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Response of Ginger to Zinc and Boron Fertilization

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Abstract: A field study was conducted at Brown Hill Soils (Eutrochrepts) of South Eastern Hilly region at Hill Tracts Agricultural Research Station, Ramgarh, Khagrachari during the Kharif seasons of 2004-2005 and 2005-2006, respectively. The objective was to evaluate the response of ginger (cv. local) to B and Zn fertilization and to find out the optimum dose of Zn and B for maximizing yield of ginger in Hilly Region. Four levels of B (0.1, 2 and 3 kg ha^{-1}) and Zn (0, 1.5, 3.0 and 4.5 kg ha^{-1}) along with combined blanket dose of $N_{180}P_{50}K_{120}S_{20}$ and CD_5 t ha^{-1} were taken in the experiment to study. It is evident from studied data revealed that Zn either in single or in combination with B made significant effect on ginger production in micronutrient deficient soils. However boron produced 46.72% higher yield in first year and 89.92% higher yield in second year over boron control (Bo) whole calculated 23.72 and 52.26% higher yield than that of Zinc in two consecutive years. The integrated effect of B and Zn was found to be highly significant and markedly influenced the rhizome yields and other yield attributes of ginger. The boron (3 kg ha^{-1}) and zinc (4.5 kg ha^{-1}) individually produced rhizome yield 23.5 and 25.8 t h^{-1} and 20.4 and 22.3 t ha^{-1} in three consecutive years of 2004-2005 and 2005-2006, respectively. However, integration of Zn and B at the maximum level ($B_{3.0}$ $Mo_{4.5}$ kg ha^{-1}) significantly produced the highest ginger yield (25.5 and 26.8 t ha^{-1}) and 125 and 143% yield increase over Boron-Zinc control (B_o Zn_o) in two successive years of study. Similarly, the highest net economic return Tk.7, 52.030 and Tk. 804000 and the highest marginal rate of return (MRR) 484 and 548%, respectively were obtained with the application of B at the rate of 3 kg ha^{-1} and Zn at the rate of 4.5 kg ha^{-1} which was found to be economically profitable for ginger production in South-Eastern Hilly region

Key words: Ginger, boron, zinc, fertilization

INTRODUCTION

Ginger (*Zingiber officinale*) is a popular spice crop in Bangladesh. It is also an important cash crop of Chittagong Hill Tracts region. Spice like ginger is an integral part of daily culinary preparation for its aromatic pungency scent and tasty flavor. The tribal and hilly farmers usually plant ginger in hill slopes either in the form of shifting cultivation locally known as Jhum cultivation or in furrows after conventionally preparing the land with subsequent ridging. These methods are very much hazardous for soil erosion due to excessive torrential rain during monsoon months. Since most of the lands in this area are hilly and rugged topography. Zero tillage or minimum tillage system of cultivation could be best suited for this region as they minimize the soil erosion (Van Doran *et al*., 1977) to a tolerable limit. Ginger can be grown in wide range of soils. But it prefers to grow in light textured and well drained soils as it can not grow and sustain in water-logged condition. Besides, the hilly farmers usually do not use any chemical fertilizer to grow this spice crop. They just dibble the ginger seeds (rhizome) and harvest after maturity. It is evident that ginger and turmeric are highly responsive to chemical fertilizers. Roy *et al*. (1992) found in their report that micro-nutrients like Zn, Fe and B with increased rates progressively increased the growth and rhizome yield of ginger. Similar observations were also made by Babu *et al*. (1995), Banafar and Tiwari, (1995) and Sugtto and Matuchah (1993) in their findings and stated that with the addition of chemical fertilizers especially nitrogen and potassium remarkably increased the yield of ginger rhizome. It is also evidenced that micro-nutrients can play an important role in disease control and even increase the post harvest life (duration) of spice crop like ginger. Moreover, many spices producers in hilly region do not feel encouraged to grow this spice ginger due to incurring huge losses by disease incidence. In Bangladesh context, there had been a very limited and sporadic research done on spices production especially for ginger and turmeric. Hence, from above points of view, such a field study was undertaken to evaluate the response of ginger for different levels of zinc and boron for maximizing yield of finger at Brown Hill Soils of South Eastern Hilly region.

