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RESEARCH ARTICLE

Effects of organic manures and mulches on the growth and yield of broccoli (*Brassica oleracea* var. *italica*) in Bangladesh

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Abstract

This investigation was carried out at the Horticulture Farm, Department of Horticulture, Bangladesh Agricultural University, Mymensingh, Bangladesh during the period of November 2022 to March 2023. The purpose of the study was to analyse the effects of various combinations of organic manures and mulches on the growth, yield contributing traits and yield of broccoli. The factorial experiment conducted with 4 levels of organic manures viz., O_1: Control (no manure applied), O_2: 10 t/ha cowdung, O_3:5 t/ha vermicompost, O_4: 5 t/ha cowdung + 2.5 t/ha vermicompost and 4 types of mulching materials viz., M_1: Control (Non-mulch), M_2: Black polythene, M_3: Water hyacinth, M_4: Rice straw. The study was set up following randomized complete block design (RCBD) with 3 replications. Results show that at 60 days after transplanting (DAT), the maximum plant height (61.35 cm), minimum days required to curd initiation (45.93) and yield per hectare (14.21 t) were obtained from O_4 (5 t/ha cowdung + 2.5 t/ha vermicompost) treatment and the minimum results found from the control treatment (O_1). In case of mulching treatment, M_2 (black polythene) mulching treatment produced the maximum plant height (63.21 cm), minimum days required to curd initiation (47.14) and the highest yield per hectare (14.22 t) at 60 DAT. The results obtained from control treatment were the lowest. It was also observed that the combination of M_2O_4 (black polythene mulch with 5 t/ha cowdung + 2.5 t/ha vermicompost) gave the highest yield (16.03 t/ha) as compared to the control treatment (7.96 t/ha). It is concluded that black polythene mulch along with 5 t/ha cowdung and 2.5 t/ha vermicompost could be an effective technology to get higher yield of broccoli.

Keywords: broccoli; black polythene; cow dung; rice straw; vermicompost; yield contributing traits; yield

Introduction

Broccoli (genus *Brassica*), which is a two-season water-demanding Cole crop, is a member of the Brassicaceae family (1, 2). It is a native of the Mediterranean region (Cauliflower is a distinct but closely related group of cultivars belonging to the same *Brassica* genus as broccoli) (3). Among the different varieties of broccoli, green broccoli has achieved greater commercial importance and consumer preference compared to the white and purple cultivars (4). At the vegetative stage, the edible part is the flower buds and the curd stem (5, 6).

Broccoli is absolutely rich in carotene, ascorbic acid, including appreciable amounts of thiamin, riboflavin, niacin and iron (7–9). It is a significant provider of nutrition, which is dietary fibre (2.6 %), protein (3.3 %), fat (3.3 %), carbohydrate (5.5 %), vitamin A, B and C, antioxidants, phytochemicals and minerals like phosphorus (P), calcium (Ca), magnesium (Mg), manganese (Mn), iron (Fe), zinc (Zn) and selenium (Se) (10–13). A few significant phytochemicals are also found in it, such as indol-3-carbinol and betacarotene that aid in the prevention of lung and breast cancer. Phytochemicals stop the formation of carcinogens or substances that cause cancer (14–16). Broccoli contains plenty of sulforaphane, which is an anticancer compound and eating broccoli once a week reduces the risk of cancer by 45 % (16–18).

Organic manure is a vital component that enhances soil fertility and reduces the need for chemical fertilisers. It also increases productivity and encourages sustainable agriculture (19–21). Organic manure holds all micro and macro nutrients that are essential for plants (22). It raises the overall microbial population of nitrogen-fixing bacteria, actinomycetes and promotes mycorrhizal symbiotic relationships in plant roots. Bioinoculant, which is a free-living nitrogen-fixing bacteria, fixes 25 –30 kg N/ha and generates hormones such as indole acetic acid (IAA) as well as gibberellins, vitamins namely biotin and folic acid and other B-groups. Azospirillum develops soil fertility and boosts plant growth by promoting the quantity and biological function of formed microorganisms in the root circumstance. Mulching is an useful agronomic cultural method that has been promoted for several reasons, including maintaining soil moisture, preventing the growth of weeds, pests and diseases, regulating the physical, chemical and biological environment of the soil, encouraging hydrothermal regimes, reducing nutrient and water losses, enhancing organic matter build-up and nutrient recycling and raising crop yield and water use efficiency (23). Mulch conserves the soil moisture and nutrients; it also decreases leaching loss and water evaporation (24–27). Mulching can minimise the requirement of water and help in retaining moisture (28–31). In

addition, mulch lessens the need for irrigation by preventing evaporation of soil water (29–34). In Bangladesh, broccoli is grown in the winter, when there is little rainfall. To transplant, grow and form curds, broccoli consumes 240–300 mm of water (35). Keeping in view, the present study was formulated to select the suitable dose of organic manure and mulching materials for quality, high-value broccoli production.

