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Growth and Yield of Broccoli (*Brassica oleracea* L. var. *italica*) Influenced by Organic, Inorganic Fertilizers and Plant Spacing

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ABSTRACT

An experiment was done at the horticulture farm, Dept. of Horticulture, Bangladesh Agricultural University (BAU), Mymensingh, to evaluate broccoli's growth and yield performance by applying organic and inorganic fertilizers and uses of various plant spacing. Two factor experiments were conducted on four (4) levels of organic and inorganic fertilizers viz., F1 (Control, no manure and fertilizer), F2 (Cowdung 20 t/ha), F3 (Urea 228 t/ha + TSP 180 kg/ha + MoP 120 kg/ha) and F4 (F2 50% + F3 50%) and three plant spacings viz., S1 (60 cm x 50 cm), S2 (50 cm x 50 cm) and S3 (50 cm x 40 cm); in the Randomized Complete Block Design (RCBD) with three replications and all the parameters studied were significantly influenced. All the parameters studied were found significant. Application of F_2 (50%) + F_3 (50%) per hectare showed the best performance on different growth parameters like plant height, the number of leaves, crown spread, minimum days taken to curd initiation, and broccoli yielded the most (16.12 t/ha). The best growth and maximum yield ((15.50 t/ ha) of broccoli was acquired by the spacing of S3 (50 cm x 40 cm). The plant height (60.45 cm), crown spread (62.45 cm), number of leaves per plant (11.60), minimum days taken to curd initiation (51.49) and yield per plant (437.83 g) were gained maximum from the treatment combination of F4S1 and the lowest were recorded from F1S3 (no manure and fertilizer with the closest spacing 50 cm x 40 cm). F4S3 treatment produced maximum gross yield per plot (11.56 kg) and yield per hectare (19.26 t/ha) but F1S1 treatment produced minimum yield per plot (5.72 kg) and yield per hectare (9.53 t/ha). The results suggest that treatments of F4 (F_2 50% + F_3 50%) and the closest spacing S3 (50 cm x 40 cm spacing), produce the most broccoli. The best results for all evaluated parameters were obtained using a combination of organic and inorganic fertilizers, with closet spacing producing the highest broccoli yield.

Keywords: *Organic, Inorganic fertilizers, Spacing, Influence, Growth, Yield, Broccoli*

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INTRODUCTION

Broccoli (*Brassica oleracea* L. var. *Italica*) is a vegetable crop that belongs to the Brassicaceae family of plants. Broccoli is one of the world's most popular vegetables. The broccoli curd is made up of a green curd that quickly develops into a multitude of fruitful flower buds after being generated from a dense flower head. (Xaxa et al., 2018). Broccoli is high in many nutrients, including fibre, vitamin C, vitamin K, iron, potassium and manganese and many plant compounds that have been associated with health benefits. Sulforaphane is the most plentiful, which may assist in preventing cancer. (Yuan et al., 2009). It also contains more protein than the majority of vegetables. This green vegetable can be consumed raw or cooked, although current research shows that mild steaming delivers the most health advantages. Broccoli is becoming increasingly popular nowadays due to its numerous uses and excellent nutritional content (Rangkadilok et al., 2004). Broccoli is enriched in glucosinolates, which have anti-cancer properties. Broccoli eaten more than once a week has been demonstrated to cut cancer incidence by 45 per cent and actually mitigate infection with retinal disorders. (Kirsh et al., 2007). Nutrients may be applied through two sources: organic and inorganic. Organic fertilizers are beneficial to the soil's physical and nutritional health. It also improves microflora activities. Organic fertilizers are better for the environment since they have a higher cation exchange capacity, a lower bulk density, a higher water holding capacity, and more nutrients. The decomposition of organic matter in the soil triggers a number of biological responses that aid in the prevention of disease-causing microorganisms. (Ramesh et al., 2010). Inorganic fertilizer (N, P, K) boosts broccoli's vegetative growth, yield, and quality. (Nkoa et al., 2002). Excessive chemical fertilizer use has unanticipated environmental consequences.

In contrast, mixed fertilizers blend organic and inorganic fertilizers to improve soil quality and productivity. This lowers the requirement for inorganic fertilizer in crop production. A high number of tomatoes per plant and plant height were obtained from mixed fertilizers (Islam et al., 2017).

Plant spacing is crucial in plant growth and development because it affects canopy formation, soil moisture loss, weed management, light interception, and crop growth rate, among other cultural practices. Closer spacing hinders intercultural operations by increasing plant competition for nutrients, air, and light, whereas broader spacing results in larger plants with more robust growth and greater quality output. It promotes the development of more leaves, branches, and healthy foliage. (Kaur et al., 2021). The plant spacing means the distance between cultivated plants and broccoli is usually planted at a distance of 50 cm between one plant and another. The quantity of the crop, as well as the size, diameter, and weight of the primary curds, are all affected by plant spacing. It also affects the quantity of sub-curds created by the plants and the formation date and growth completion of the curds, where density affects the flowering duration. (Hussainy & Manea, 2019). Depending on how close they are grown, they can also receive less air than they require for proper growth. Plants can be more vulnerable to depositing essential nutrients if they are not provided with enough space.