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MATERIALS AND METHODS

The field experiment was conducted at Brown Hill Soils (Eutrochrepts) of Hill Tracts Agricultural Research Station, Ramgarh, Khagrachari during Kharif seasons of 2001-2005 and 2005-2006 to find out the optimum dose of Zn and B for boosting ginger yield in hilly region. The experimental soil was found to be strongly acidic in nature and the organic matter including other nutrients element status was below critical levels. The physical and chemical properties of analyzed soil sample are presented in Table 1.

The field trials were laid out in randomized block design having replications thrice. The unit plot size and seed to seed distance were 4×5 m and 50×25 cm, respectively. There were sixteen treatment combinations comprising each of 4 levels of B (0, 1, 2 and 3 kg ha^{-1}) and 4 levels of Zn (0, 1.5, 3.0 and 4.5 kg ha^{-1}) along with blanket does of $N_{180}P_{50}K_{120}S_{20}$ and CD_5 t ha^{-1} were taken in study. Local rhizome (cv.) of ginger was used as a test crop. All PKSZnB and CD were applied as source of urea, TSP, MP, Gypsum, Boric Acid and Zinc Oxide during final land preparation. Nitrogen was applied around the plants in split at 80 and 110 days after planting rhizome seeds. Intercultural operations like mulching, weeding, earthing up etc were done as required by the experiment. The seeds were planted in first week of April, 2004 and 2005, respectively and harvested on mid February for both the years. Necessary data on different parameters were recorded from 10 randomly selected plants. The collected data on plant height, leaves number, number of fingers, finger size and weight and yield of ginger per plant were analyzed statistically and adjusted with Least Significant Difference (LSD) at 5% level of significance.

RESULTS AND DISCUSSION

Effect of boron: The significant influence on all the factors studied were made by applying boron over B control (B_o). Plant height, leaves number, fingers number,

Table 1: Nutrient status of experimental soil prior to fertilizer application

Chemical properties	pH	OM	Ca	Mg	K	Total N (%)	P	S	B	Cu	Fe	Mn	Zn
		----------	meq/100 g	----------			----------	----------	----------	μg g^{-1}	----------	----------	----------
Initial soil	4.5	0.90	1.2	0.5	0.09	0.056	3.0	11	0.23	3.8	200	12	1.2
Critical level	-	-	2.0	0.8	0.2	-	14.0	14.0	0.2	1.0	10.0	5.0	2.0

Source: Soil Science Laboratory, BARI

Table 2a: Main effects of boron and zinc on the yield and yield attributes of Ginger at HARS, ramgarh during 2004-2005

Boron level (kg ha^{-1})	Plant height (cm)	No. of leaves plant	No. of Fingers			Wt. of fingers/ plants (g)	Wt. of gingers/ plants (g)	Wt. of. Corm (g)	Finger Size		Ginger yield t ha^{-1}	%increasein yield over control
			Primary fingers	Secondary fingers	Tertiary fingers				Length (cm)	Diameter (cm)		
B_0	19.1d	9.0d	2.8d	3.7d	3.1d	157d	205d	24.7d	3.9d	5.6d	12.2d	-
B_1	33.4c	12.3c	3.2c	4.6c	3.5c	175c	326c	32.7c	4.3c	6.3c	14.4c	18.03
B_2	47.3b	14.5b	3.5b	5.16	3.76	202b	243b	35.1b	4.5b	6.96	17.8b	27.87
B_3	58.4a	17.2a	3.8a	6.7a	4.5a	244a	289a	38.6a	5.5a	7.6a	23.5a	46.72
LSD (0.05)	*	0.73	0.25	*	*	*	*	*	*	*	*	
Zn (kg ha^{-1})												
Zn_o	33.6d	12.0d	3.2d	4.6d	3.4	181d	226	30.3d	4.2d	6.2d	15.5d	-
$Zn_{1.5}$	38.6c	13.2c	3.3c	4.9c	3.6	191c	237	32.1c	4.6c	6.5c	15.6c	15.50
$Zn_{3.0}$	41.5b	13.4b	3.4b	5.1b	3.8	200b	242	33.6b	4.7b	6.8b	17.4b	13.3
$Zn_{4.5}$	44.6a	14.4a	3.6a	5.4a	3.9	207a	258	35.0a	4.8a	6.9a	20.4a	23.0
LSD (0.05)	*	0.73	0.25	*	*	*	*	*	*	*	*	

