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Influence of Micronutrients and Manures on Growth and Yield of Garlic (*Allium sativum* L.) in Sandy Loam Soil

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Authors' contributions

This work was carried out in collaboration between all authors. Author MMAM designed the study, wrote the protocol, managed the experimental process, performed statistically analyses and wrote the first draft of the manuscript. Author MBA collected the related review and wrote the reference part of the manuscript. Author MHR wrote the part of partial budget analysis in the manuscript. Author ABP did linguistic corrections of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Proper nutrient management is very important for increase yield of field crops in any type of soil. Field experiments were conducted under sub-tropical condition of Bangladesh for two consecutive years to study the response of garlic cv. Multiclove local to different combination of boron (B), zinc (Zn), cowdung (CD), chicken manure (CM) and mustard oil cake (OC) in the sandy loam soil. The treatments consisted of 12 combinations with B, Zn, CD, CM and OC. Application of boron had tremendous effect on growth and yield but Zn had no significant influence on growth and yield in garlic. OC added fertilizer combination showed the best performances regarding yield and yield

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attributes. CM added fertilizer combination had the second highest yield performance and showed non-significant difference with OC added fertilizer combination in garlic. Application of OC is not beneficial due to 30 times higher price than CD and CM. CM added fertilizer combination showed higher bulb yield with the higher economic return than CD added fertilizer combination. CM added fertilizer combination also had almost equal investment and cost-benefit ratio in comparison with CD. The lowest marginal benefit-cost ratio was observed in OC added fertilizer combination though it showed higher bulb yield as well as economic benefit. Based on marginal rate of return, the marginal farmers' may be advised to follow NPKSB + CD fertilizer combination. The farmers having ability to invest more, may go to the treatment of NPKSBZn + CM or NPKSBZn + OC for maximum economic benefit and also sustainable soil health in sandy loam soil.

Keywords: Garlic; cow dung; chicken manure; mustard oil cake, zinc; boron; yield.

1. INTRODUCTION

Garlic (*Allium sativum* L.) is very popular all over the world as spice and also for its medicinal properties [1]. In Asia, garlic has been an integral part of the people's daily diet and its use is very common in almost all food preparations [2,3]. The yield is very low (3.01 t ha^{-1}) in Bangladesh as compared to the world average yield of 9.67 t ha^{-1} [4]. Reasons for the low yield of garlic are mainly due to depletion of macro and micro-nutrients from the soil, use of low yielding varieties with low or no inputs and poor management practices. Due to shortage of land, we have no scope to extent cultivation area of garlic. The per hectare yield of garlic can be increased by efficient use of manures and fertilizers. Therefore, in order to increase yield of local cultivars, different practices along with proper manuring and fertilization can play a vital role in this aspect.

Both manures and fertilizers enhance the growth and yield of garlic to a great extent. The effect of organic manure on garlic is crucial as it is a heavy feeder. Manures supply all essential nutrients as well as improve physical, chemical and biological properties of soil [5] and may help boost the production of garlic to peasant farmers. Organic manure also improves soil structure through aggregation favourably influencing tillage properties, crusting, water infiltration, moisture retention, aeration, temperature and root penetration. Moreover, organic manures do not create any health hazards and environmental pollution. But in Bangladesh, most soils have less than 1.5%, and some even less than 1% organic matter contents [6]. Now a day's gradual deficiency in soil organic matter and reduced yield of crop are an alarming factor and burning issue for the farmers and agriculturists. So, to check soil health hazard and environmental pollution, the use of organic fertilizers should be encouraged. Previously in several studies, the effects of integrated use of organic-inorganic nitrogen on yield and quality of garlic were investigated. Researchers have found that addition of animal manure resulted in higher garlic yield compared to sole application of inorganic NPK fertilizer [3,6,7]. In Bangladesh, the organic fertilizers like cowdung and chicken manure are available due to increasing dairy and poultry farm. On the other hand, the price of oil cake is very high (30 times higher) comparable to cowdung and chicken manure. The experimental evidences on the effects of different organic manure on garlic are limited under Bangladesh conditions.