Materials and Methods

Description of experimental sites, climate and soil

The experimental work was conducted at the Horticulture farm, Bangladesh Agricultural University (BAU), located at 24.60 N latitude and 90.50 E longitude, during the Rabi season (November 2022 – March 2023) (36). The area under examination is around 19 m above sea level. The soil texture of the experimental area was silty loam with pH varying from 6.68 to 6.92 (37). The topography of the selected plot of land was medium-high land. The old Brahmaputra floodplain alluvial land texture, which falls under Agro ecological zone 9. The selected plot was at medium elevation and had remained fallow during the previous year. The nutrient status of the farm's soil within a depth of 0–20 cm was tested by the Humboldt Soil Testing Laboratory, Department of Soil Science, BAU.

Experimental treatments and design

The two-factor research, which comprised of 16 treatment combinations and was laid out in a randomized complete block design (RCBD) with 3 replications. The total experimental area was divided into 3 blocks each of which was sub-divided into 16 plots. The total number of plots was 48. Organic manure viz., cowdung 10 t/ha, vermicompost 5 t/ha and 5t cowdung + 2.5 t/ha vermicompost, were applied to the field according to the treatment regimen. Three types of mulches, including black polythene, water hyacinth and rice straw were used. Organic mulching was placed on the respective plots as per layout.

Measurement of growth traits

The growth parameters recorded in this study were plant height (cm), number of leaves per plant, leaf diameter (cm), largest leaf length (cm) and days required for curd initiation. Plant height was measured from the base of the plant at the soil surface to the tip of the tallest leaf to use scale. Leaf diameter and largest leaf length were measured using a measuring tape. The number of leaves per plant was counted manually. Plant height, number of leaves per plant and leaf diameter were recorded at 30, 45 and 60 days after transplanting (DAT). Days to curd initiation were calculated as the number of days from transplanting to the visible appearance of the curd.

Measurement of yield and yield contributing

The parameters of the collected data from the experimental field were diameter of curd, weight of curd, number of primary curds per plot, number of secondary curds per plant, number of secondary curds per plot, weight of secondary curd per plant, weight of secondary curd per plot, diameter of secondary curd per plant, yield per plant, yield per plot and yield per hectare. Slide calipers, digital weighing scale, Vernier caliper, measuring tape were used in this case.

Statistical analysis

After calculating the mean value for each treatment, the *F* variance test was used to analyse the variance for the majority of the characters in question. The Least Significant Difference (LSD) of the test was taken at 1 % and 5 % the level of probability (38). Statistical analysis carried out through Statistix 10.

Results

Effects of manures and mulches on the growth parameters

The present experiment was conducted to determine the appropriate doses of organic manures and suitable mulching materials for the growth and yield of broccoli. The results of the effects of cowdung, vermicompost and different mulching materials on the growth and yield of broccoli are presented chronologically.

Plant height is an important growth attribute of broccoli. At 60 DAT, the highest plant height (61.35 cm) was measured from 5 t/ha cowdung + 2.5t/ha vermicopost (O_4), whereas the lowest plant height (53.48 cm) was recorded from control treatment (O_1) 0 kg/ha (Fig. 1). With respect to mulching, the tallest plant (63.21 cm) was obtained under the treatment of black polythene mulch (M_2) and the shortest plant (51.17 cm) was recorded from no mulching treatment (M_1) at 60 DAT (Fig. 2). The combination of organic manure and mulching materials also showed significant effect on plant height (cm) of broccoli at different DAT. The highest plant height (67.83 cm) was measured from the combination of black polythene and 5 t/ha cowdung + 2.5 ton/ha vermicompost (M_2O_4) and the lowest plant height (48.17 cm) was recorded from the treatment where no organic manure and mulching (M_1O_1) were used at 60 DAT.

The maximum number of leaves per plant (18.92) was counted from 5 t/ha cowdung + 2.5 t/ha vermicompost (O_4) and the minimum number of leaves (14.33) was recorded from control treatment of organic manure 0 kg/ha (O_1) at 60 DAT (Fig. 3). In case of mulching the maximum number of leaves per plant (19.42) was found from black polythene (M_2) and the minimum number of leaves per plant (14.17) was recorded from no mulching (M_1) at 60 DAT (Fig. 4). The highest number of leaves (22) was obtained from the combination of black polythene and 5 t/ha cowdung + 2.5 t/ha vermicompost (M_2O_4).