Table 2b: Main effects of Boron and Zinc on the yield and yield attributes of Ginger at HARS, Ramgarh during 2005-2006

Boron level (kg ha^{-1})	Plant height (cm)	No. of leaves Plant	No. of fingers			Wt. of fingers/ plants (g)	Wt. of. gingers/ plants (g)	Wt. of Corm (g)	Finger size		Grain yield (t ha^{-1})	%increasein yield over control
			Primary fingers	Secondary fingers	Tertiary fingers				Length (cm)	Diameter (cm)		
B_0	19.7d	9.2d	2.7d	3.2d	3.3d	158d	207d	25.0d	4.1d	5.7d	13.2	-
B_1	34.0c	13.3c	3.3c	3.6c	3.7c	179c	327c	34.1c	4.6c	6.6c	1457	18.94
B_2	48.1b	15.2b	3.7b	3.8b	4.0b	213b	247b	37.7b	4.6b	6.76	19.3	46.22
B_3	60.3a	17.3a	4.0a	4.7a	4.9a	252a	293a	41.0a	5.8a	8.0a	25.8	89.92
LSD (0.05)	*	0.70	*	*	*	*	*	*	*	*	*	
Zn (kg ha^{-1})												
Zn_o	27.3d	12.3d	3.3d	4.7d	3.5d	182d	225d	31.0d	4.2d	6.3d	16.2d	-
$Zn_{1.5}$	37.2c	14.0c	3.4c	5.0c	3.6c	192c	238c	33.2c	4.7c	6.6c	17.2c	6.17
$Zn_{3.0}$	49.2b	14.7b	3.6b	5.2b	3.7b	203b	244b	342b	4.8b	6.9b	18.2b	12.34
$Zn_{4.5}$	53.3a	15.0a	4.5a	5.6a	4.0a	209a	261a	36.3a	5.0a	7.3a	22.3a	27.66
LSD (0.05)	0.66	0.23	*	*	*	*	*	*	*	*	*	

finger size, finger weights and rhizome yield per plant significantly increased with the increase in B rates up to 3 kg B ha^{-1}. It is also evidenced from the Table 2a and b revealed that yield and other yield related parameters significantly progressed in upward trend. However, applied 4 levels of B with treated plants, 3 kg B ha^{-1} at maximum level significantly accelerated the growth and other yield contributing characters of ginger. The highest Plant height (58.4 and 60.3 cm), maximum leaves number (27.2 and 26.1/plant) were recorded with 3 kg B ha^{-1} followed by boron at the rate of B_2 kg ha^{-1} and statistically different over B control (B_0). In the same manner, individual weight of finger, finger size and weight of turmeric per plant significantly increased with the increase of B level up to 3 kg B ha^{-1}. The ginger crop significantly responded to B levels from 0 to t 3 B kg ha^{-1} as the native soil was found to be Boron deficient. However, the maximum finger size (5.5×7.6 cm and 5.8×8.0 cm), weight of ginger (289 and 293/plant) and the highest ginger yield (23.5 and 25.8t ha^{-1}) were obtained by applying boron at the rate of 3 kg B ha^{-1}. Similar results were reported by Roy *et al.* (1992), Gupta and Singer (1998) and Venkatesha *et al.* (1995). It was also observed that both B and Zn had encouraging effect on ginger but the effect of B was more pronounced than that of zinc.

Effect of zinc: The yield and yield contributing characters of ginger are shown in Table 2a and b stated that as like boron, Zn made an significant influence on growth and

Table 3a: Interaction effect of boron and zinc on the yield and yield attributes of ginger of HARS, Ramgah, Khagrachari, during 2004-2005

