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Effect of Organic, Inorganic Fertilizers and Plant Spacing on the Growth and Yield of Cabbage

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Abstract: The impact of chemical farming and the negative consequences on the environment and human health in Bangladesh are on the rise. Organic farming is gaining attention and increasing globally because it is eco-friendly, safe and has benefits for human health. A field study was conducted at the horticulture farm of Bangladesh Agricultural University (BAU), Mymensingh, to evaluate the growth and yield performance of cabbage cv. Atlas—70 using organic and inorganic fertilizers in various plant spacing arrangements. Two factor experiments were conducted on plant spacings of 60 cm × 40 cm (S_1), 60 cm × 50 cm (S_2) and 60 cm × 60 cm (S_3) and fertilizers vermicompost (T_1), biogen (T_2), integrated plant nutrient system (IPNS) Organic (2/3) + inorganic (1/3) (T_3) and inorganic (T_4). IPNS (T_3) application increased the marketable yield (54.77 t·ha^{-1}) of cabbage. The highest marketable yield (48.75 t·ha^{-1}) was obtained with a plant spacing of 60 cm × 40 cm (S_1). No significant variation was found in plant spacings S_1 and S_2. The treatment combination of S_2T_3 recorded the highest plant height (37.81 cm), plant spread (47.75 cm), cabbage head (21.80 cm), stem length (12.31 cm), thickness of the cabbage head (12.53 cm) and marketable yield (65.0 t·ha^{-1}). The results suggest that IPNS (T_3) combining organic and inorganic fertilizer applications with a 60 cm × 50 cm spacing (S_2T_3) increases the yield performance of cabbage.

Keywords: biogen; cabbage; growth; plant density; vermicompost; yield

1. Introduction

The sustainability of conventional agriculture in Bangladesh is under threat from the continuous degradation of land and water resources, as well as declining yield due to indiscriminate use of agro-chemicals. Use of synthetic fertilizers and pesticides in agriculture production increased tremendously after the green revolution [1,2]. Environmental impacts of excessive applications of chemical fertilizers in Bangladesh have been reported [3].Excessive use of chemical fertilizers causes unforeseen environmental impacts and sensitivity to pests and diseases through the oversupply of nitrogen [4]. Organic farming practices are a potential way to decrease the negative environmental impact of excessive amounts of chemical fertilizers [5,6]. Organic fertilizers are environmentally friendly and improve soil health, water-holding capacity, high cation exchange capacity and low bulk density and they a foster diverse population of beneficial soil microorganisms [7–9]. Alternatively, there are mixed fertilizers or integrated plant nutrient systems (IPNS) where organic fertilizer is combined with inorganic fertilizer for soil improvement and higher yield. This reduces the dependency and need for a higher amount of inorganic fertilizer in crop production. Organic fertilizers contain

macro- and micro-nutrients, vitamins, growth-promoting factors indole 3-acetic acid (IAA), gibberellic acid (GA), and beneficial microorganisms [10,11], and they increase production in ways similar to inorganic fertilizers [12–17]. Cabbage (*Brassica oleracea* var. *capitate* L.), is a nutritious and high-value leafy vegetable in Bangladesh [18] and it is widely grown in both tropical and temperate regions. The major cabbage-growing countries of the world are South Korea, Germany, Japan, India, South Africa and China. The average yield of cabbage in Bangladesh is far lower (13.25 t·ha^{-1}) than other countries (32.31 t·ha^{-1}) [19,20]. Plant spacing and fertilizer applications have significant influence on the growth and yield in crop production. Optimum plant spacing ensures the proper use of land, as well as growth and nutrition in plants. The judicial application of organic or inorganic fertilizers is an important consideration to improve the yield and quality of the product. Earlier reports suggest that a combined application of manures and fertilizers (integrated plant nutrient system, IPNS) increases the yield and improves the quality of vegetables [21]. The objective of the work is to evaluate the growth and yield performance of cabbage in various plant spacing arrangements using different organic and inorganic fertilizers.