MATERIALS AND METHODS

The research was conducted at Bangladesh Agricultural University's Horticulture Farm, Department of Horticulture, Mymensingh during the period from October, 2018 to March 2019. The experimental region is part of the Brahmaputra Flood Plain's Agro-ecological Zone-9 (AEZ-9) (FAO, 1988). The three replications of the two-factor experiment were set up in a randomized complete block design. One factor consisted of Organic, Inorganic fertilizer viz., F_1 = Control, no use of organic, inorganic fertilizer, F_2= Cowdung (20 t/ha), F_3 = Urea 228 kg/ha + TSP 180 kg/ha + MoP 120 kg/ha [BARC 2012], F_4 = F_2 (50%) + F_3 (50%) and other one having Plant spacing viz., S_1 = 60 cm x 50 cm, S_2 = 50 cm x

50 cm and S_3 = 50 cm x 40 cm. The variety used in this experiment was "Premium Crop" hybrid broccoli. The seed of the said variety was produced by Takii & Co. Ltd. Kyoto, Japan and was gathered from a local seed supply agency. On 27 October, 2018, ten gm (10 g) of seeds were sown in the seedbed at Bangladesh Agricultural University's Horticulture Farm, Mymensingh. Organic, inorganic, and plant spacing combinations were randomly distributed to each block based on the treatment combination. The treatment combinations are 12. The total experimental area (28.5 x 16.5 m) was split into three equal blocks, representing the replications. Each unit plot measured 3m x 2m in size. The total number of plots was 36. The space between two adjacent blocks and plots were maintained at 50 cm and 50 cm, respectively. Each block contained 12 plots. Organic and Inorganic fertilizer were applied to the field as per treatment of the experiment. Organic manures and TSP were applied during final land preparation. Urea and MP were given in three instalments, with the first instalments occurring 30 days following transplantation. The second and third instalments were top-dressed after 45 and 60 days of transplanting (FRG, 2012). Uniform-sized 25 days old seedlings were transplanted in the experimental plots on 20 November, 2018. Each plot had 20, 24 and 30 plants at the spacings of 60 cm x 50 cm, 50 cm x 50 cm and 50 cm x 40 cm respectively. Irrigation, weeding, mulching, staking, etc. were done as and when required. To protect young plants, the soil was sprayed with insecticides (Cinocarb 3G @ 4 kg/ha) during final field preparation. The 1st harvesting was done at first on 28 January, and the last harvesting was done on 4 March, 2019.

Statistical Analysis

The MSTAT statistical package program was used to collect and statistically evaluate data on various parameters. The MSTAT statistical package program was used to collect and statistically evaluate the mean for all t on various parameters. The mean for all treatments was calculated, and the F-test was used to do the analysis of variance for all characters. The least significant difference (LSD) test was used to determine the significance of differences between the pairs of treatment means. (Gomez & Gomez, 1984).

RESULTS

Growth parameters

Plant growth parameters are influenced by different levels of organic and inorganic fertilizers, as well as plant spacing i.e. plant height, crown spread, number of leaves, length of the longest leaf, Days required for visible curd initiation, weight of primary curd, weight of secondary curd, fresh weight of leaves, diameter of the stem.

Plant height

The use of various quantities of organic and inorganic fertilizers significantly impacts plant height. At 30, 45, and 60 days after transplanting (DAT), plant height was measured. At 60 days after transplant, the F4 (F2 50% + F3 50%) treatment produced the highest plant height (57.93 cm) and the F1 (control) treatment produced the lowest (47.79 cm) (Fig. 1A). At 60 DAT, the tallest plant (55.23 6 cm) was measured at the widest spacing S1 (60 cm x 50 cm), while the shortest (50.72 cm) was measured at the closest spacing S3 (50 cm x 40 cm). **(**Fig. 2A). For the combined impacts of various organic + inorganic fertilizer doses and various plant spacing, the highest plant height (60.45 cm) was acquired from the treatment combination of F_4S_1 (F_2 50% + F_3 50% and 60 cm x 50 cm plant spacing) and lowest (42.52 cm) from the treatment combination of control treatment with closest spacing (50 cm x 40 cm) at maximum vegetative stage (table 1).