Level of B (kg ha^{-1})	Level of Zn. (kg ha^{-1})	No. of leaves/ plant	Plant height (cm)	No. of finger			Wt. of fingers/ plant (g)	Wt. of ginger/ plant (g)	Wt. of corm/ plant (g)	Finger size		Ginger yield (t ha^{-1})
				Primary fingers	Secondary fingers	Tertiart fingers				Length (cm)	Diameter (cm)	
B_0		13.3	7.3	2.4	2.9	2.7	144	200	19.6	3.2	4.8	10.50
B_1	Zn_0	24.0	11.3	3.2	4.4	3.4	170	222	30.8	4.3	6.1	15.1
B_2		44.1	13.3	3.4	4.9	3.7	189	235	34.1	4.5	6.7	18.3
B_3		53.1	16.3	3.7	6.2	4.0	221	251	37.0	4.9	7.2	22.0
B_o	$Zn_{1.5}$	19.6	9.3	2.9	3.5	3.1	158	206	22.3	4.0	5.6	12.0
B_1		33.6	12.0	3.2	4.4	3.6	174	226	33.2	4.3	6.3	16.3
B_2		46.4	15.0	3.6	5.0	3.7	199	235	34.7	4.6	6.8	19.5
B_3		55.1	16.6	3.8	6.6	4.3	232	282	38.1	5.7	7.3	22.9
B_o	$Zn_{3.0}$	21.1	9.0	3.0	4.2	3.3	164	206	27.2	4.1	6.0	12.7
B_1		36.2	12.7	3.2	4.6	3.6	176	230	38.2	4.4	6.4	17.0
B_2		47.6	14.7	3.6	5.1	3.7	209	241	35.4	4.6	7.0	20.2
B_3		61.0	17.3	3.5	6.8	4.8	252	290	38.6	5.8	7.8	23.8
B_o	$Zn_{4.5}$	22.6	10.3	3.2	4.3	3.3	165	210	29.8	4.2	6.0	11.0
B_1		40.1	13.3	3.4	4.8	3.7	179	230	33.6	4.4	6.4	17.4
B_2		51.2	15.3	3.7	5.4	3.8	213	260	36.2	4.7	7.1	21.1
B_3		64.3	18.7	4.2	7.2	4.9	273	334	40.70	5.9	8.2	25.5
LSD (0.05)		1.26	1.46	0.51	0.72	0.14	9.27	10.38	1.52	0.13	0.12	0.46
CV%		2.9	6.6	9.0	3.2	3.3	2.9	6.2	2.8	7.1	3.4	5.1

Table 3b: Interaction effect of boron and zinc on the yield and yield attributes of ginger of HARS, Ramgah, Khagrachari, during 2005-2006

Level of B (kg ha^{-1})	Level of Zn. (kg ha^{-1})	Plant height cm	No. of leaves/ plant	No. of finger			Wt. of fingers/ plant (g)	Wt. of ginger/ plant (g)	Wt. of corm/ plant (g)	Finger size		Ginger yield (t ha^{-1})
				Primary fingers	Secondary fingers	Tertiary fingers				Length (cm)	Diameter (cm)	
B_o		13.4	7.4	2.4	2.8	2.8	145	206	18.7	3.3	4.7	11.7
B_1	Zn_0	24.3	11.3	3.3	4.5	3.3	172	225	31.0	4.3	6.2	17.3
B_2		45.1	14.0	4.0	4.9	3.8	192	237	35.2	4.5	6.8	18.0
B_3		55.0	17.3	4.6	6.4	4.3	223	255	38.3	5.2	7.4	22.8
B_o		20.0	10.0	3.0	3.6	3.2	153	207	23.3	4.1	5.5	13.0
B_1	$Zn_{1.5}$	34.0	12.6	3.5	4.5	3.7	176	230	35.0	4.5	6.4	16.7
B_2		44.0	15.2	3.9	5.3	3.8	200	337	36.2	4.7	6.9	20.6
B_3		56.3	17.5	4.8	6.8	4.6	236	287	38.3	5.9	7.6	23.7
B_o		21.3	9.5	3.0	4.3	3.4	166	208	28.3	4.3	6.2	13.3
B_1	$Zn_{3.0}$	37.2	13.3	3.6	4.7	3.7	177	236	39.3	4.6	6.5	17.6
B_2		48.3	15.2	3.6	5.2	4.8	213	243	39.7	4.9	7.2	21.0
B_3		63.03	18.0	4.5	7.0	4.8	259	297	40.2	6.0	7.8	24.5
B_o		23.0	10.5	3.2	4.4	3.6	166	212	30.0	4.6	6.3	12.3
B_1	$Zn_{4.5}$	40.1	13.7	4.0	4.9	3.9	182	233	40.2	4.7	6.5	17.7
B_2		52.2	16.3	4.1	5.5	4.7	217	270	45.3	5.3	7.3	22.3
B_3		66.0	19.8	4.9	7.9	5.2	282	340	48.20	6.7	8.9	26.8
LSD (0.05)		1.28	1.51	0.52	0.69	0.12	9.22	10.36	1.50	0.12	0.15	0.52
CV%		4.8	5.5	7.6	4.2	5.2	6.2	6.9	404.00	7.3	5.7	5.2

