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EFFECTS OF ZINC AND BIOCHAR ON THE YIELD AND NUTRIENT CONTENT OF SWEET GOURD

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Abstract

A field experiment was conducted during rabi season of 2022-2023 at the research field of Bangladesh Agricultural Research Institute (BARI), Gazipur to find out the effect of zinc (Zn) and biochar on the yield and Zn concentration of sweet gourd. There were eight treatment combinations with four rates of Zn (0, 2, 4, & 6 kg ha^{-1}) and two rates of biochar (0 & 3 t ha^{-1}). The experiment was laid out in a two factorial randomized complete block design with three replications. Application of 2 kg Zn ha^{-1} and 3 t biochar ha^{-1} recorded the highest yield (30.2 t ha^{-1}), vitamin C (7.84 mg 100 g^{-1}), vitamin β-carotene (41.4 mg 100 g^{-1}) and total suspended solid content (7.57° brix). The same treatment (T_6) showed the Zn concentration (29 mg kg^{-1} in flesh and 60.3 mg kg^{-1} in seed) of gourd. Combined application of Zn and biochar together enhanced gourd yield more than that of exclusive application either of them. Combined application of 2 kg Zn ha^{-1} and biochar 3 t ha^{-1} could be a promising strategy for enhancing sweet gourd production in Bangladesh.

Keywords: Gourd yield, TSS, Vitamin B-carotene, Vitamin-C, Zinc sulphate,

1. Introduction

Sweet gourd (Cucurbita maxima) is one of the most common and popular vegetables in Bangladesh, belonging to the Cucurbitaceae family. It is a good source of carbohydrate, vitamin A, vitamin C and minerals (Chuwa *et al.,* 2023). Sweet gourd peel, flesh and seeds are good source of total phenolic, total flavonoid, total carotenoid and mineral contents (Hussain *et al.,* 2021). Many phytochemicals and essential nutrients, which are beneficial to health are present in sweet gourd (Jun *et al.,* 2006; Dhar *et al.,* 2017). However, sweet gourd production is constrained by several factors, such as low soil fertility, nutrient deficiency, and biotic and abiotic stresses. In 2022-2023, the major vegetables growing areas in Bangladesh covering 310288 ha with a total yield of 3667058 M. ton where only the Rabi pumpkin growing areas in Bangladesh covering 18167 ha with a total production of 227046 M. ton and a yield of 12.5 t ha^{-1}(BBS, 2023).

Among the micronutrients, Zn deficiency is prominent in Bangladesh soils. The deficiency of this nutrient has arisen in this country mainly due to continuous mining of soil nutrients for increased cropping intensity (198 % at present). Biochar is an insoluble, aromatic, low-density and carbon-rich solid material produced by the pyrolysis of biomaterials under anoxic conditions and relatively high temperature (>300ºC). It is a stable form of organic carbon that improves soil condition and sequestrates carbon. Biochar adds organic matter, N, K, P, Mg, Ca, and other micronutrients which enhance the soil enzymes and microbial activity (Zhu *et al.,* 2017; Zulfiqar *et al.,* 2019). In the past decade, combining biochar and various fertilizers to improve plant growth and agricultural production attracted substantial interest (Chen *et al.,* 2019). So, the combined application of biochar with Zn could be a viable option to minimize the adverse effects of trace metals on plants, reducing their bioavailability, and also improve antioxidant activities and biomass of plant as compared to sole application of biochar or Zn (Chen *et al.* 2019; Farooq *et al.,* 2020). Previously, several biochar studies were conducted with and without chemical fertilizers but information regarding effect of Zn and biochar in sweet gourd plant are not much available. Thus, the study was undertaken with the objectives to assess the effect of Zn and biochar on the Zn concentration and yield of sweet gourd and to determine a suitable combination of Zn and biochar application.

2. Materials and Methods

2.1 Experimental site and initial soil status

A field experiment was conducted at the research field of Bangladesh Agricultural Research Institute (BARI), Gazipur during Rabi season of 2022-2023. The experimental site falls under the agroecological zone Madhupur Tract (AEZ 28). Initial soil samples were collected from a depth of 0-15 cm and analyzed prior to application of different fertilizers. The soil properties were texture: sandy clay loam, pH 6.67, OM 1.80%, total N 0.08%, exchangeable K 0.18 me%, available S 12.3 mg kg^{-1}, available P 6 mg kg^{-1}, available zinc 0.7 mg kg^{-1} and available boron 0.18 mg kg^{-1}.

