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Growth and yield of broccoli (*Brassica oleracea* L. var. *italica*) impacted by seedling age and mulching materials

Afsana Yasmin [1], **Md Mokter Hossain** [2*], **Md Habibur Rahman** [2]

[1]Department of Horticulture, Faculty of Agriculture, Khulna Agricultural University, Khulna, Bangladesh
[2]Department of Horticulture, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

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Md Rezaul Karim
mrkarim1996@yahoo.com

**Corresponding Author*
Md Mokter Hossain
mokter.agr@bau.edu.bd

ABSTRACT

The experiment was conducted at the Horticulture Farm of the Department of Horticulture, Bangladesh Agricultural University to explore the influence of seedling age and mulching materials on growth and yield of broccoli. The experiment consisted of three seedling ages *viz*., 21, 28, 35 days and five mulching materials *viz*., control (Non-mulch), black polythene, rice straw, water hyacinth and white polythene. The experiment was laid out following randomized complete block design with three replications. Results showed that the highest plant height (34.91 cm), number of leaves (15.81), yield (12.19 t/ha) were recorded in 35-day-old seedling (A3 treatment). Among the mulching treatments, the highest plant height (33.55 cm), number of leaves (16.66), yield (11.11 t/ha) were recorded under black polythene mulch (T2 treatment) while non-mulch control condition (T1 treatment) performed inferior on most of the studied parameters. Regarding the combined effects of seedling age and mulching materials, it was observed that maximum number of leaves (16.80) and highest plant height (36.58 cm). Maximum diameter of primary curd (15.60 cm), minimum days to curd initiation (64.39 days after transplanting), weight of primary curd (410.31 g), fresh weight of leaves (745.33 gm), dry matter of primary curd (19.43%), yield (13.41 t/ha) were obtained from A3T2 treatment (35-day-old seedling with black polythene) and the lowest were recorded from A1T1 (21-day-old seedling with non-mulch control condition) treatment. It was found that 35-day-old seedling with black polythene performed superior on plant growth and yield of broccoli whereas the lowest results obtained from 21-day-old seedling with non-mulch control condition. However, it can be concluded that the highest production of broccoli is obtained from 35-day-old seedling and black polythene mulch.

Keywords: Growth, curd weight, yield, broccoli

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1 Introduction

Broccoli (*Brassica oleracea* L. var. *italica*) is an edible green plant in the Brassicaceae family whose large flowering head is eaten as a vegetable. It was originated from temperate region, but has been distributed in both the sub-tropical and tropical areas and introduced in Bangladesh several years ago. Broccoli is found among the Mediterranean region (Decoteau, 2000). Broccoli is also called as crown of jewel nutrition because it is rich in vitamins and minerals (Vasanthi et al., 2009). Broccoli resulted from breeding of cultivated Brassica crops in the northern Mediterranean starting in about the six century BC (Maggioni et al., 2010). Broccoli is a nutritional powerhouse full of vitamins, minerals, fiber and antioxidants. Fresh broccoli comprises of 89.1%water, 2500 IU vitamin A

and 113 mg vitamin C per 100 g by weight (Dhaliwal, 2012). The cancer- fighting attributes of broccoli are not new and previous studies have related these benefits to the high levels of active phytochemicals called glucosinolates (Zhao et al., 2007).

Cultivation of any crop depends on several factors including seedling age and mulching materials. Early planted cowpea, broccoli, tomato crops resulted in longer duration and produced taller plants with more number of leaves, higher plant spread and more leaf size index as well as the lowest percentage of abnormal curds than late planted crops and finally imputed to higher curd yield (Grabowska et al., 2007; Hoque, 2006). The highest fresh weight of leaves per plant, percent dry matter of primary curd, yield per hectare were recorded with older seedlings (45 days in tomato and 40 days in cucumber) while the minimum results were obtained from younger seedlings due to older transplants were more adaptable in the field than younger (Choi et al., 2002).

In most of the time irrigation increase the cost of production resulting in unprofitable production of broccoli and make growers frustrated. Mulching can minimize the necessity of water and helps in retaining moisture. Poly mulch has shown the higher soil moisture and temperature throughout growing period. The highest available nutrients such as soil organic carbon and NPK content were observed in poly mulch. For quality traits such as dry matter, total sugar, β-carotene and vitamin-C content, the control was superior. The highest growth, yield contributing traits and yield of broccoli were obtained from water hyacinth mulch while the lowest from no mulch (Islam, 2013). The maximum average yield was obtained from black polythene mulch while minimum yield was given by no mulch treatment (Bora and Babu, 2014; Hashem, 2005; Santos et al., 2003; Campiglia et al., 2000).

Mulch also increases soil porosity and suppresses weed growth (Uwah and Iwo, 2011). Mirecki (2009) investigated the influence of organic mulch straw on production of broccoli under the climate-ecological conditions. The main role of organic mulches in vegetable crops cultivation is to protect the soil surface from the influence of unfavourable factors and to improve the growing conditions for the crop plants (Olfati et al., 2008). Very limited information is available on the effect of age of seedlings and different mulching materials on growth and yield of broccoli, Therefore, the research was undertaken to find out the effect of age of seedlings and different mulching materials on growth and yield of broccoli.