Judicial application of organic and inorganic fertilizers is important for the production of garlic. Farmers of Bangladesh are mostly habituated with the use of macro-nutrients, especially nitrogen, phosphorus, sulphur and potassium for crop production. But the use of micro-nutrients is limited. Most of the researches on nutrition of garlic limit the recommendation for major nutrients like N, P and K but micronutrients also play a vital role in driving the growth and development of plants. Among the micronutrients, boron is one of the most important micro-nutrients, although it is required in very small quantity [8]. Boron has an effect on cell wall structure and also has a major effect on cell elongation and root growth [9,10]. The nutrient is also important in cell division, nitrogen and carbohydrate metabolism and water relation in plant growth [11,12,13]. Among micronutrient elements, zinc and boron have important role on pollination, fruit set and total yield [14,15]. Zinc is known to have an important role either as a metal component of enzymes or as a functional, structural or regulatory factor of a large number of enzymes [10,15]. Significant effects were noticed on yield and yield attributes of garlic when micronutrients were used [12,13]. Application of boron can increase bulb size, number of cloves/bulb and yield of onion and

garlic [9,16]. Response of garlic to zinc application is also evident [16,17]. In addition, integration of organic manure with N, P, K, S, Zn, and B can increase the efficiency of chemical fertilizers and also improve the soil condition for the production of crops [2,17]. However, information on the use of poultry and oil cake manures in combination with inorganic fertilizers for garlic is scanty in Bangladesh. Moreover, despite the ranking of garlic as one of the most important medicinal crops in the world, the present production level do not meet the demand of the teeming population and there's virtually little literature available in Bangladesh with reference to the effects of sole organic manure on the growth and yield of garlic. Therefore, an attempt was made to study the response of garlic to manures (cowdung, chicken manure and oil cake) and micronutrients (zinc and boron) in presence of N, P, K, and S in Gangachara soil series of Tista Mean Floodplain, Bangladesh.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The experiment was conducted at the Sub-station farm of Bangladesh Institute of Nuclear Agriculture (BINA), Rangpur during December to April of 2010-2011 and 2011-2012. The soil was sandy loam belonging to the Gangachara series of Tista Meander Floodplain, Bangladesh. Some physical and chemical properties of the experimental soil collected from a depth of 0-15 cm prior to the application of fertilizer were analyzed. Chemical characteristics of the collected soil were determined by Hunter method [18]. The soil was slightly acidic (pH 6.3), low in fertility status having organic matter 0.90%, available NH_4-N 65 µg g^{-1}, phosphorus 18 µg g^{-1}, potassium 0.15 meq100g^{-1}, available sulphur 10 µg g^{-1}, boron 0.16 µg $g^{-1}$and zinc 1.6 µg g^{-1}.

2.2 Experimental Design and Treatments

Experiment was laid out in randomized complete block design with three replicates. The unit plot size was 2 m × 2 m with plant spacing of 15 cm × 15 cm. The treatments consisted of 12 combinations with B, Zn, CD (cow dung), CM (chicken manure) and OC (mustard oil cake) in the form of borux, zinc sulphate, cowdung, chicken manure and oil cake at the rate of 19, 9, 5000, 5000 and 5000 kg ha^{-1}, respectively [4]. The macronutrients, N, P, K and S were applied each plot in the form of urea, triple super phosphate (TSP), muriate of potash (MP) and gypsum at the rate of 220, 210, 240 and 110 kg ha^{-1}, respectively. The whole amount of TSP, MP, gypsum, borux, zinc sulphate, CD, CM, OC and one third urea were applied as basal dose during final land preparation three days before clove planting. The remaining urea was applied as top dressing in two equal instalments in the third and sixth weeks after planting followed by irrigation. The fertilizer combinations were: NPKS (Control), NPKS+CD, NPKS+CM, NPKS+OC, NPKSZn+CD, NPKSZn+CM, NPKSZn+OC, NPKSB+CD, NPKSB+CM, NPKSB+OC, NPKSBZn+CD, NPKSBZn+CM and NPKSBZn+OC. It is noted that cowdung contain 0.77% N, 0.44% P_2O_5 and 0.46% K_2O, chicken manure contain 1.15% N, 1.19% P_2O_5 and 0.85% K_2O and mustard oil cake manure contain 5.07% N, 1.77% P_2O_5 and 1.25% K_2O. The cost of fertilizer and gross return were calculated considering the following rates of fertilizer: Taka (Tk) 16.00 kg^{-1} urea, Tk. 22.00 kg^{-1} TSP, Tk. 15.00 kg^{-1} MP, Tk. 12.00 kg^{-1} gypsum, Tk. 300.00 kg^{-1} ZnSO4, Tk. 280.00 kg^{-1} borux, Tk. 0.60 kg^{-1} CD, Tk. 1.00 kg^{-1} CM and Tk. 30 kg^{-1} OC. The bulb of garlic rate was Tk. 70.00 kg^{-1}.