Crown spread of plant

For crown spread of plants, The widest plant canopy (58.23 cm) was achieved with the F4 (F2 50% + F3 50%) treatment with organic and inorganic fertilizer administration at 60 DAT. In contrast, the smallest (51.05 cm) was observed with the control at the maximum vegetative stage (Fig. 1B). The plant spacing at 60 DAT, the widest spacing (60 cm x 50 cm) produced the maximum crown spread

(55.99 cm). In contrast, the closest spacing (50 cm x 40 cm) gave the minimum crown spread (52.17 cm) (Fig. 2B). At 60 DAT, the combined impacts of organic and inorganic fertilizers and plant spacing, the treatment combination of F4S1 (F2 50% + F3 50% and 60 cm × 50 cm plant spacing) produced the greatest crown spread (62.45 cm) and the smallest (50.01 cm) with the control treatment with the closest spacing (50 cm x 40 cm) at maximum vegetative stage. (Table 1)

Number of leaves per plant

At 60 DAT at maximum vegetative stage, the treatment combination F4S1 (F2 50% + F3 50% and 60 cm x 50 cm plant spacing) generated the highest number of leaves per plant (11.60), while the treatment combination F1S3 (control and 50 cm x 40 cm plant spacing) generated the lowest number of leaves per plant (8.02). (Table 2).

Length of largest leaf

At 60 DAT at maximum vegetative stage, the treatment combination F4S1 (F2 50% + F3 50% and 60 cm × 50 cm plant spacing) generated the longest leaf (52.51 cm), while the treatment combination F1S3 (control and 50 cm x 40 cm plant spacing) generated the shortest leaf (40.02 cm). (Table 2).

Days required for visible curd initiation

Days required for visible curd initiation, the lowest time (51.49) was needed for curd initiation was achieved from the F_4S_1 (F_2 50% + F_3 50% and 60 cm x 50 cm plant spacing) treatment. In contrast, the longest time (61.48) required from the treatment combination of F_1S_3 (control and 50 cm x 40 cm plant spacing) (Table 3).

Weight of primary curd per plant

The treatment combination F4S1 (F2 50% + F3 50% and 60 cm x 50 cm plant spacing) generated the most weight of primary curd per plant (352.21 g), while the treatment combination F1S3 produced the least weight of primary curd per plant (192.95 g) (control and 50 cm x 40 cm plant spacing) (Table 3).

Weight of secondary curd per plant

The maximum secondary curd weight (85.62 g) was acquired from the F4S1 treatment combination (F2 50% + F3 50% and 60 cm x 50 cm plant spacing) while the lowest curd weight (33.76 g) was reported from the F1S3 treatment combination (control and 50 cm x 40 cm spacing) (Table 3).

Fresh weight of leaves per plant

The F4S1 treatment (F2 50% + F3 50% and 60 cm × 50 cm plant spacing) had the highest fresh weight of leaves per plant (73.18 g), whereas the F1S3 treatment (control and 50 cm x 40 cm plant spacing) had the lowest (42.31 g). (Table 3).

