 = native fertility (control), BCR = benefit cost ratio

CONCLUSIONS

Present fertilizer recommendations for okra should be updated by increasing 25% more nutrients. Thus, a package of $N_{125}P_{22.5}K_{61}S_{15}Zn_{2.19}B_{0.75}$ kg ha^{-1} may be recommended for the cultivation of okra for the Grey Terrace Soil at Gazipur (AEZ–28) or soil alike. The same treatment also produced a higher economic return. Reduced tillage appeared to be profitable for its lower cost and lesser soil intervention for better health. Therefore, for eco-friendly agriculture, IPNS package formulated with 75% nutrient needs from chemical fertilizers ($N_{75}P_{13.5}K_{37}S_9Zn_{1.31}B_{0.45}$ kg ha^{-1}) and rest 25% from compost (4.3 t ha^{-1}) in conjunction with medium depth tillage (10–12 cm) would be the best option in bringing sustainable yield and better soil health.

REFERENCES

Bouyoucos, G.J. 1962. Hydrometer method improved for making particle size analysis of soils. Agron. J. 54: 464–465.

Bray, R.H. and L.T. Kurtz. 1945. Determination of total, organic and available forms of phosphorus in soils. Soil Sci. 59: 39–45.

Bremner, J.M. and C.S. Mulvaney. 1982. Nitrogen–total, pp. 595–624. *In*: A.L. Page, (Ed.), Methods of Soil Analysis, Part II. Chemical and Microbiological Properties. Amer. Soc. Agron., Inc., Madison, Wisconsin, USA.

Chaterjee, G.P., U. Thapa and P. Tripathy. 2005. Effect of organic nutrition in sprouting broccoli (*Brassica oleracea* L. var. Italica Plenck). Veg. Sci. 32(1): 51–54.

Dean, B.B. 1994. Cultivation, fertilization, and irrigation, pp. 69–83. *In*: Managing the Potato Production System. Haworth Press, Inc., New York, USA.

Dillon, J.L. and J.B. Hardaker. 1993. Farm Management Research for Small Farmer Development. Food and Agriculture Organization of the United Nations, Rome, Italy.

FRG (Fertilizer Recommendation Guide). 2012. Fertilizer Recommendation Guide. Bangladesh Agricultural Research Council, Farmgate, Dhaka, Bangladesh.

Gayathri, K. and P.S.S. Reddy. 2013. Effect of integrated nutrient management on the growth and yield of okra (*Abelmoschus esculentus* (L.) Moench) cv. Arka Anamika. Veg. Sci. 40(2): 246–248.

Lang, N.S., R.G. Stevens, R.G. Thornton, W.L. Pan and S. Victory. 1999. Potato Nutrient Management Guide for Central Washington. Bulletin no. 1871. Washington State University Extension, Pullman, Washington.

Mal, B., P. Mahapatra and S. Mohanty. 2014. Effect of diazotrophs and chemical fertilizers on production and economics of Okra (*Abelmoschus esculentus*, L.) Cultivars. Am. J. Plant Sci. 5: 168–174.

Mc Lean, E.O. 1982. Soil pH and lime requirement, pp. 199–224. *In*: A.L. Page, (Ed.), Methods of Soil Analysis, Part II. Chemical and Microbiological Properties. Amer. Soc. Agron., Inc., Madison, Wisconsin, USA.

Naidu, A.K., S.S. Kushwah and Y.C. Dwivedi. 2000. Performance of organic manures, bio and chemical fertilizers and their combinations on microbial population of soil, growth and yield of okra. JNKVV Res. J. 33: 34–38.

Nelson, D.W. and L.E. Sommers. 1996. Total carbon and organic matter, pp. 961–1010. *In*: D.L. Sparks, A.L. Page, P.A. Helmke and R.H. Loeppert, (Eds.), Methods of Soil Analysis, Part III. Chemical Method. Amer. Soc. Agron., Inc., Madison, Wisconsin, USA.

Noor, S., N.C. Shil, M.A. Haque and A.T.M. Farid. 2007. Integrated nutrient management for broccoli-okra cropping sequence. J. Asiat. Soc. Bangladesh. Sci. 33(1): 85–94.

Omotoso, S.O. and O.S. Shittu. 2007. Effect of NPK fertilizer rates and method of application on growth and yield of okra (*Abelmoschus esculentus*, L. Moench.). Res. J. Agron. 1(2): 84–87.

Perrin, R.K., D.L. Winkelmann, E.R. Moscardi and J.R. Anderson. 1979. From Agronomic Data to Farmers Recommendations: An Economic Training Manual. CIMMYT, Mexico.

Premsekhar, M. and V. Rajashree. 2009. Influence of organic manures on growth, yield and quality of okra. Am.–Eurasian. J. Sustain. Agric. 3(1): 6–8.

Shil, N.C., M.A. Rahman, A.T.M.A.I. Mondol, M.J. Alam and R.A. Begum. 2015. Effects of tillage methods and residue management on soil properties and yield of potato–maize–T. aman rice cropping pattern, pp. 9–17. *In*: Annual Research Report 2014–2015. Division of Soil Science, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh.

Singh, A., J. Sharma, K.H. Rexer and A. Varma. 2000. Plant productivity determinants beyond minerals, water and light: *Piriformospora indica* – a revolutionary plant growth promoting fungus. Curr. Sci. 79(11): 1548–1554.

Sultana, M.S. 2002. Effect of nitrogen, phosphorus, potassium, sulphur and boron on okra. M.S. Thesis. Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur, Bangladesh.

Tabatabai, M.A. 1982. Sulfur, pp. 501–538. *In*: A.L. Page, (Ed.), Methods of Soil Analysis, Part II. Chemical and Microbiological Properties. Amer. Soc. Agron., Inc., Madison, Wisconsin, USA.

Tan, K.H. 1996. Soil Sampling, Preparation and Analysis. Marcel Dekker, Inc., New York, USA.

Thomas, G.W. 1982. Exchangeable cations, pp. 159–164. *In*: A.L. Page, (Ed.), Methods of Soil Analysis, Part II. Chemical and Microbiological Properties. Amer. Soc. Agron., Inc., Madison, Wisconsin, USA.

Zugec, I. 1986. The effect of reduced soil tillage on maize (*Zea mays* L.) grain yield in Eastern Croatia (Yugoslavia). Soil Till. Res. 7: 19–28.