2.3 Intercultural Operations and Data Collections

The cloves of Multiclove local variety were planted on December 8 and harvested on April 10 in both cropping years. Intercultural operations such as irrigation, weeding, mulching etc were done as when necessary for normal plant growth and development. At harvest, fifteen plants were randomly selected per plot for recording data of plant parameters and yield components. The whole plot was harvested for bulb yield.

2.4 Statistical Analyses

The collected data were analyzed statistically using computer package program, MSTAT-C. Partial budget analysis and marginal analysis of undominated fertilizer response to bulb yield on average of two years were done following Elias and Karim [19].

3. RESULTS AND DISCUSSION

3.1 Morphological Parameters

Results indicated that all the micronutrients and manures increased plant height, pseudostem diameter, leaf number, leaf length and leaf fresh weight of both years (Table 1). The taller plant,

the higher number of leaf production, leaf length and fresh leaf weight were recorded in NPKSBZn+CM and NPKSBZn+OC applied plant with being the highest in NPKSBZn+OC. The lowest morphological parameters were obtained from plants in the control (NPKS) plots. In general, chicken manure and oil cake added fertilizer combinations always showed high growth performance than cowdung added fertilizer combinations. The higher growth performance of garlic plants in CM and OC amended soil because of greater nutrients content (N, P, K) in CM and OC than cowdung. Similar result was also reported by Kabir et al. [20] in garlic. Results further indicated that B treated plots had significant improvement of plant growth and development with Zn amended plots having less influence on plant growth and development in sandy loam soil. Many researchers [10,16,17] reported that application of boron increase plant height, clove number and size in garlic that supported the present results.

Table 1. Effect of micronutrients and manures on plant height and pseudoastem thickness of garlicconducted at BINA farm, Rangpur during the seasons of 2010-11 and 2011-12

Treatments	Plant height (cm)			Pseudostem diameter (cm)	Leaf length (cm)	Leaves plant^{-1} (no)	Fresh weight leaf^{-1} (g)
	2010-11	2011-12	Mean	2010-11	2010-11	2010-11	2010-11
NPKS (Control)	43.5 e	42.6 e	43.1 f	0.86 b	30.0 g	7.27 d	1.15 g
NPKS + CD	55.5 d	42.8 e	49.2 e	0.83 b	32.3 f	7.83 c	1.78 f
NPKS + CM	55.5 d	47.6 cd	51.6 d	0.82 b	34.4 e	8.37 b	2.20 e
NPKS + OC	60.4 c	48.0 cd	54.2 c	0.87 b	35.1 de	8.77 a	2.59 d
NPKSZn + CD	62.4 b	43.0 e	52.7cd	0.79 b	34.6 e	8.60 b	2.30 e
NPKSZn + CM	54.7 d	52.2 ab	53.5 c	0.84 b	34.2 e	8.47 b	1.92 f
NPKSZn + OC	54.5 d	48.9 bc	51.7 d	0.84 b	36.3 c	8.63 ab	1.82 f
NPKSB + CD	63.7 b	46.0 d	54.9 c	0.87 b	37.0 bc	8.90 a	3.20 b
NPKSB + CM	62.7 b	49.0 bc	55.8bc	0.96 a	35.7 d	8.63 ab	3.30 b
NPKSB + OC	62.4 b	50.0 b	56.2 b	0.98 a	37.9 b	8.90 a	2.93 c
NPKSBZn + CD	62.8 b	48.1 c	55.4bc	0.87 b	35.9 cd	8.77 ab	2.58 d
NPKSBZn + CM	65.9 a	52.8 a	59.4 a	0.97 a	38.5 ab	8.83 a	3.25 b
NPKSBZn + OC	68.3 a	52.4 a	60.3 a	1.00 a	40.6 a	9.17 a	3.68 a
F-test	**	**	**	*	**	**	**
CV (%)	4.52	4.18	4.35	4.69	3.88	5.86	4.88

*In a column, same letter (s) indicates do not differ significantly at P ≤0.05; *, ** indicate significant at 5% and 1% levels of probability, respectively*

Table 2. Effect of micronutrients and manures on bulb diameter and cloves production bulb^{-1}of garlic conducted at BINA farm, Rangpur during the seasons of 2010-11 and 2011-12