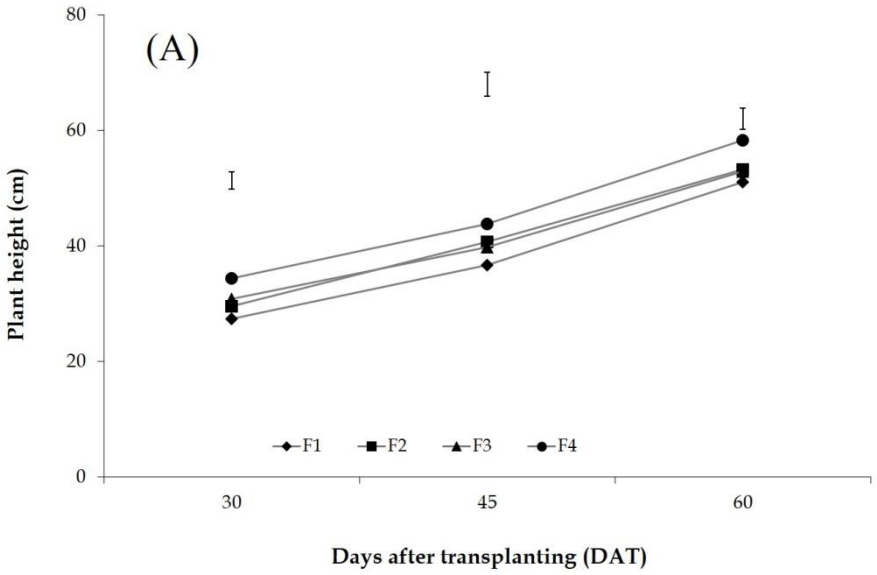
Diameter of stem

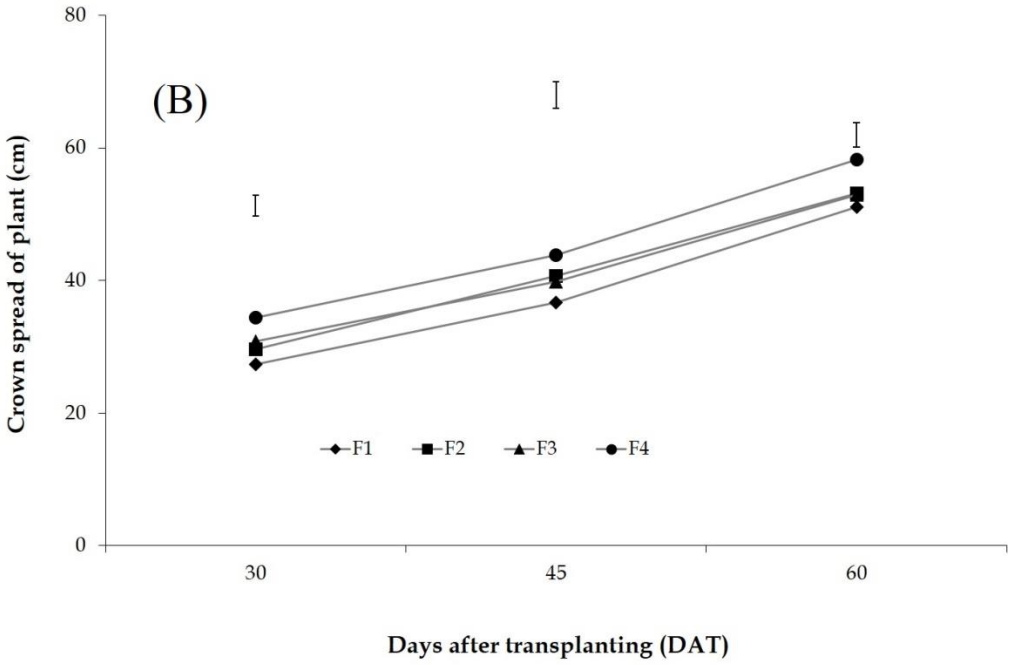
The diameter of the stem is largest (3.93 cm) in the F4S1 treatment (F2 50% + F3 50% and 60 cm × 50 cm plant spacing) and smallest (2.98 cm) in the F1S3 treatment (control and 50 cm x 40 cm plant spacing). (Table 3).

Yield contributing traits and yield of broccoli

The treatment combination F4S1 (F2 50% + F3 50% and 60 cm × 50 cm plant spacing) produced the maximum yield per plant (437.83 g), while the treatment combination F1S3 produced the lowest yield per plant (226.71 g) (control and 50 cm x 40 cm plant spacing) (Table 3). The combination of organic, inorganic fertilizers and plant spacing, the treatment combination of F4S3 (F2 50% + F3 50% and 50 cm x 40 cm plant spacing) produced the maximum yield per plot (11.56 kg), while the treatment combination of F1S1 produced the lowest yield per plot (5.72 kg) (control and 60 cm x 50 cm plant spacing) (Table 3). The highest yield per hectare (16.12 t) was noted from F_4 (F_2 50% + F_3 50%) treatment while the lowest curd yield per hectare (10.82 t) was acquired with control treatment (Fig. 1C). For plant spacing, the S3 (50 cm x 40 cm) treatment produced the highest yield per hectare (15.50 t), while the S1 (60 cm × 50 cm) treatment produced the lowest yield per hectare (12.04 t). (Fig. 2C). The combination of organic, inorganic fertilizers and plant spacing, the treatment combination of F4S3 (F2 50% + F3 50% and 50 cm x 40 cm plant spacing) provided the best yield per hectare (19.26 t), while the treatment combination of F1S1 provided the

lowest yield per hectare (9.53 t) (control and 60 cm x 50 cm plant spacing) (Fig. 3).