2. Materials and Methods

The experiment was conducted at the Horticulture Farm of Bangladesh Agricultural University (BAU), Mymensingh during November 2014 to February 2015 on cabbage cv. Atlas—70. Seeds (hybrid F_1) obtained locally (Sakata Seed Corporation, Japan). Soil samples of experimental plot collected from various places depth of 15 cm and sent to Agrivarsity Humboldt Soil Testing Laboratory for analysis. Two factors experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The double factor experiment consisted of three plant spacings, 60 cm × 40 cm (S_1), 60 cm × 50 cm (S_2) and 60 cm × 60 cm (S_3). Four fertilizer treatments applied, vermicompost@17 t·ha^{-1} (T_1), Biogen@15 t·ha^{-1} (T_2), integrated plant nutrient system (IPNS) @ 2/3 organic fertilizer + 1/3 inorganic fertilizer (T_3) and Inorganic (Urea@326 kg·ha^{-1}, TSP@104 kg·ha^{-1}, MoP@120 kg·ha^{-1}, Boric acid@5.88 kg·ha^{-1} and Zinc sulphate@5.55 kg·ha^{-1}) (T_4). In the IPNS system, two-thirds part organic fertilizer consists of equal amount of vermicompost and Biogen fertilizers. Fifteen, 12 and 9 plants were planted in each plot (1.8 m × 2.0 m), in three spacing S_1, S_2, and S_3, respectively. Inorganic fertilizer was used as control. Biogen fertilizer (MATI Organics Ltd., Dhaka, Bangladesh) nutritional composition was N (0.5%–4.0%), P (0.3%–0.5%), K (0.3%–0.5%), S (0.1%–0.5%), Zn (0.1%) and Cu (0.05%). Vermicompost was obtained from Horticulture farm of BAU. In Bangladesh, vermicompost nutrient composition is varies (N: 0.5%–4%, P: 0.5%–3%, K: 0.5%–3%, and S: 0.1%–0.5%, personal contact with BARC, Bangladesh). Seedlings were raised in seedbeds (3 m × 1 m) and field was prepared with a power tiller. Organic fertilizers (vermicompost and biogen), triple superphosphate (TSP), $ZnSO_4$, and boric acid were applied before planting. Inorganic fertilizers (urea and potash) were applied in two parts at 15 and 35 days after transplanting as band application [22]. Healthy transplants (three weeks old) were selected from the seedbed and transplanted in the experimental plots. Planting was done in the afternoon to avoid transplanting shock. Seedlings were watered after transplanting. Banana leaves were used around seedlings as mulch. Weeding and irrigation were done manually. Five plants were selected randomly for data collection in each plot and labeled. Data collected on plant height, plant diameter, stem length, head thickness, and head diameter. Marketable weight (compact head) per plant was measured and total marketable yield recorded. Data were statistically analyzed with MSTAT-C software. The means for all the characters were performed by *F* test. The mean differences among the treatments were evaluated with LSD test at 1% and 5% level of significance [23].

3. Results and Discussion

The soil analysis before the planting and after the harvesting of cabbage indicated the soil organic matter content was 2.55% and 2.60%, respectively. During planting, the soil pH was 6.43 and the electrical conductivity (EC) was 72.54 (μc/cm). The soil pH and EC increased after harvesting the

crop [24].The average yield of cabbage was significantly influenced by the organic and inorganic fertilizer treatments and plant spacings. The plant height was recorded at 15, 30, 45 and 60 days after transplanting (DAT). The plant height was significantly different ($p \leq 0.01$) between the fertilizer and spacing treatments. The spread of the cabbage plant data was recorded at 15, 30, 45 and 60 DAT. The maximum spread of plants (47.57 cm) was at 60 DAT observed in IPNS (T_3), followed by the vermicompost (T_1) (44.34 cm) and inorganic fertilizer (T_4) (41.97 cm) applications. In earlier reports, the 60 cm × 50 cm spacing was suitable for plant growth [25]. In the combined effect at 60 DAT, the treatment S_2T_3 (60 cm × 50 cm spacing) × (2/3 organic + 1/3 inorganic) showed the highest mean height of cabbage (37.81 cm) followed by the treatments S_3T_3 (35.96 cm) and S_2T_2 (35.73 cm). The lowest mean height of cabbage (33.03 cm) was produced from the treatment S_1T_4 (Table 1). Results showed that the wider spacing was superior in yield attributes. Similar findings in the plant height of cabbage were obtained by various researchers [25,26] and IPNS or the application of mixed fertilizers influenced the plant height [27,28]. The wider spacing did not produce highest yield as number of plants reduced by the unit area. The results indicated that application of organic fertilizers and inorganic fertilizers combined showed improved growth and the maximum plant spread. These findings are in agreement with the reports where vermicompost or poultry manure along with inorganic fertilizer application yielded high plant spread [27–29].