Treatments	Bulb diameter (cm)			Cloves bulb^{-1} (no)		
	2010-11	2011-12	Mean	2010-11	2011-12	Mean
NPKS (Control)	3.06 e	3.42 b	3.24 c	18.9 e	21.6 b	20.3 d
NPKS + CD	3.42 d	3.53 ab	3.48 b	21.6 c	22.9 ab	22.3bc
NPKS + CM	3.51 cd	3.75 a	3.63 a	19.2 de	22.1 b	20.2 d
NPKS + OC	3.81 a	3.50 a	3.66 a	25.4 a	22.5 ab	24.0 a
NPKSZn + CD	3.57 bc	3.40 b	3.48 b	21.7 c	22.2 ab	22.0 bc
NPKSZn + CM	3.59 b	3.57 a	3.58 ab	20.3 d	22.5 ab	21.4 cd
NPKSZn + OC	3.61 b	3.33 b	3.47 b	26.0 a	22.3 ab	24.2 a
NPKSB + CD	3.71 ab	3.36 b	3.54 ab	24.0 ab	21.2 b	22.6 b
NPKSB + CM	3.49 d	3.73 a	3.61 ab	24.2 ab	22.6 a	23.4 ab
NPKSB + OC	3.73 ab	3.60 a	3.67 ab	23.3 b	21.7 b	22.5 b
NPKSBZn + CD	3.74 ab	3.41 b	3.58 ab	23.6 b	21.6 b	22.6 b
NPKSBZn + CM	3.87 a	3.59 ab	3.73 a	23.5 b	21.8 b	22.7 b
NPKSBZn + OC	3.97 a	3.71 a	3.84 a	23.9 ab	23.3 a	23.6 ab
F-test	**	*	**	**	*	**
CV (%)	4.32	3.99	4.15	6.17	5.74	5.45

*In a column, same letter (s) indicates do not differ significantly at P ≤0.05; *, ** indicate significant at 5% and 1% levels of probability, respectively*

3.2 Yield Attributes and Yield

Bulb diameter, number of cloves bulb^{-1}, clove size and bulb yield increased significantly over control by applying different combination of micronutrients, boron and zinc, and manures, cowdung, chicken manure and mustard oil cake (Tables 2 and 3). Among the manures added plots, OC showed better performance on yield attributes and bulb yield in garlic but showed no significant difference with the plants of CM added plots. The highest number of cloves bulb^{-1} (23.6 bulb^{-1}) in both years was observed in NPKSBZn+OC followed by NPKSB+CM (23.4 bulb^{-1}) with same statistical rank. In contrast, the lowest number of cloves bulb^{-1} was recorded in control plots. Similar result was also observed in case of bulb size (Table 3). In general, the plants of CM and OC added plots performed better in case of yield attributes than CD added plots. Application of Zn without B had no significant influence on yield and yield related traits in garlic (Fig. 1). On the other hand, application of B had tremendous positive effect on garlic yield.

The higher bulb yield was observed in CM and OC added plots in presence of B. Among the B added combinations, NPKSBZn+OC performed the highest bulb yield (6.88 t ha^{-1}) followed by NPKSBZn+CM (6.45 t ha^{-1}) with same statistical rank. The bulb yield was higher in boron added OC combination or boron added CM combination might be due to increase number of cloves bulb^{-1} and increase clove size. This result is consistent with many studies which reported that application of boron along with OC or CM increased bulb yield in garlic [3,6,17]. On the other hand, there was similar effect between CM and CD on plant growth and yield in brinjal [21].

Table 3. Effect of micronutrients and manures on clove size and bulb yield of garlic conducted at BINA farm, Rangpur during the seasons of 2010-11 and 2011-12