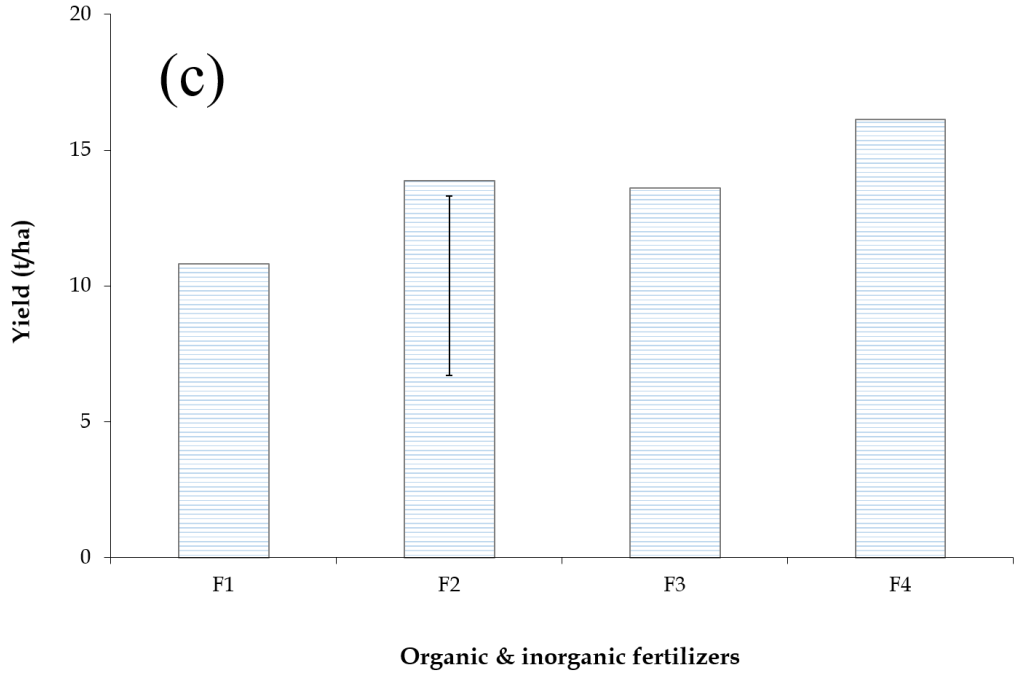
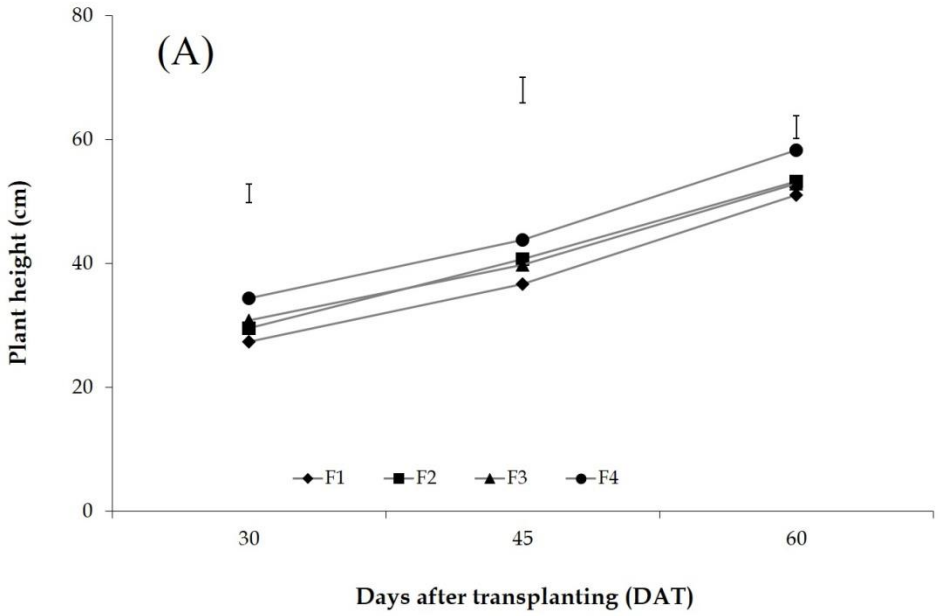
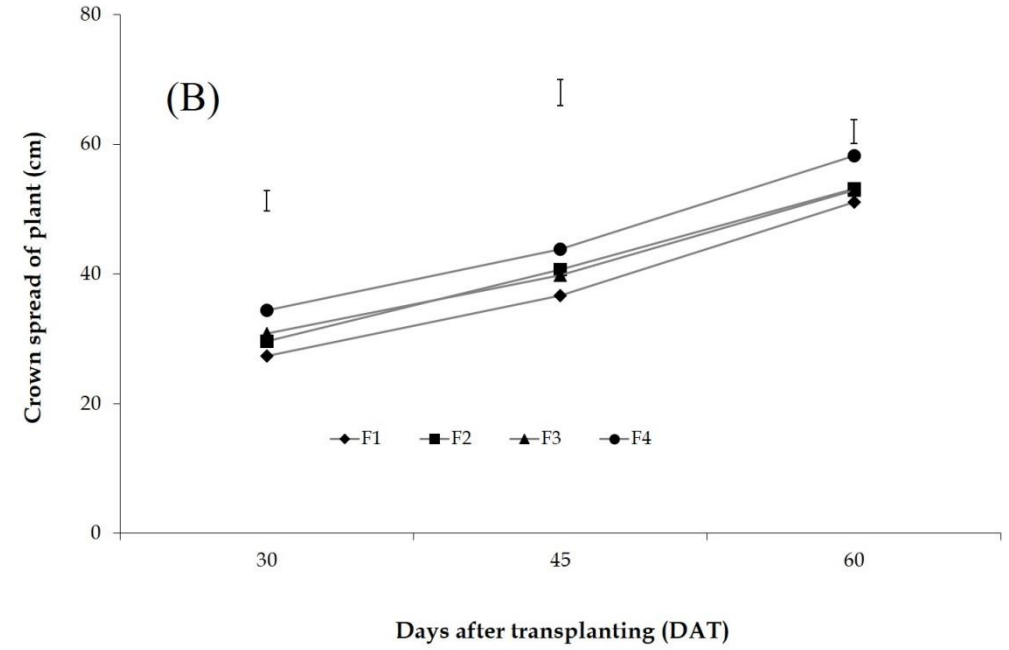


Figure 1. Effect of organic and inorganic fertilizers on plant height (A), crown spread of plant (B) and yield (C) of broccoli. The vertical bars represent LSD at 1% level of significance. F_1 = Control, F_2 = Cowdung (20 t/ha), F_3 = Urea 228 kg/ha + TSP 180 kg/ha + MoP 120 kg/ha and F_4 = F_2 (50%) + F_3 (50%).