The longest leaf (47.63 cm) was found in 5 t/ha cowdung + 2.5 t/ha vermicompost (O_4) and the shortest leaf (41.88 cm) was obtained from control (O_1) treatment (Fig. 5). The maximum leaf length (45.97 cm) was obtained from black polythene (M_2) and the minimum (43.37 cm) was found from no mulching (M_1) (Fig. 6). Among the treatment combination it was found that the highest length of the largest leaf length (48.72 cm) at 60 DAT was observed in treatment of black polythene and 5 t/ha cowdung + 2.5 t/ha vermicompost (M_2O_4) and the lowest (40.30 cm) at control treatment no organic manure and mulching (M_1O_1) at 60 DAT.

The widest leaf (36.54 cm) was measured from 5 t/ha cowdung + 2.5 t/ha vermicompost (O_4) treatment and the narrowest (27.29 cm) was recorded from control treatment (O_1) at 60 DAT (Fig. 7). The highest leaf diameter (35.71 cm) was recorded from black polyene (M_2) and the lowest diameter (27.04 cm) was recorded from no mulching (M_1) treatment at 60 DAT (Fig. 8). The maximum leaf diameter (42.83 cm) was found from the treatment combination of black polythene and 5 t/ha cowdung + 2.5 t/ha vermicompost (M_2O_4).

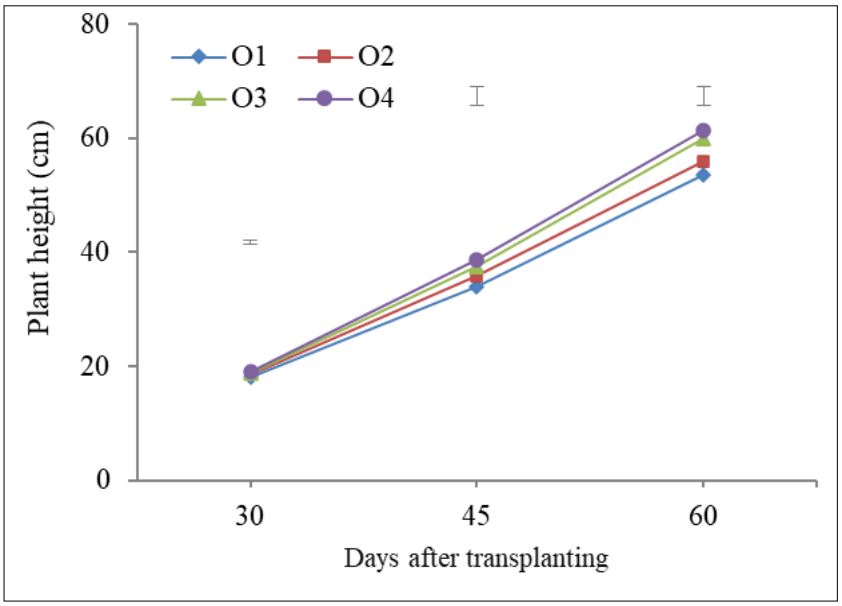

Fig. 1. Effects of organic manure on plant height of broccoli. Vertical bars represent LSD at 1 % level of significance. O_1: Control (no manure applied), O_2: 10 t/ha cowdung, O_3: 5 t/ha vermicompost, O_4: 5 t/ha cowdung + 2.5 t/ha vermicompost.

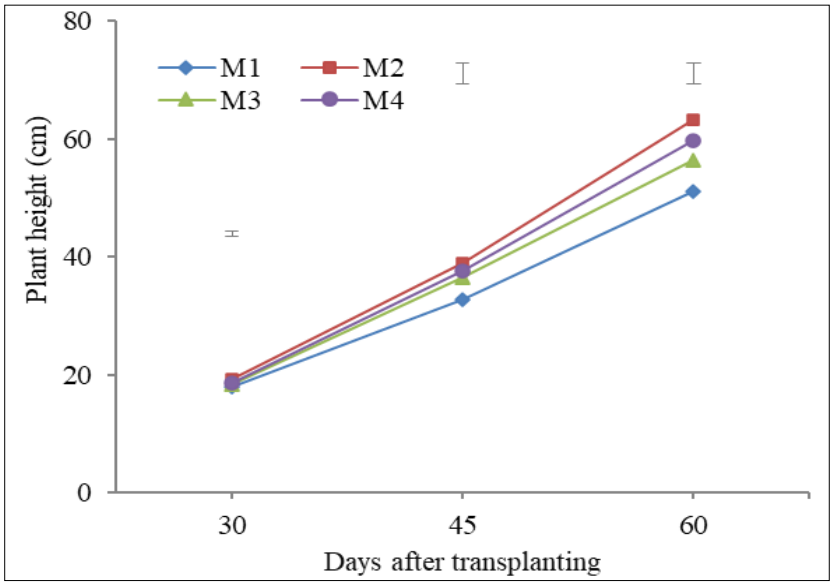

Fig. 2. Effects of mulches on plant height of broccoli. Vertical bars represent LSD at 1 % level of significance. M_1: Control (Non-mulch), M_2: Black polythene, M_3: Water hyacinth, M_4: Rice straw.