other yield attributes of ginger. It was appeared in the Table 2a and b that with the increase of zinc levels, all the growth and yield contributing parameters significantly increased in linear trend. But this increment among the studied parameters was not distinctly expressed. Four levels of Zn was applied to the treated plots, Zn at the highest rate (4.5 kg ha^{-1}) significantly affected the yield and other yield contributing characters. Plant height, leaves number, fingers number, fingers size and fingers weight/plant and ginger (rhizome) yield increased progressively against the application of Zn at 4.5 kg ha^{-1}. However, the highest plant height (44.6 and 53.3cm), number of leaves (14.4 and 15.0/plant), number of fingers (14.1 and 10.9/plant) were recorded by applying 4.5 kg Zn ha^{-1} which was statistically at par to the treatment $Zn_{3.0}$ but significantly higher over lower dose of boron ($B_{1.5}$ kg ha^{-1}) and boron control (Bo) treatments in two consecutive years. Other parameters like ginger weight, finger size and rhizome yield progressed in upwards direction. The larger finger size (4.8×6.9 and 7.0×7.3 cm), the ginger weight (258 and 26 g/plant) and the highest rhizome yield (20.4 and 22.3 t ha^{-1}) were recorded with 4.5 kg Zn ha^{-1} which was statistically differed over other Zinc levels and (23 and 37.66%) yield increase over the Zn control (Zn_0) in both the years of study. This result strongly supported the findings of Pandey (1992) and Mohanty *et al.* (1993). They also stated that the combined blanket does of NPK along with micronutrients significantly increase the rhizome yield.

Interaction effect of Zn and B: The data on studied parameters are placed in Table 3a and b reflected that combined application of Zn and B significantly augmented the yield and yield contributing permanents over control (Zn Bo). It was also revealed that growth and other yield attributes were highly increased with the subsequent addition of Zn and B. The significant increase in plant height, leaves number, fingers number were also noticed with the application of Zn-B integration up to $Zn_{4.5}B_{3.0}$ kg ha^{-1}. However, the highest plant height (64.3 and 66.0 cm), maximum leaves numbers (16.3 and 18.7/plant) were recorded at the highest level of $B_{3.0}Zn_{4.5}$ kg ha^{-1} which was statistically similar with treatment $B_{2.0}Zn_{4.5}$ but significantly higher over lower dose of $B_{1.0}Zn_{1.5}$ kg ha^{-1} and the control treatment (B_0Zn_0), respectively. This result was partially corroborated with the findings of Patra (1998) and Wilson and Ovid (1993). The response of ginger to Zn and B was found to be more distinct might be the possible reason of deficiency of said elements in the studied soil. Other parameters like finger weight per plant, finger size and rhizome yield were also significantly affected by successive addition of Zn and B with increasing rates. A judicious integration of both macro and micro-nutrients along with organic manure not only increased the rhizome yield but also helped to contain soil fertility to some extent. However, the significant increase of finger weight, finger size and ginger yield were noticeably increased with the increment of Zn and B. The integration of B and Zn at the rate of $B_{3.0}Zn_{4.5}$ Kg ha^{-1} along with recommended dose of $N_{180}P_{50}K_{120}S_{20}$ and CD_5 t ha^{-1} produced the largest finger size (5.9×8.2 and 6.7×8.9 cm), rhizome weight (334 g and 340 g/plant) and the highest ginger yield (25.5 and 26.8 t ha^{-1}) in two consecutive years of 2004-2005 and 2005-2006, respectively.

ECONOMICS

The economic analysis of integrated effect of B and Zn on the yield of ginger are shown in Table 4a and b and

Table 4a: Partial budget and dominance analysis for response of ginger to zinc and boron at HARS, Ramgarh, Khagrachari during 2004-2005