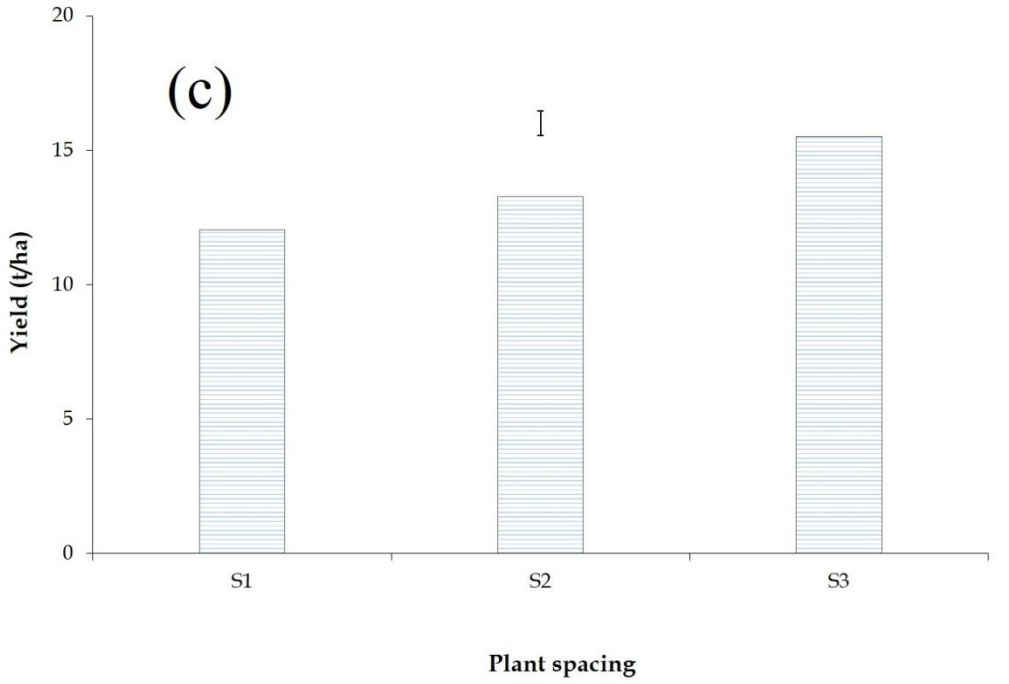


Figure 2. Effect of plant spacing on (A) plant height, (B) crown spread of plant, and (C) yield of broccoli. The vertical bars represent LSD at 1% level of significance. S_1 = 60 cm x 50 cm, S_2 = 50 cm x 50 cm and S_3 = 50 cm x 40 cm.

Table 1. Combined effects of plant spacing and organic-inorganic fertilizers on plant height and crown spread of plant at different days after transplanting of broccoli

Treatment combination	Plant height (cm) at different days after transplanting (DAT)			Crown spread of plant (cm) at different days after transplanting (DAT)			
	30	45	60	30	45	60	
S_1F_1	28.10	40.53	51.74	30.03	40.61	52.49	
S_1F_2	29.97	41.70	53.26	31.60	41.70	55.19	
S_1F_3	30.37	43.37	55.48	33.24	42.42	53.83	
S_1F_4	38.41	46.67	60.45	36.85	46.38	62.45	
S_2F_1	23.25	35.57	49.12	27.08	39.34	50.65	
S_2F_2	28.45	40.44	51.70	31.40	40.52	52.38	
S_2F_3	30.25	42.73	55.34	30.80	39.22	52.86	
S_2F_4	38.21	46.01	57.17	33.89	42.62	57.63	
S_3F_1	17.22	33.14	42.52	24.98	29.98	50.01	
S_3F_2	28.34	40.16	50.84	25.81	39.89	52.00	
S_3F_3	28.26	41.02	53.33	28.28	37.83	52.05	
S_3F_4	31.06	45.91	56.16	32.45	42.39	54.62	
$LSDs_{0.05}$	1.37		1.36	1.54	1.33	1.77	1.61
$LSD_{0.01}$	1.86		1.85	2.10	1.81	2.40	2.19
Level of significance	**		**	**	**	**	**

** = Significant at 1% level of probability, F_1 = Control, F_2 = Cowdung (10 ton/ha), F_3 = 325 kg/ha Urea + 150 kgkg/ha TSP + 140 kg/ha MoP, F_4 = 5 ton/ha cowdung + 215 kg/ha Urea + 75 kg/ha TSP + 80 kg/ha MoP, S_1 = 60cm x 50 cm, S_2 = 50cm x 50 cm, S_3 = 50cm x 40 cm

Table 2. Combined effects of plant spacing and organic-inorganic fertilizers on number of leaves/plant and length of largest leaf at different days after transplanting of broccoli