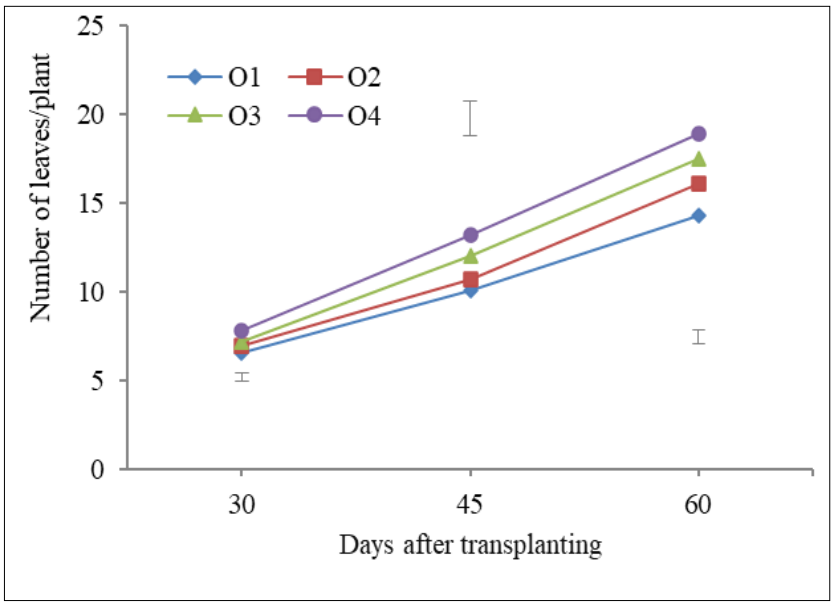

Fig. 3. Effects organic manure on number of leaves/plant of broccoli. Vertical bars represent LSD at 1 % level of significance. O_1: Control (no manure applied), O_2: 10 t/ha cowdung, O_3: 5 t/ha vermicompost, O_4: 5 t/ha cowdung + 2.5 t/ha vermicompost.

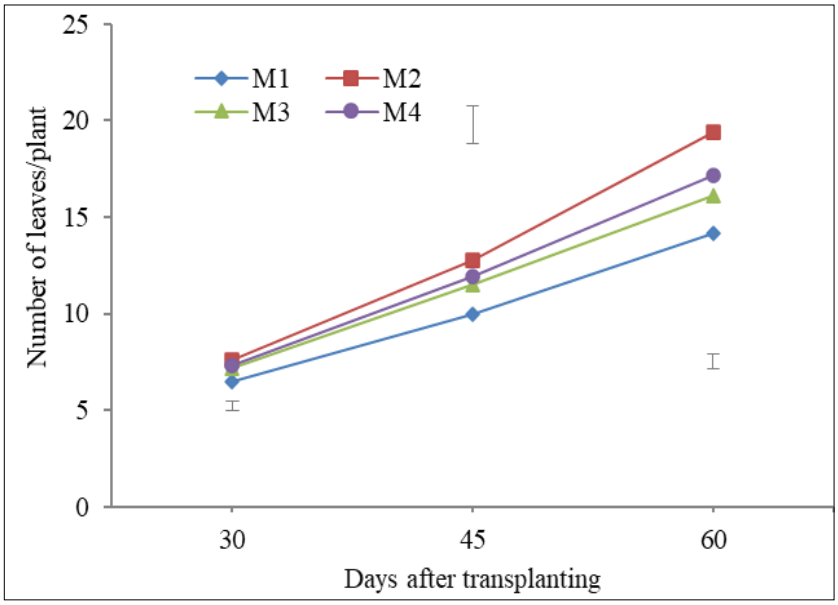

Fig. 4. Effects of mulches on number of leaves/plant of broccoli. Vertical bars represent LSD at 1 % level of significance. M_1: Control (Non-mulch), M_2: Black polythene, M_3: Water hyacinth, M_4: Rice straw.