Table 1. Effect of organic and inorganic fertilizers and spacing on plant height and the spread of the cabbage at different days after transplanting (DAT).

Treatment Combinations	Plant Height (cm) at DAT				Spread of the Plant (cm) at DAT			
	15	30	45	60	15	30	45	60
S_1T_1	9.76	20.45	30.62	33.31	13.39	26.54	34.77	43.90
S_1T_2	9.83	22.11	31.25	33.37	13.16	26.53	34.67	43.20
S_1T_3	10.60	23.99	33.30	35.85	14.63	29.09	36.50	45.57
S_1T_4	9.15	21.85	30.52	33.03	12.30	24.63	33.04	41.19
S_2T_1	9.90	21.66	30.83	34.38	14.00	28.83	36.07	44.67
S_2T_2	10.65	22.85	33.47	35.73	14.40	28.38	36.35	44.87
S_2T_3	12.00	25.49	35.73	37.81	15.57	29.90	38.50	47.75
S_2T_4	10.93	22.84	32.69	34.67	13.54	27.28	34.08	42.40
S_3T_1	9.83	20.70	30.66	33.92	13.60	26.77	34.82	44.45
S_3T_2	10.03	22.35	32.11	34.99	14.24	27.85	35.50	43.79
S_3T_3	11.28	25.47	34.35	35.96	14.91	29.40	38.15	46.40
S_3T_4	9.67	22.71	32.06	34.25	12.67	25.93	33.97	42.33
$LSD_{0.05}$	0.541	0.186	0.533	0.579	1.380	0.505	0.347	0.780
$LSD_{0.01}$	0.735	0.252	0.724	0.787	1.876	0.687	0.472	1.060
Level of significance	**	**	**	**	NS	**	**	**

S_1 = 60 cm × 40 cm; T_1 = Vermicompost; S_2 = 60 cm × 50 cm; T_2 = Biogen; S_3 = 60 cm × 60 cm; T_3 = IPNS (2/3 organic + 1/3 inorganic) and T_4 = Inorganic; ** = Significant at 1% level of probability. NS: Non-Significant.

The highest yield was obtained from the integrated plant nutrient system (IPNS, T_3) compared to the other treatments of organic fertilizer, biogen and inorganic fertilizers (data not shown). Higher yields obtained were with mixed fertilizers over other fertilizer applications. The combined treatment S_2T_3 (60 cm × 50 cm spacing) × (2/3 organic + 1/3 inorganic) showed the highest length of stems (12.31 cm) followed by S_2T_2 (12.01 cm), while the lowest length of stems was recorded in S_1T_4 (10.60 cm) (Table 2). Sharma [30] found that the integrated application of organic and inorganic fertilizers significantly increased the vegetative growth.

The plant spacing of 60 cm × 50 cm (S_2) produced the highest number of roots per plant. The highest number of roots was recorded from the IPNS treatment followed by T_1, while the lowest number of roots was obtained from the T_4 treatment. The highest number of roots (16.20/plant) was produced from the S_2T_3treatment (60 cm × 50 cm) × (2/3 organic + 1/3 inorganic), while the lowest number of roots was found in the S_1T_4 treatment (12.53/plant) (Table 2). Rai et al. [27] reported similar findings that when vermicompost was applied in the soil with NPK (nitrogen-phosphorous-potassium),

some metallic trace elements stimulated the growth of roots [28]. A higher number of roots indicate improved growth in the combined treatment and higher yield.

Table 2. Effects of organic and inorganic fertilizers with different spacing on yield and yield-contributing characteristics of cabbage.