Treatments combination	Ginger yield t ha^{-1}	Total variable cost	Gross return (Tk. ha^{-1})	Gross margin (Tk ha^{-1})
T_1 = B_oZn_o	10.5	11,448	3,15,000	3,03,552
T_2 = B_1Zn_o	15.1	11,859	4,53,000	4,41,141
T_3 = B_2Zn_o	18.3	12,271	5,49,000	5,36,729
T_4 = B_3Zn_o	22.0	12,682	6,60,000	6,44,318
T_5 = $B_oZn_{1.5}$	12.0	11,544	3,60,000	3,48,456
T_6 = $B_1Zn_{1.5}$	16.3	11,955	4,89,000	4,77,045
T_7 = $B_2Zn_{1.5}$	19.5	12,367	5,85,000	5,72,633
T_8 = $B_3Zn_{1.5}$	22.9	12,778	6,87,000	6,74,222
T_9 = $B_0Zn_{3.0}$	12.7	11,640	3,18,000	3,06,360
T_{10} = $B_1Zn_{3.0}$	17.0	12,051	5,10,000	4,97,949
T_{11} = $B_2Zn_{3.0}$	20.2	12,463	6,06,000	5,93,537
T_{12} = $B_3Zn_{3.0}$	23.8	12,844	7,14,000	7,01,156
T_{13} = $B_0Zn_{4.5}$	11.0	11,736	3,30,000	3,18,264
T_{14} = $B_1Zn_{4.5}$	17.4	12,144	5,22,000	50,98,56
T_{15} = $B_2Zn_{4.5}$	21.1	12,559	6,33,000	6,20,441
T_{16} = $B_3Zn_{4.5}$	25.5	12,970	7,05,000	7,52,030

Price: Urea: Tk. 6.00/kg, TSP: Tk. 12.00/kg, MP: Tk. 8.00/kg, GYP: Tk. 4.00/kg, Boric Acid: Tk.70.00/kg, Zinc Oxide: Tk. 50.00/kg, Cowdung: Tk. 0.75/kg, Ginger: Tk. 30/kg

Table 4b: Partial budget and dominance analysis for response of ginger to zinc and boron at HARS, Ramgarh, Khagrachari during 2005-2006

Treatments Combination	Ginger yield (t ha^{-1})	Total variable Cost (Tk ha^{-1})	Gross return (Tkv ha^{-1})	Gross margin (Tk. ha^{-1})
T_1 = B_oZn_o	10.7	11,448	3,21,000	3,09,552
T_2 = B_1Zn_o	16.7	11,859	5,01,000	4,89,141
T_3 = B_2Zn_o	18.0	12,271	5,40,000	5,27,729
T_4 = B_3Zn_o	22.8	12,682	6,84,000	6,71,318
T_5 = $B_oZn_{1.5}$	13.0	11,544	3,90,000	3,7,8456
T_6 = $B_1Zn_{1.5}$	17.3	11,955	5,19,000	5,07,045
T_7 = $B_2Zn_{1.5}$	20.6	12,367	6,18,000	605,633
T_8 = $B_3Zn_{1.5}$	23.7	12,778	7,11,000	6,98,222
T_9 = $B_0Zn_{3.0}$	12.0	11,640	3,60,000	3,48,360
T_{10} = $B_1Zn_{3.0}$	17.6	12,051	5,28,000	515,949
T_{11} = $B_2Zn_{3.0}$	21.0	12,463	6,30,000	5,17,537
T_{12} = $B_3Zn_{3.0}$	24.5	12,844	7,35,000	7,221,56
T_{13} = $B_0Zn_{4.5}$	12.3	11,736	3,69,000	3,57,264
T_{14} = $B_1Zn_{4.5}$	17.7	12,144	5,31,000	5,188,56
T_{15} = $B_2Zn_{4.5}$	22.3	12,559	6,69,000	6,56,441
T_{16} = $B_3Zn_{4.5}$	26.8	12,970	8,0,4,000	7,91,030

Price: Urea: Tk. 6.00/kg, TSP: Tk. 12.00/kg, MP: Tk. 8.00/kg, GYP: Tk. 4.00/kg, Boric Acid: Tk.70.00/kg, Zinc Oxide: Tk. 50.00/kg, Cowdung: Tk. 0.75/kg, Ginger: Tk. 30/kg

Table 5a: Marginal analysis of cost undominated treatment for response of ginger to zinc and Boron at HARS, Ramgarh, Khagrachari during 2004-2005