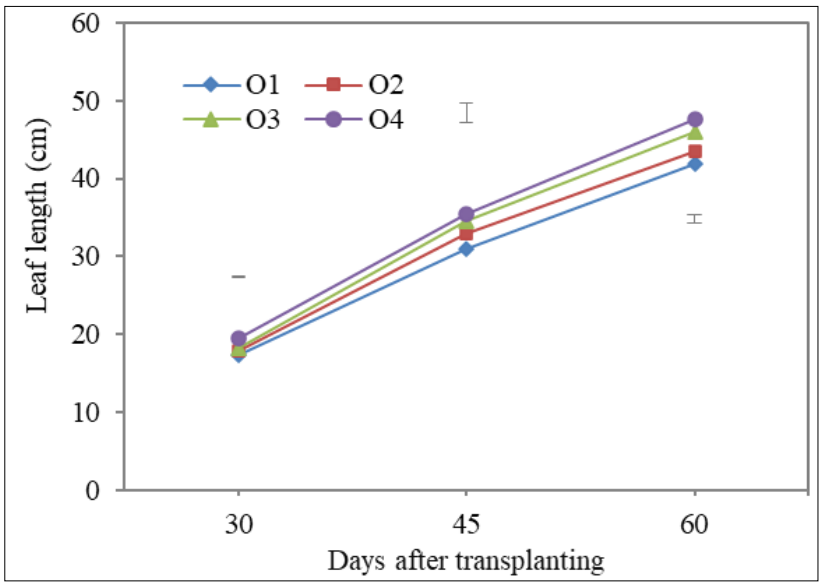

Fig. 5. Effects of organic manure on leaf length of broccoli. Vertical bars represent LSD at 1 % level of significance. O_1: Control (no manure applied), O_2: 10 t/ha cowdung, O_3: 5 t/ha vermicompost, O_4: 5 t/ha cowdung + 2.5 t/ha vermicompost.

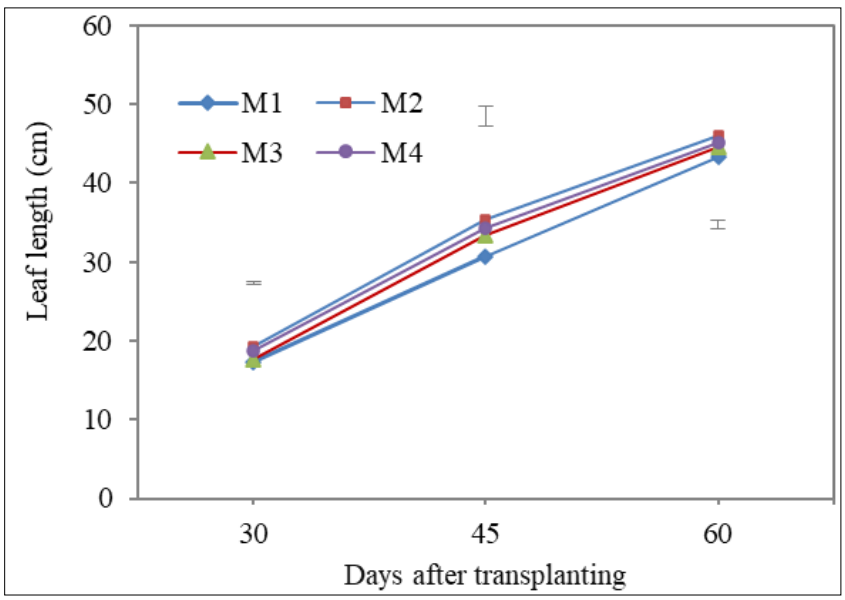

Fig. 6. Effects of mulches on leaf length of broccoli. Vertical bars represent LSD at 1 % level of significance. M_1: Control (Non-mulch), M_2: Black polythene, M_3: Water hyacinth, M_4 : Rice straw.

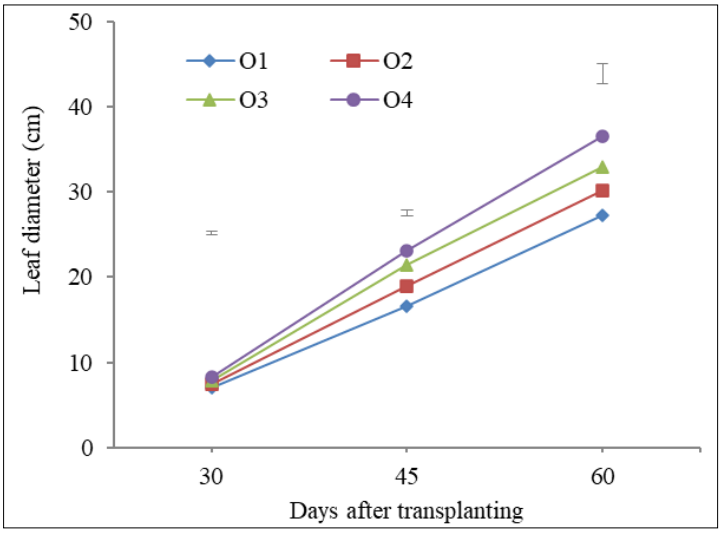

Fig. 7. Effects of organic manure on leaf diameter of broccoli. Vertical bars represent LSD at 1 % level of significance. O_1: Control (no manure applied), O_2: 10 t/ha cowdung, O_3: 5 t/ha vermicompost, O_4: 5 t/ha cowdung + 2.5 t/ha vermicompost.