Soil pH was measured in 1:2.5 soil: water ratio by a combined glass calomel electrode (Jackson, 1958). Organic carbon determination was done by wet oxidation method (Walkley and Black, 1934). Total N was determined by modified Kjeldahl method. Phosphorus was determined by Bray and Kurtz method. Elements K, Ca and Mg were determined by NH_4OAc and Cu, Fe, Mn & Zn by DTPA extraction methods followed by AAS reading. Boron was determined by $CaCl_2$ extraction method, while S by turbidimetric method with $BaCl_2$. Total soluble solids content (TSS) was determined at 20°C with a refractometer and reported as Brix. Vitamin C (ascorbic acid) was determined by classical titration method using 2, 6-dichlorophenol indophenols solution and express as mg $100g^{-1}$ of fresh weight (Miller, 1998). Total carotenoids were measured by spectrophotometer (T-40, PG Instrument Ltd.UK) at 451ɳm (Alasalvar*et al.,* 2005).

2.2 Biochar preparation

Biochar used in this study was produced from farm curing agricultural waste by slow pyrolysis at a temperature of 500°C to 700°C for two hours in a locally made house. The biochar had organic carbon content of 41%, N content of 1.05%, P content of 0.02%, K content of 0.57%, Zn content of 0.02%, Fe content of 0.21%, Mn content of 0.02%, and pH 8.0.

2.3 Treatments

There were eight treatments comprising four doses of Zn (0, 2, 4 & 6 kg ha^{-1}) and two doses of biochar (0 & 3 t ha^{-1}), shown in Table 1. A basal application was made with 4 t ha^{-1}cowdung, 38.4 kg ha^{-1} P as TSP, 40.2 kg ha^{-1} K as MoP and 16.5 kg ha^{-1} S as gypsum in pit 7 days before planting, and fertilizers were mixed thoroughly with the soil. In the pits zinc (as zinc $ZnSO_4$. 7 H_2O) and biochar were also added into the pits with other fertilizers. Nitrogen from urea was applied around the plant as side dressing at 15, 35, 55 and 75 days after transplanting under moist soil condition.

2.4 Experimental work

The experiment was conducted at the experimental field under Soil Science Division of Bangladesh Agricultural Research Institute (BARI), Gazipur during 2022-2023.The design of the experiment was randomized complete block design (RCBD) having three replications. Total number of plots was 24 (8 × 3). The unit plot size was 2.5 m × 2.5 m with a spacing of 1.25m ×1.25 m. After final land preparation pits were kept open in the sun for 7 days. The variety under test was BARI Mistikumra 2. Eighteen days' old healthy and equal sized seedlings were transplanted in the pit on 28 December, 2022. Necessary intercultural operations including irrigation were done throughout the cropping season for proper growth and development of the plant. Sweet gourds were started to harvest on 28 March, 2023. The fruit weight and number of fruits per plot determined the fruit yield per plot.

Plant (fruits) samples were dried in an oven at 70°C for 72 hours and the dry samples were then finely ground in a grinder for laboratory analysis. After harvest, the soil from each plot was thoroughly mixed and approximately 100 g soil was sampled for laboratory analysis.

2.5 Statistical analysis

All field and laboratory data were statistically analyzed by statistical package STATISTIX-10 to examine the treatment effects and mean comparisons were done by Tukey HSD test at 5% level of significance.

3. Results and Discussion

3.1 Effects of Zinc and biochar on yield and yield components of sweet gourd

The combined effect of zinc and biochar significantly influenced yield parameters (Table

1). The highest fruit length of sweet gourd was found in T_6 (2 kg Zn ha^{-1} + 3 t ha^{-1} biochar) treatment (13 cm) which was significantly higher over others, except T_7 treatment (12.7 cm). The highest fruit diameter (63.3 cm) as well as highest thickness of flesh (3.39 cm) were observed in T_6 treatment. The highest number of seeds $fruit^{-1}$ (321) was noted in T_7 treatment which was statistically identical with T_6 (295), T_8 (292) and T_3 treatments (276) and significantly higher over other treatments. The marked response in single fruit weight due to combined Zn and biochar application was found in T_6 treatment (2.58 kg). Significant variation also found in fruit yield of sweet gourd. Like many other parameters, T_6 treatment recorded the highest fruit yield (30.2 t ha^{-1}) which was statistically identical with T_7 (29.5 t ha^{-1}), but higher over all others.