Treatment combination	No. of leaves/plant at different days after transplanting (DAT)			Length of largest leaf (cm) at different days after transplanting (DAT)		
	30	45	60	30	45	60
S_1F_1	7.81	7.78	8.87	12.95	31.45	41.93
S_1F_2	8.37	8.78	10.56	16.35	32.51	50.95
S_1F_3	8.67	8.94	10.63	16.56	31.25	42.55
S_1F_4	8.92	9.20	11.60	17.37	33.13	52.51
S_2F_1	6.79	7.74	8.19	11.24	30.95	40.30
S_2F_2	7.53	8.70	10.38	15.92	32.47	48.97
S_2F_3	7.23	8.83	9.38	16.27	31.04	41.85
S_2F_4	7.94	8.81	10.35	16.37	32.53	50.70
S_3F_1	6.37	7.39	8.02	10.51	30.56	40.02
S_3F_2	7.50	7.84	9.48	15.48	31.68	48.31
S_3F_3	7.16	8.54	9.33	16.10	31.04	40.02
S_3F_4	7.79	8.73	9.97	16.05	32.38	50.47
$LSDs_{0.05}$	0.16	0.25	0.29	0.34	0.17	0.50
$LSD_{0.01}$	0.22	0.33	0.39	0.46	0.23	0.67
Level of significance	**	**	**	**	**	**

** = Significant at 1% level of probability, F_1 = Control, F_2 = Cowdung (10 ton/ha), F_3 = 325 kg/ha Urea + 150 kgkg/ha TSP + 140 kg/ha MoP, F_4 = 5 ton/ha cowdung + 215 kg/ha Urea + 75 kg/ha TSP + 80 kg/ha MoP, S_1 = 60cm x 50 cm, S_2 = 50cm x 50 cm, S_3 = 50cm x 40 cm

Table 3. Combined effects of plant spacing and organic-inorganic fertilizers on yield and yield contributing characters of broccoli

Treatment combination	Days required to curd initiation	Weight of primary curd/plant (g)	Weight of secondary curd/plant (g)	Fresh weight of leaves (g)	Diameter of stem (cm)	Yield/plant (g)	Yield/plot (kg)
S_1F_1	57.82	239.48	46.40	52.36	3.60	285.88	5.72
S_1F_2	55.33	283.00	68.24	68.20	3.70	351.24	7.02
S_1F_3	53.22	297.36	72.23	63.22	3.86	369.59	7.39
S_1F_4	51.49	352.21	85.62	73.18	3.93	437.83	8.76
S_2F_1	57.84	248.50	41.30	51.00	3.30	289.80	6.96
S_2F_2	55.43	276.62	66.61	59.04	3.64	343.23	8.24
S_2F_3	54.22	276.35	56.59	61.24	3.55	332.94	7.99
S_2F_4	51.80	288.56	74.10	70.64	3.87	362.67	8.70
S_3F_1	61.48	192.95	33.76	42.31	2.98	226.71	6.80
S_3F_2	56.45	272.13	52.03	56.74	3.59	324.17	9.73
S_3F_3	55.00	251.30	52.39	54.83	3.14	303.69	9.11
S_3F_4	52.32	311.29	73.89	67.06	3.16	385.18	11.56
$LSDs_{0.05}$	0.142	8.56	2.59	1.78	0.09	8.10	0.23
$LSD_{0.01}$	0.193	11.64	3.52	2.42	0.13	11.01	0.31
Level of significance	**	**	**	**	**	**	**

** = Significant at 1% level of probability, F_1 = Control, F_2 = Cowdung (10 ton/ha), F_3 = 325 kg/ha Urea + 150 kgkg/ha TSP + 140 kg/ha MoP, F_4 = 5 ton/ha cowdung + 215 kg/ha Urea + 75 kg/ha TSP + 80 kg/ha MoP, S_1 = 60cm x 50 cm, S_2 = 50cm x 50 cm, S_3 = 50cm x 40 cm