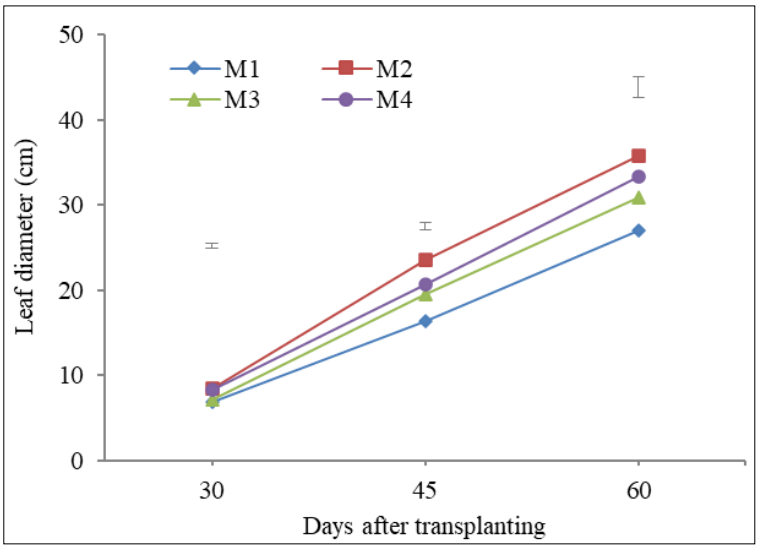

Fig. 8. Effects of mulches on leaf diameter of broccoli. Vertical bars represent LSD at 1 % level of significance. M_1: Control (Non-mulch), M_2: Black polythene, M_3: Water hyacinth, M_4: Rice straw.

Curd initiation time was highly influenced by organic manure and mulching materials. The maximum days (51.01) required to curd initiation was recorded from the control treatment (0 kg/ha) (O_1) and 5t /ha cowdung + 2.5 t/ha vermicompost (O_4) taken the minimum days to curd initiation (45.91 days). In respect of days required to curd initiation of broccoli, no mulching (M_1) treatments required maximum time (49.96 days) and black polythene (M_2) took minimum days (47.14) to initiate curd in broccoli. Curd initiation (45.24 days) was early in combination of black polythene and 5 t/ha cowdung + 2.5 t/ha vermicompost (M_2O_4) treatment (Table 1).

Effect of manures and mulches on the yield parameters

The widest primary curd (14.33 cm) was found in treatment combination of black polythene and 5 t/ha cowdung+ 2.5 t/ha vermicompost (M_2O_4) and the narrowest primary curd was found from treatment combination, where no organic manure and mulches were used (M_1O_1) (9.00 cm) (Table 1).

The highest secondary curd diameter (8.25 cm) was found in treatment combination of black polythene and 5t/ha cowdung + 2.5 t/ha vermicompost (M_2O_4) and the lowest secondary curd diameter was found in treatment combination control and no mulching (M_1O_1) (3.83 cm) (Table 1).

The combined effect of organic manure and mulching on the curd of broccoli was significant. However, there was a significant variation among the treatment combinations in curd weight. The heaviest primary curd (228.4 1 g) was obtained from the treatment combination of black polythene and 5 t/ha cowdung + 2.5 t/ha vermicompost (M_2O_4) and the lightest curd (114.52 g) was recorded from the control treatment with no organic manure and mulches (M_1O_1) (Table 1).

Secondary curd weight of broccoli was significantly influenced by the combined effect of organic manure and mulching. The highest secondary curd weight (92.18 g) was found from the treatment combination of (M_2O_4) (black polythene and 5 t/ha cowdung + 2.5 t/ha vermicompost) and the lowest secondary curd weight (44.58 g) was observed the treatment combination of no organic manure and mulching (M_1O_1) (Table 1).