Table 1. Yield and yield attributes of sweet gourd as influenced by zinc and biochar

Treatments	fruit length (cm)	Fruit diameter(cm)	Thickness of flesh (cm)	No. of seeds $fruit^{-1}$	Single fruit weight (kg)	Fruit yield (kg/plot)	Fruit yield t/ha
T_1 ($Zn_0Biochar_0$)	8.42d	57.3 d	2.4 c	233 c	1.55 c	6.6 e	10.6 e
T_2 ($Zn_2Biochar_0$)	11.0bc	60.5 bc	3.14 ab	255 bc	2.42ab	15.3 bc	24.4 bc
T_3 ($Zn_4Biochar_0$)	11.1bc	60.7 bc	3.22 ab	276 abc	2.45 ab	16.3 b	26 b
T_4 ($Zn_6Biochar_0$)	10.3c	59.6 c	2.88 abc	253 bc	2.05bc	14.4 cd	23 cd
T_5 ($Biochar_3$)	10.6c	59.0 cd	2.66 bc	253 bc	2.01 bc	13.4 d	21.4 d
T_6 ($Zn_2Biochar_3$)	13.0a	63.3 a	3.39 a	295 ab	2.58 a	18.9 a	30.2 a
T_7 ($Zn_4Biochar_3$)	12.7 ab	62.2 ab	3.28 ab	321 a	2.41 ab	18.4 a	29.5 a
T_8 ($Zn_6Biochar_3$)	11.0bc	61.3 abc	2.95 abc	292 ab	2.17 ab	13.7 d	21.9 d
CV%	5.82	1.37	3.15	6.73	8.10	3.68	3.68

Subscripts of Zn and biochar represent kg ha^{-1} and t ha^{-1}, respectively.

Means followed by same letter (s) in a column do not differ significantly at the 5% level of significance by DMRT.

Biochar increased yield and yield contributing parameters, which is consistent with the findings of Parkash and Singh (2020). Zinc alone performed better than biochar alone. Overall results indicate that combined application of Zn at 2 kg $ha^{-1}$and biochar at 3 t ha^{-1} demonstrated the best results.

3.2 Effects of zinc and biochar on flowering of sweet gourd

Zinc and biochar play a great role on flower production and sex ratio (male/female) of sweet gourd. Among the eight treatments, application of 2 kg Zn ha^{-1} and biochar 3 t ha^{-1}produced both highest male (46) and female flowers (11) (Table 2). Biochar has variable effects on flower production and size. Conversa *et al.* (2015) showed that the flower number of Pelargonium (Pelargonium zonale L.) was higher in 30% biochar treatments but was reduced with 70% biochar. Mineral nutrients can affect sex expression by regulating plant hormone synthesis (Megharaj *et al.,* 2017). According to the table 4, Application of 2 kg Zn ha^{-1} and biochar 3 tha^{-1}produced lower sex ratio by increasing the female flowers by 42.5% over control. Flower sex ratio is the predictor of pollination efficiency in monoecious plants (Cuevas and Polito, 2004).

Table 2. Flower production of sweet gourd as influenced by zinc and biochar application

Treatments	Male flowers	Female flowers	Sex ratio
T_1 (Zn_0 $Biochar_0$)	30.7	6.33	4.84
T_2 (Zn_2 $Biochar_0$)	44.0	9.67	4.55
T_3 (Zn_4 $Biochar_0$)	43.7	9.67	4.52
T_4 (Zn_6 $Biochar_0$)	41.7	9.00	4.63
T_5 ($Biochar_3$)	41.3	9.00	4.59
T_6 (Zn_2 $Biochar_3$)	46.0	11.00	4.18
T_7 (Zn_4 $Biochar_3$)	45.0	10.00	4.50
T_8 (Zn_6 $Biochar_3$)	42.3	9.00	4.70

Subscripts of Zn and biochar represent kg ha^{-1} and t ha^{-1}, respectively.