Treatments combination	Gross margin (Tk. ha^{-1})	Total variable cost (Tk. ha^{-1})	Marginal increase in gross margin (Tk. ha^{-1})	Marginal increase in variable cost	Marginal rate of return % (MRR)
T_{16} = $B_3Zn_{4.5}$	7,52,030	12,979	50,874	105	408
T_{12} = $B_3Zn_{3.0}$	7,01,156	12,844	26,934	66	404
T_8 = $B_3Zn_{1.5}$	6,74,222	12,778	26,904	96	280
T_4 = B_3Zn_0	6,7,318	12,682	26,877	123	219
T_{15} = $B_2Zn_{4.5}$	6,20,441	12,559	26,904	96	280
T_{11} = $B_3Zn_{3.0}$	5,93,537	12,463	20,904	96	218
T_7 = $B_2Zn_{1.5}$	5,72,633	12,367	35,904	96	374
T_3 = B_2Zn_0	5,36,729	12,271	26,873	127	212
T_{14} = $B_1Zn_{4.5}$	5,09,856	12,144	11,907	93	128
T_{10} = $B_1Zn_{3.0}$	4,97,949	12,051	20,904	96	218
T_6 = $B_1Zn_{1.5}$	4,77,045	11,955	35,904	96	374
T_2 = B_1Zn_0	4,41,141	11,859	41,877	123	340
T_{13} = $B_0Zn_{4.5}$	3,18,264	11,736	11,904	96	124
T_9 = $B_2Zn_{3.0}$	3,06,360	11,640	2,808	192	15
T_1 = B_0Zn_0	3,03,552	11,448	-	-	-

Table 5b: Marginal analysis of cost undominated treatment for response of ginger to zinc and Boron at HARS, Ramgarh, Khagrachari during 2004-2005

Treatments Combination	Gross margin (Tk. ha^{-1})	Total variable cost (Tk. ha^{-1})	Marginal increase in gross margin (Tk. ha^{-1})	Marginal increase in variable cost	Marginal rate of return % (MRR)
T_{16} = $B_2Zn_{4.5}$	8,04,000	12,970	69000	126	548
T_{12} = $B_2Zn_{3.0}$	7,35,000	12,844	24000	66	364
T_8 = $B_2Zn_{1.5}$	7,11,000	12,778	27000	96	281
T_4 = B_2Zn_0	6,84,000	12,682	15000	123	122
T_{15} = $B_2Zn_{4.5}$	6,69,000	12,559	39000	96	406
T_{11} = $B_2Zn_{3.0}$	6,30,000	12,463	12000	96	125
T_7 = $B_2Zn_{1.5}$	6,18,000	12,367	78000	96	812
T_3 = B_2Zn_0	5,40,000	12,271	9000	127	81
T_{14} = $B_1Zn_{4.5}$	5,31,000	12,144	3000	93	32
T_{10} = $B_1Zn^{3.0}$	5,28,000	12,051	9000	96	94
T_6 = $B_1Zn_{1.5}$	5,19,000	11,955	18000	96	188
T_2 = B_1Zn_0	507,000	11,859	132000	123	107
T_{13} = $B_0Zn_{4.5}$	3,69,000	11,736	9000	96	94
T_9 = $B_2Zn_{3.0}$	3,60,000	11,640	39000	192	203
T_1 = B_0Zn_0	3,21,000	11,448	-	-	-

Table 5a and b, respectively. It is evident from the tables that the highest gross margin Tk. 7,52,030 and 8,04000/- by T_{16} (B_3 $Zn_{4.5}$ kg ha^{-1}) which was significantly dominated over other treatments. This was due to higher yield of ginger. The highest Marginal Rate of Return (MRR) 484 and 547.62% was also derived from same treatment combination T_{16} (B_{310} $Zn_{4.15}$ kg ha^{-1}) in the two Pears study. It is meant that if the farmer would invest Tk. 100, he might get benefit of Tk. 484 and Tk. 547.62, respectively. So from the economic point of view, application of B at the rate of 3 kg ha^{-1} along with 4.5 Kg Zn ha^{-1} can be profitable for maximizing the yield of ginger.

CONCLUSIONS

It is revealed from two years study, that zinc and boron made an encouraging effect on the yield and yield attributes of ginger. However, it is summarized from the studied result that B at the rate of 3.0 kg ha^{-1} and Zn 4.5 kg ha^{-1} along with combined blanket dose of $N_{180}P_{50}K_{120}S_{20}$ and CD 5 t ha^{-1} was found to be optimum for maximizing yield of ginger in South-Eastern Brown Hill Soils (Eurochrepts) of Chittagong Hill Tract Region.

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