The highest yield per hectare (14.22 t/ha) was calculated from the application of black polythene mulch (M_2). Other hand the lowest yield per hectare (9.24 t) was obtained from no mulching (M_1) treatment (Table 2). Data showed in Table 3 expressed that the maximum yield per hectare (14.21 t/ha) were recorded with the application of 5 t/ha cowdung + 2.5 t/ha vermicompost (O_4), whereas the lowest yield per hectare

Table 1. Combined effects of manure and mulches on curd weight/plant and curd diameter of broccoli in different periods of time

Treatment combination	Days to curd initiation	Primary curd weight (g/plant)	Primary curd diameter (cm)	Secondary curd weight (g/plant)	Secondary curd diameter (cm)
M_1O_1	53.00	114.52	9.00	44.58	3.83
M_1O_2	51.50	127.33	10.00	60.31	5.12
M_1O_3	49.00	135.66	11.33	63.21	5.17
M_1O_4	46.33	153.65	11.33	63.82	6.02
M_2O_1	49.50	181.96	11.00	65.25	6.08
M_2O_2	47.33	195.81	11.00	75.87	7.74
M_2O_3	46.50	214.92	12.00	83.07	8.17
M_2O_4	45.24	228.41	14.33	92.18	8.25
M_3O_1	51.05	158.19	9.00	57.63	4.87
M_3O_2	50.42	181.36	11.00	72.46	5.59
M_3O_3	47.56	189.29	11.33	75.22	5.83
M_3O_4	46.17	211.35	12.00	82.05	6.17
M_4O_1	50.50	164.62	9.67	60.56	5.63
M_4O_2	50.25	203.44	11.00	74.69	6.10
M_4O_3	46.54	213.18	11.33	78.92	6.33
M_4O_4	46.00	218.11	13.00	87.10	6.60
$LSD_{0.05}$	0.76	4.15	0.24	2.33	0.28
$LSD_{0.01}$	1.02	5.59	0.33	3.14	0.37
Level of significance	**	**	**	**	**

** indicates significant at 1 % level of probability O_1: Control (no manure applied), O_2: 10 t/ha cowdung, O_3: 5 t/ha vermicompost, O_4: 5 t/ha cowdung + 2.5 t/ha vermicompost, M_1: Control (Non-mulch), M_2: Black polythene, M_3:Water hyacinth, M_4: Rice straw.

Table 2. Main effects of mulching on yield and yield contributing characters of broccoli

Mulching	No. of secondary curds/ plant	No. of secondary curds/ plot	Primary curd weight (g/plot)	Secondary curd weight (g/plot)	Yield (g/plant)	Yield (kg/plot)	Yield (t/ha)
M_1	1.42	17.00	1593.48	695.77	190.77	2.29	9.54
M_2	3.33	40.00	2463.30	949.12	284.37	3.41	14.22
M_3	1.92	23.00	2220.58	862.07	256.89	3.08	12.84
M_4	2.63	31.50	2398.07	903.81	275.16	3.30	13.76
$LSD_{0.05}$	0.10	1.20	24.83	13.95	2.51	0.03	0.12
$LSD_{0.01}$	0.14	1.62	33.44	18.79	3.39	0.04	0.17
Level of significance	**	**	**	**	**	**	**

** indicates significant at 1 % level of probability M_1: Control (Non-mulch), M_2: Black polythene, M_3: Water hyacinth, M_4: Rice straw.

Table 3. Main effects of organic manure on yield and yield contributing characters of broccoli

Organic manure	No. of secondary curds/ plant	No. of secondary curds /plot	Primary curd weight (g/plot)	Secondary curd weight (g/plot)	Yield (g/plant)	Yield (kg/plot)	Yield (t/ha)
O_1	1.67	20.00	1857.89	684.06	211.83	2.54	10.59
O_2	2.17	26.00	2123.82	849.96	247.82	2.97	12.39
O_3	2.42	29.00	2259.17	901.28	263.37	3.16	13.17
O_4	3.04	36.50	2434.55	975.46	284.17	3.41	14.21
$LSD_{0.05}$	0.10	1.20	24.83	13.95	2.51	0.03	0.12
$LSD_{0.01}$	0.14	1.62	33.44	18.79	3.39	0.04	0.17
Level of significance	**	**	**	**	**	**	**

** indicates significant at 1 % level of probability O_1: Control (no manure applied), O_2: 10 t/ha cowdung, O_3: 5 t/ha vermicompost, O_4: 5 t/ha cowdung + 2.5 t/ha vermicompost.

(10.59 t/ha) was obtained from control (O_1) treatment. The yield per hectare was influenced significantly with the combined application of organic manure and mulching. The highest yield per hectare (16.03 t) was achieved in black polythene and 5 t/ha cow dung+ 2.5 t/ha vermicompost (M_2O_4). The lowest yield (7.96 t/ha) was obtained from control treatment, where no organic manure and mulching (M_1O_1) were used (Table 4).

Discussion

In this study, the impact of organic manures and mulches on growth and yield of broccoli was evaluated. It was observed that 5 t/ha cowdung along with 2.5 t/ha vermicompost produced the highest yield per plant, per plot and even per hectare as compared to untreated control plants. These results were supported by many other reports. The application of vermicompost was noticed in the crop production and got the maximum yield and minimal yield was observed under the control treatment (39). Broccoli growth and development responded more positively to vermicompost than to the other organic manures used, as per the results of the experiment (40, 41).