Treatments	100-clove weight (g)			Bulb yield (t ha^{-1})			Yield increased over control (%)
	2010-11	2011-12	Mean	2010-11	2011-12	Mean	
NPKS (Control)	65.00 g	64.67 f	64.84 f	3.55 g	4.85 d	4.20 f	---
NPKS + CD	76.53 f	77.33 e	76.93 e	4.35ef	5.22bc	4.80e	14.3
NPKS + CM	82.10 e	85.00bc	83.55 d	4.47 e	5.53 b	5.00 d	19.0
NPKS + OC	83.90 e	81.67 d	82.78 d	6.13 c	5.28bc	5.71 c	36.0
NPKSZn + CD	85.67 e	76.00 d	80.83 d	4.53 f	4.96 cd	4.80 e	14.3
NPKSZn + CM	92.67 d	88.00b	90.33bc	5.35 d	5.26bc	5.30 cd	26.2
NPKSZn + OC	96.90 c	78.00 e	87.45 c	5.35 d	5.30bc	5.32 cd	26.7
NPKSB + CD	105.3 b	81.33 d	93.33 b	6.32 c	5.05 c	5.68 c	35.2
NPKSB + CM	112.0ab	101.7 a	106.8 a	6.08 c	5.93 a	6.01 b	43.1
NPKSB + OC	108.3 b	86.33bc	87.31 c	6.13 c	5.92 a	6.03 b	43.6
NPKSBZn + CD	94.57cd	83.00cd	88.79 c	6.13 c	5.36 b	5.75 c	27.6
NPKSBZn + CM	98.23 c	92.33 b	90.23bc	6.93 b	5.97 a	6.45 ab	53.6
NPKSBZn + OC	116.0 a	100.7 a	108.3 a	7.66 a	6.10 a	6.88 a	63.8
F-test	**	**	**	**	**	**	
CV (%)	7.82	6.55	6.68	8.44	7.92	8.18	

*In a column, same letter (s) indicates do not differ significantly at P ≤0.05;** indicate significant at 1% levels of probability*

Table 4. Pooled effect of cowdung, chicken manure and oil cake on morphological characters of garlic along with chemical fertilizer combinations averaged over two years

Manures	Plant height (cm)	Pseudostem diameter (cm)	Leaves plant^{-1} (no)	Leaf length (cm)	Leaf fresh weight (g leaf^{-1})
Control	43.6 b	0.86 b	7.27 b	30.0 c	1.25 c
Cowdung	53.1 a	0.83 b	8.53 a	35.0 b	2.47 b
Chicken manure	55.0 a	0.91 a	8.58 a	35.7 ab	2.67 a
Oil cake	55.6 a	0.92 a	8.87 a	37.5 a	2.75 a

In a column, same letter (s) indicates do not differ significantly at P ≤0.05

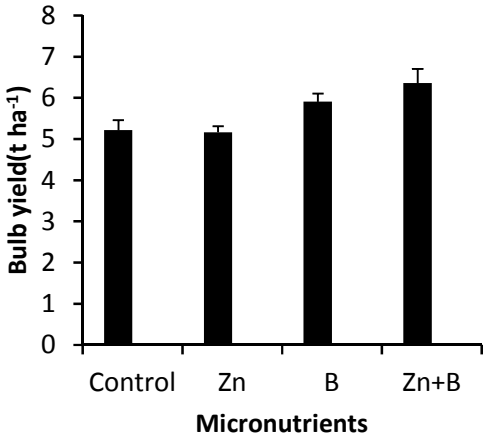

Fig. 1. Effect of Zn and B on bulb yield in garlic

3.3 Effect of Manures on Morphological Yield Attributes of Garlic

Considering the pooled effect of CD, CM and OC on morphological characters and yield attributes, results showed that the morphological characters such as plant height, pseudostem diameter, number of leaves plant^{-1}, leaf length, and yield attributes such as number of cloves bulb^{-1}, bulb diameter, 100-clove weight and bulb yield were greater in the plants of CM and OC added plots than CD added plots (Tables 4 and 5). Among CM and OC, the morphological characters, yield attributes and bulb yield was higher in the plants of OC added plots than CM added plots with non-significant different among each other. However, application of OC is not beneficial due to 15 time's high price than CD and CM. A researcher reported fruit yield of brinjal was superior in CM and OC amendment plants than CD amendment plants [21] that supported the present experimental results.

3.4 Partial Budget Analysis

It was observed that application of different combination of B, Zn, CD, CM and OC had positive effect on economic return over control (Table 6). Considering the effect between B and Zn, B added plots showed higher benefit as compared to Zn added plots due to greater yield performance of garlic in B than in Zn. Amongst B added nutrient combinations, NPKSBZn + OC had the highest benefit over control (164,580 Tk. ha^{-1}) followed by NPKSBZn + CM (144,480 Tk. ha^{-1}). Similarly, in general, CM added plots had higher benefit than CD and OC added plots. Marginal benefit-cost ratio was also highest in CM added plots which was apparently similar to CD added plots. The lowest marginal benefit-cost ratio was observed in OC added fertilizer combination though it showed higher bulb yield as well as economic benefit.