Treatment Combinations	Head Diameter (cm)	Root Length (cm)	Stem Length (cm)	Number of Roots Plant^{-1}	Head Thickness (cm)	Marketable Weight (kg·plant^{-1})	Marketable Yield (t·ha^{-1})
S_1T_1	18.07	17.69	10.91	13.80	10.25	1.03	42.91
S_1T_2	19.33	17.65	11.07	13.93	11.23	1.10	45.83
S_1T_3	20.07	18.65	11.27	14.47	11.42	1.46	60.83
S_1T_4	18.80	18.39	10.60	12.53	10.55	1.09	45.42
S_2T_1	19.68	19.90	11.51	15.67	11.58	1.13	37.67
S_2T_2	19.98	19.50	12.01	15.53	11.46	1.40	46.33
S_2T_3	21.80	19.66	12.31	16.20	12.53	1.95	65.00
S_2T_4	19.97	20.37	11.42	13.67	11.26	1.31	43.67
S_3T_1	18.80	17.75	11.19	14.73	10.75	1.11	30.81
S_3T_2	19.83	18.90	11.39	14.47	11.25	1.21	30.25
S_3T_3	20.45	19.06	11.39	14.73	11.52	1.54	38.50
S_3T_4	19.01	19.40	11.16	13.33	10.80	1.15	37.75
$LSD_{0.05}$	0.522	0.502	0.257	0.227	0.200	0.107	1.90
$LSD_{0.01}$	0.709	0.683	0.349	0.309	0.272	0.146	2.58
Level of significance	**	**	**	**	**	**	**

S_1 = 60 cm × 40 cm; S_2 = 60 cm × 50 cm; S_3 = 60 cm × 60 cm; T_1 = Vermicompost; T_2 = Biogen; T_3 = IPNS (2/3 organic + 1/3 inorganic) and T_4 = Inorganic; ** = Significant at 1% level of probability.

The longest roots (20.37 cm) and shortest roots (17.65 cm) were recorded in combined treatments S_2T_4 (60 cm × 50 cm spacing) × (inorganic) and S_1T_2, respectively (Table 2).Earlier reports suggest that plants grown in wider spacing produced the highest root length due to the low density of plants per unit area [26,31].

The combined treatment of fertilizers (T_3) and spacing treatments (S_2) (S_2T_3) provided the highest thickness of the cabbage (12.53 cm) in the treatment S_2T_3 (60 cm × 50 cm) × (2/3 organic + 1/3 inorganic) and the lowest (10.25 cm) in the treatment S_1T_1 (Table 2). Haque [29] reported that the effect of the mixed fertilizer application (organic and inorganic) resulted in the highest thickness of the cabbage head.

This compactness also has the rational trend of the combination where a higher yield was obtained (Table 2). S_2 showed improved growth and yield compared to S_1. This illustrated that there was a higher plant density and population per plot in S_2compared to S_1.The treatment S_2 recorded the highest and S_1 obtained the lowest diameter of the cabbage head. The highest diameter of the cabbage head was recorded from the treatment S_2T_3 (60 cm × 50 cm) × (2/3 organic + 1/3 inorganic) followed by the treatments S_3T_3 (20.45 cm) and S_1T_3 (20.07 cm), and the lowest was obtained from the treatment S_1T_1 (Table 2). These results are in agreement with previous reports where poultry manure and NPK had a higher head diameter compared to the control [29,32]. Kedino et al. [33] reported a higher head diameter in combined organic and inorganic fertilizer (FYM + NPK) applications.

The combined treatment of spacing and fertilizers S_2T_3 (60 cm × 50 cm) × (2/3 organic + 1/3 inorganic) produced the highest marketable weight (1.95 kg·plant^{-1}) (Table 2). The highest marketable yield was obtained in the plant spacing S_1compared to S_3 and S_2 (data not shown). It was hypothesized that there was a lower yield in higher plant spacing due to lower plant numbers. The plant spacing T_2 showed the best performance, except in the thickness of the cabbage and the diameter of the cabbage. No significant yield was found among the plant spacings S_2 and S_1. The marketable yield of the cabbage was highest in IPNS compared to other fertilizers treatments. In combination, IPNS fitted very well with the plant spacing T_2. S_1, S_2 and S_3 showed improved yield with IPNS compared to vermicompost, biogen and inorganic fertilizer (Table 2). IPNS showed improved results in our tomato trial compared with different types of organic and inorganic fertilizers,

conducted in the same year and at the same location of the cabbage experiment (Horticulture farm of BAU) [24]. The S_2T_3 application recorded the highest and S_3T_2recorded the lowest marketable yield in cabbage, which is in agreement with previous reports of cabbage and tomato [26,32,34–36].

4. Conclusions

The study showed that the integrated plant nutrient system (IPNS) is suitable for the improved growth and yield of cabbage with plant spacing (S_2, 60 cm × 50 cm). Organic and inorganic mixed fertilizers in a 60 cm × 50 cm spacing (S_2T_3) have the potential to enhance yield in cabbage and to reduce the quantity and doses of inorganic fertilizer.

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