3.3 Vitamin C, Β-Carotene and TSS content

According to the Table 3, the highest Vit. C (7.84 mg $100g^{-1}$) and β-Carotene (41.4 mg $100g^{-1}$) were found in T_6 treatment. The highest TSS was also observed in T_6 treatment (7.57 °Brix) where nutrient availability was higher compared to others. Danilchenko *et al.* (2000) analyzed a range of 8.93-20.63 mg 100 g^{-1} for ascorbic acid in ripe sweet gourd. Karanja *et al.* (2011) observed that β-carotene content of fresh sweet gourd pulp was 9.15-41.28 µg g^{-1}. Besides, Noelia *et al.* (2011) and Muralidhara *et al.* (2014) showed that the TSS in pumpkin ranged from 1.00 to 15.00 and 3.17 to 8.70 ˚B, respectively. Zinc and biochar together increased sweet gourd yield and quality but optimal combination of 2 kg Zn ha^{-1} and biochar 3 t ha^{-1} acting as the best treatment than others.

Table 3. Quality characters of sweet gourd as influenced by the combined effect of zinc and biochar

Treatments	Vit. C (mg 100g^{-1})	β-Carotene (mg 100g^{-1})	TSS (°Brix)
T_1 ($Zn_0Biochar_0$)	5.09	21.6	5.67
T_2 ($Zn_2Biochar_0$)	5.76	30.8	6.23
T_3 ($Zn_4Biochar_0$)	6.66	36.2	6.60
T_4 ($Zn_6Biochar_0$)	6.27	25.4	6.70
T_5 ($Biochar_3$)	5.49	25.1	6.43
T_6 ($Zn_2Biochar_3$)	7.84	41.4	7.57
T_7 ($Zn_4Biochar_3$)	7.06	39.8	7.17
T_8($Zn_6Biochar_3$)	6.70	36.3	6.80

Subscripts of Zn and biochar represent kg ha^{-1} and t ha^{-1}, respectively.

3.4 Zinc content and uptake

Zinc and biochar showed different effects on the accumulation of Zn in the sweet gourd (Table 4). The highest Zn concentration (29 mg kg^{-1}in flesh and 60.3 mg kg^{-1}in seed of sweet gourd seed) and the highest Zn uptake (0.091 kg ha^{-1} in flesh and 0.067 kg ha^{-1} in seed) were recorded in T_6 treatment where 2 kg Zn ha^{-1} and biochar 3 tha^{-1} were applied together. The highest zinc content (89.2 mg kg^{-1}) and uptake (0.16 kg ha^{-1}) in fruit (flesh and seed) were also found in T_6 treatment. Zinc content levels vary from 15 to 100 μg g^{-1}depending on plant age, stage, soil and climate (Ovca *et al.,* 2011).

Table 4. Zinc content and uptake of sweet gourd as influenced by the combined effect of zinc and biochar

Treatments	Sweet gourd flesh		Sweet gourd seed		Sweet gourd fruit	
	Zn content (mg kg^{-1})	Zn uptake (kg ha^{-1})	Zn content (mg kg^{-1})	Zn uptake (kg ha^{-1})	Total Zn content (mg kg^{-1})	Total Zn uptake (kg ha^{-1})
T_1 ($Zn_0Biochar_0$)	21.0	0.021	51.2	0.024	72.2	0.045
T_2 ($Zn_2Biochar_0$)	24.5	0.069	55.0	0.046	79.6	0.115
T_3 ($Zn_4Biochar_0$)	26.5	0.078	56.7	0.053	83.2	0.131
T_4 ($Zn_6Biochar_0$)	22.9	0.052	54.1	0.043	77.0	0.096
T_5 ($Biochar_3$)	23.5	0.049	52.3	0.040	75.8	0.090
T_6 ($Zn_2Biochar_3$)	29.0	0.091	60.3	0.067	89.2	0.158
T_7 ($Zn_4Biochar_3$)	28.8	0.087	59.0	0.064	87.8	0.151
T_8 ($Zn_6Biochar_3$)	22.5	0.049	53.7	0.045	76.2	0.094

Subscripts of Zn and biochar represent kg ha^{-1} and t ha^{-1}, respectively.

4. Conclusions

Zinc and biochar improved yield of sweet gourd by influencing soil and plant factors. Combined application of zinc and biochar positively influenced the Zn enrichment, vit. C and β-Carotene content. Single application of zinc fertilizer performed better than that of biochar, however their combined application performed the best than either single application. In AEZ-28, combined application of zinc and biochar worked the best, especially 2 kg Zn ha^{-1} and biochar 3 t ha^{-1} resulting in a yield of 30.2 t ha^{-1}.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

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