Marginal analysis of undominated fertilizer response data recorded the highest marginal rate of return (16.03%) in NPKSB + CD fertilizer added plots followed by NPKD + CD fertilizer added plots (13.00%). The third highest marginal rate of return was recorded in NPKSB + CM fertilizer added plots (10.55%). The lowest marginal rate of return was recorded in NPKSBZn + OC fertilizer added plots (2.01%). Based on marginal rate of return, it may be concluded that for garlic cultivation under sandy loam soil, the marginal farmers' may be advised to follow NPKSB + CD fertilizer combination. The farmers having ability to invest more may go to the treatment of NPKSBZn + CM or NPKSBZn + OC for maximum economic benefit and also sustainable soil health.

Table 5. Pooled effect of cowdung, chicken manure and oil cake on yield attributes and bulb yield of garlic along with chemical fertilizer combinations averaged over two years

Manures	Cloves bulb^{-1} (no)	Bulb diameter (cm)	100-clove weight (g)	Bulb yield (t ha^{-1})	Bulb yield increased over control (%)
Control	20.3 b	3.19 c	61.3 c	4.20 d	---
Cowdung	22.1 a	3.50 b	83.3 b	5.24 c	24.8
Chicken manure	21.9 a	3.64 a	93.4 a	5.72 ab	36.2 (9.2)
Oil cake	23.3 a	3.66 a	93.0 a	5.95 a	41.7 (13.5)

In a column, same letter (s) indicates do not differ significantly at P ≤0.05; Figures in parenthesis indicate % increase bulb yield over cowdung

Table 6. Partial budget analysis for fertilizers and manures use of bulb yield of garlic (average over two years)

Treatments	Economic yield (t ha^{-1})	Gross margin profit (Tk. ha^{-1})	Variable cost (Tk. ha^{-1})	Net margin benefit (Tk. ha^{-1})	Marginal net margin benefit (Tk. ha^{-1})	Marginal benefit-cost ratio
NPKS(Control)	4.20	294,000	13,060	280,940	---	21.51
NPKS + CD	4.80	336,000	16,060	319,940	39,000	19.92
NPKS + CM	5.00	350,000	18,060	331,940	51,000	18.38
NPKS + OC	5.71	399,700	28,060	371,640	90,700	13.24
NPKSZn + CD	4.80	336,000	18,760	317,240	36,300	16.91
NPKSZn + CM	5.30	371,000	20,760	350,240	69,300	16.87
NPKSZn + OC	5.32	372,400	30,760	341,640	60,700	11.11
NPKSB + CD	5.68	397,600	21,380	376,220	95,280	17.60
NPKSB + CM	6.01	420,700	23,380	397,320	116,380	16.99
NPKSB + OC	6.03	422,100	33,380	388,720	107,780	11.64
NPKSBZn + CD	5.75	402,500	24,080	378,420	97,480	15.72
NPKSBZn+ CM	6.45	451,500	26,080	425,420	144,480	16.31
NPKSBZn + OC	6.88	481,600	36,080	445,520	164,580	12.35

Table 7. Marginal analysis of undominated fertilizers response to bulb yield of garlic (average of two years)

Treatments	Net margin benefit (Tk. ha^{-1})	Variable cost (Tk. ha^{-1})	Marginal increase in net margin (Tk. ha^{-1})	Marginal increase in variable cost (Tk. ha^{-1})	Marginal rate of return (%)
NPKSBZn + OC	445,520	36,080	20,100	10,000	2.01
NPKSBZn + CM	425,420	26,080	28,100	2,700	10.41
NPKSB + CM	397,320	23,380	21,100	2,000	10.55
NPKSB + CD	376,220	21,380	25,980	1,620	16.03
NPKSZn + CM	350,240	20,760	18,300	2,700	6.78
NPKS + CM	331,940	18,060	12,000	2,000	6.00
NPKS + CD	319,940	16,060	39,000	3,000	13.00
NPKS (Control)	280,940	13,060	---	---	---

4. CONCLUSION

In sandy loam soil, application of boron along with chemical fertilizers and manures is beneficial for garlic cultivation. Mustard oil cake added fertilizer combination demonstrated the best performances regarding yield and yield attributes with the lowest marginal benefit-cost ratio. Based on marginal rate of return, the marginal farmers' may be advised to follow NPKSB + CD fertilizer combination. The farmers having ability to invest more may go to the treatment of NPKSBZn + CM or NPKSBZn + OC for maximum economic benefit and also sustainable soil health.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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