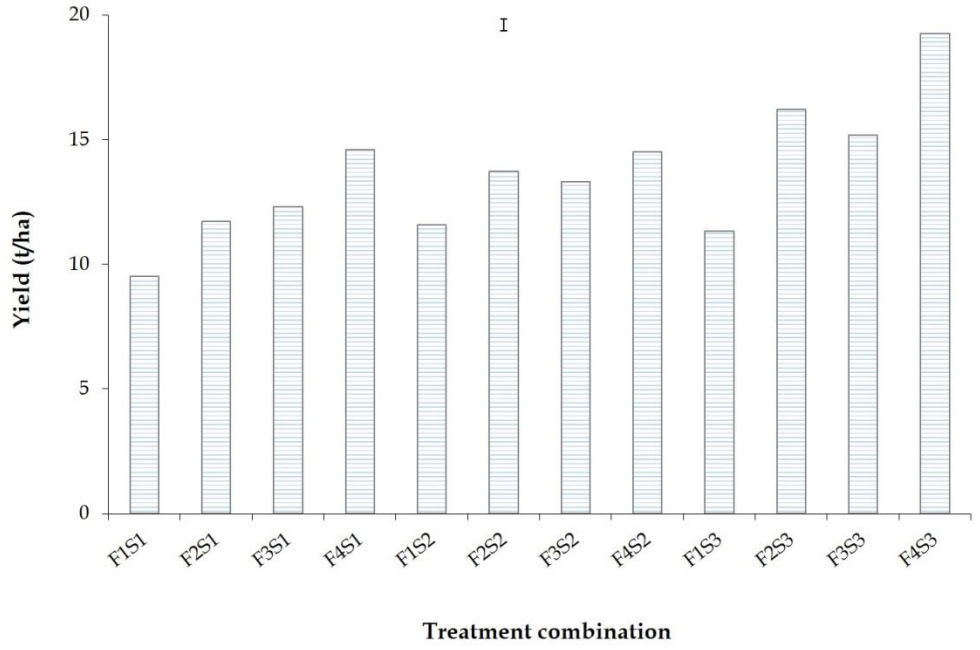


Figure 3. Combined effect of organic-inorganic fertilizers and plant spacing on yield of broccoli. The vertical bar represents LSD at 5% level of significance. , F_1 = Control, F_2 = Cowdung (10 ton/ha), F_3 = 325 kg/ha Urea + 150 kg kg/ha TSP + 140 kg/ha MoP, F_4 = 5 ton/ha cowdung + 215 kg/ha Urea + 75 kg/ha TSP + 80 kg/ha MoP, S_1 = 60cm x 50 cm, S_2 = 50cm x 50 cm, S_3 = 50cm x 40 cm.

DISCUSSION

The organic, inorganic fertilizers and plant spacing substantially impacted broccoli development and yield. On various days after transplanting, significant doses of organic and inorganic fertilizers are applied on the broccoli under study. Under the F4 (F2 50% + F3 50%) treatment, all of the parameters were determined to be at their maximum. The finding is consistent with the report of Singh et al. (2010) on cauliflower. This could be owing to the availability of nutrients, particularly organic manures, and an improvement in soil water holding capacity, as Roe and Cornforth (2000) discussed earlier. They noticed that applying the manure to the muskmelon and broccoli sales boosted the greatest potential net income.

Furthermore, Organic manure activates a variety of living organisms, releasing phytohormones that may boost plant growth and nutrient uptake (Arisha et al., 2003). For multiplication, such organisms require nitrogen. This is a feasible explanation for why using organic manure with inorganic fertilizer improved dry matter buildup.

For plant spacing, the plant height, crown spread of plant, number of leaves per plant and length of largest leaf, minimum days taken to curd initiation, weight of primary curd, weight of secondary curds, fresh weight of leaves per plant and diameter of stem were found maximum under wider spacing (60 cm x 50 cm). These outcomes could be due to favourable environmental circumstances that existed throughout the crop's initial growth. The current findings are similar to those of Uddain et al. (2012) in knolkhol and Yadav et al. (2013) in cauliflower. Plants planted in wider spacing experience less competition for space, nutrients and light between the plants and thus have maximum food accumulation ability. This resulted in luxurious vegetative growth and the largest possible curd weight. These findings are consistent with previous cauliflower research. (Khatun et al., 2011) and broccoli (Hossain et al., 2010). Under close spacing, the total yield per plot and per hectare was highest (50 cm x 40 cm). This was owing to a larger plant population per unit area. These findings are in close accordance with findings of in broccoli (Bhangre et al., 2011). In quality aspects such as maximum chlorophyll content in leaves and maximum vitamin C content in heads (60 cm x 50 cm), greater spacing was achieved. Plants grown at wider spacing, resulting in enhanced photosynthesis and dry matter content. Similar findings in broccoli were previously reported (Bola et al., 2017). The TSS of sprouting broccoli was unaffected by the spacing.

The use of a combination of organic and inorganic fertilizers, as well as plant spacing, had a substantial impact on plant height. The plant height, crown spread , number of leaves per plant, length of largest leaf, minimum days taken to curd initiation, weight of primary curd, weight of secondary curds, fresh weight of leaves per plant and diameter of stem were found to be maximum from the treatment combination of F4S1 (F2 50% + F3 50% and 60 cm x 50 cm plant spacing) and the lowest were recorded with the treatment combination of control with closest spacing (50 cm x 40 cm) at maximum vegetative stage. F4S1 (F2 50% + F3 50% and 60 cm x 50 cm plant spacing) had the best yield per plot and yield per hectare, whereas control with the closest spacing had the lowest (50 cm x 40 cm).

CONCLUSION

According to the findings of this study, broccoli responded effectively to the application of organic and inorganic fertilizers, plant spacing, and their interaction in terms of growth, yield, and net profit. The best treatment combination (F2 50% + F3 50% and 50 cm x 40 cm plant spacing) provided the maximum yield of 19.26 t/ha and was also the most profitable for broccoli production. On the other side, the treatment combination of (control and 60 cm x 50 cm plant spacing) had the lowest yield of 9.53 t/ha.

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