In case of mulch application, it was found that black polythene mulch produced the maximum yield per plant (284.37 g), yield per plot (3.41 kg) and yield per hectare (14.22 t) as compared to non-mulched control treatment. Our findings are in agreement with the earlier results, they got maximum yields after using black polythene mulch (42).

Mulching with black polythene led to an increase in plant height, leaf area, number of leaves per plant and number of branches per plant compared to the control (43). The use of black polyethylene mulch led to increased yield, possibly due to improved soil moisture retention, enhanced water use efficiency, greater water availability to plants, increased microbial activity and a weed-free root zone. These factors likely contributed to better nutrient absorption, promoting vegetative growth, which in turn

Table 4. Combined effects of manure and mulches on yield and yield contributing characters of broccoli

Treatment combination	No. of secondary curds/ plant	No. of secondary curds/ plot	Primary curd weight (g/plot)	Secondary curd weight (g/plot)	Yield (g/plant)	Yield (kg/plot)	Yield (t/ha)
M_1O_1	1.00	12.00	1374.28	535.00	159.11	1.91	7.96
M_1O_2	1.33	16.00	1527.92	723.66	187.63	2.25	9.38
M_1O_3	1.33	16.00	1627.92	758.56	198.87	2.39	9.94
M_1O_4	2.00	24.00	1843.80	765.84	217.47	2.61	10.87
M_2O_1	2.67	32.00	2183.52	783.00	247.21	2.97	12.36
M_2O_2	3.33	40.00	2349.76	910.48	271.69	3.26	13.58
M_2O_3	3.67	44.00	2579.04	996.84	297.99	3.58	14.90
M_2O_4	3.67	44.00	2740.88	1106.16	320.59	3.85	16.03
M_3O_1	1.33	16.00	1898.28	691.52	215.82	2.59	10.79
M_3O_2	1.33	16.00	2176.32	869.46	253.82	3.05	12.69
M_3O_3	1.67	20.00	2271.52	902.68	264.52	3.17	13.23
M_3O_4	3.33	40.00	2536.20	984.60	293.40	3.52	14.67
M_4O_1	1.67	20.00	1975.48	726.72	225.18	2.70	11.26
M_4O_2	2.67	32.00	2441.28	896.24	278.13	3.34	13.91
M_4O_3	3.00	36.00	2558.20	947.04	292.10	3.51	14.61
M_4O_4	3.17	38.00	2617.32	1045.24	305.21	3.66	15.26
$LSD_{0.05}$	0.20	2.40	49.66	27.90	5.03	0.06	0.25
$LSD_{0.01}$	0.27	3.24	66.87	37.57	6.77	0.08	0.33
Level of significance	**	**	**	**	**	**	**

** indicates significant at 1 % level of probability O_1: Control (no manure applied), O_2: 10 t/ha cowdung, O_3: 5 t/ha vermicompost, O_4: 5 t/ha cowdung + 2.5 t/ha vermicompost, M_1: Control (Non-mulch), M_2: Black polythene, M_3: Water hyacinth, M_4: Rice straw.

enhanced the rate of photosynthesis and the movement of photosynthesis from the leaves to the curd (44–48). According to the findings of the research, the growth and development of broccoli were more positively affected using vermicompost than by the use of other organic manures (49, 50).

Conclusion

From this study it may be concluded that effect of organic manure and mulch on growth and yield of broccoli was significant. Broccoli plants does not required watering as the mulch conserved soil moisture, prevented weed and different soil diseases. Organic manures increased the productivity of the soil, reducing soil evaporation, bulk density, enhancing soil aeration, increasing soil pore space, regulating soil temperature, enhancing soil water infiltration, water holding capacity, soil water content and field capacity improving soil biological activity. However, the combination of M_2O_4 (black polythene mulch with 5 t/ha cowdung + 2.5 t/ha vermicompost) gave that highest yield (16.03 t/ha.). For broccoli cultivation in Mymensingh region it can be recommended to use 5 t/ha cowdung + 2.5 t/ha vermicompost along with black polythene mulch to get better growth and higher yield.

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Authors' contributions

DRD experimented, collected data, performed statistical analysis and drafted the manuscript. MHR contributed to the planning, along with designing the study, provided suggestions to plant protection and reviewed the article. MMH reviewed the entire manuscript and offered critical feedback, AD formatted the reference section, supported in statistical analysis and assisted with data collection in the field. TJ assisted with data collection and manuscript preparation. RS formatted the conclusion and reviewed the reference section. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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