2 Materials and Methods

The present study was conducted at the Horticulture Farm, Department of Horticulture, Bangladesh Agricultural University, Mymensingh during the period from October, 2018 to March, 2019. The experimental area belongs to the Agro-ecological zone-9 (AEZ-9) Brahmaputra Flood Plain (FAO, 1988). The two-factor experiment was laid out in randomized complete block design with three replications. One factor consisted of three seedling ages *viz*., A1: 21-, A2: 28-, A3: 35-day old and other having five mulching materials *viz*., T1: control (no mulch), T2: black polythene, T3: rice straw, T4: water hyacinth and T5: white polythene. The variety used in this experiment was Green Carpet hybrid broccoli. The seed of the said variety was produced by Takii & Co. Ltd. Kyoto, Japan and purchased from Notun Bazar, Mymensingh. To get different age group of seedlings, seeds were sown in the seed bed at 8, 15 and 22 October 2018, respectively. In each block, combinations of seedling age and mulching material were assigned randomly according to treatment combination. The size of a unit plot was 1.8 m $\times$ 1.5 m. A distance of 0.3 m between the plots and 0.6 m between the blocks was kept. The crop was fertilized with well decomposed cowdung, nitrogen, phosphorus, potassium, sulphur, zinc and boron at the rate of 5 ton, 105 kg, 36 kg, 60 kg, 18 kg, 2.0 kg and 1.2 kg ha^{-1}, respectively (FRG, 2012). Urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum, zinc sulphate and borax were used as the sources of nitrogen, phosphorus, potassium, sulphur, zinc and boron, respectively. Half of cowdung and entire quantity of TSP, gypsum, zinc sulphate and borax were applied during final land preparation. Rest of cowdung was applied in pits before planting of seedlings. Urea and MoP were applied in three equal installments at 15, 30 and 45 days after transplanting (FRG, 2012). Irrigation, weeding, mulching, staking, etc. were done as and when required. Data on various parameters were collected and statistically analyzed using the MSTAT statistical package program. The mean for all treatments were calculated and analysis of variance for all the characters was performed by F-test. Significance of differences between the pairs of treatment means were evaluated by the least significant difference (LSD) test (Gomez and Gomez, 1984).

3 Results and Discussion

3.1 Growth parameters

The different age of seedlings and mulching materials affect plant growth parameters i.e. plant height, number of leaves, diameter of primary curd, days required for curd initiation, weight of primary curd, fresh weight of leaves, percent dry matter of primary curd, fresh weight of roots. Plant height and number of leaves were significantly influenced by the different seedling age, mulching materials and combination of seedling age and mulching materi-

als at different days after transplanting (DAT). For plant height, the seedling age at 58 DAT, the tallest plant (34.91 cm) was observed from A3 treatment (35-day-old seedling) and the shortest plant (30.53 cm) from A1 treatment (21-day-old seedling) (Fig. 1A). The mulching materials at 58 DAT, the tallest plant (33.55 cm) was obtained from T2 treatment (Black polythene) and the shortest plant (31.11 cm) from T1 treatment (control) (Fig. 2A). The combination of seedling age and mulching materials at 58 DAT, the tallest plant (36.58 cm) was obtained from A3T2 treatment (35-day-old seedling with black polythene) and the shortest plant (29.87 cm) from A1T2 treatment (21-day-old seedling with non-mulch) (Table 1).

For number of leaves, the seedling age at 58 DAT, the maximum number of leaves (15.81) was observed from A3 treatment (35-day-old seedling) and the minimum number of leaves (15.24) from A1 treatment (21-day-old seedling) (Fig. 1B). The mulching materials at 58 DAT, the maximum number of leaves (16.66) was obtained from T2 treatment (black polythene) and the minimum number of leaves (14.81) from T1 treatment (non-mulch) (Fig. 2B). The combination of seedling age and mulching materials at 58 DAT, the maximum number of leaves (16.57) was obtained from A3T2 treatment (35-day-old seedling with black polythene) and the minimum number of leaves (14.50) from A1T1 treatment (21-day-old seedling with non-mulch) (Table 2).

The largest diameter of primary curd (15.60 cm) was obtained from A3T2 treatment (35-day-old seedling with black polythene) and the smallest diameter of primary curd (11.68 cm) from A1T1 treatment (21-day-old seedling with non-mulch) (Table 3). Maximum days required for curd initiation (64.39 DAT) was obtained from A1T1 treatment (21-day-old seedling with non-mulch) and the minimum days required for curd initiation (51.69 DAT) from A3T2 treatment (35-day-old seedling with black polythene) (Table 3).

The maximum weight of primary curd (410.31 g) was obtained from A3T2 treatment (35-day-old seedling with black polythene) and the minimum weight of primary curd (270.27 g) from A1T1 treatment (21-day-old seedling with non-mulch) (Table 3). Maximum fresh weight of leaves (745.33 g) was obtained from A3T2 treatment (35-day-old seedling with black polythene) and the minimum fresh weight of leaves (656.36 g) from A1T1 treatment (21-day-old seedling with non-mulch) (Table 4).

Maximum dry matter of primary curd (19.43%) was obtained from A3T2 treatment (35-day-old seedling with black polythene) and the minimum dry matter of primary curd (13.89%) from A1T1 treatment (21-day-old seedling with non-mulch) (Table 4). Fresh weight of roots per plant was significantly influenced by combination of different seedling age and different mulching materials. Maximum fresh weight of roots per plant (80.87 gm) was obtained from A3T2 treatment (35-day-old seedling with black polythene) and the minimum fresh weight of roots per plant (26.28 gm) from A1T1 treatment (21-day-old seedling with non-mulch) (Table 4).

3.2 Yield contributing traits and yield of broccoli

Different age of seedlings and mulching materials have an effect on yield and yield contributing traits i.e. yield per plant, per plot and per hectare. The combined effect of different seedling age and different mulching materials on the yield per plant was found to be statistically significant. Maximum yield (496.81 g plant^{-1}) was obtained from A3T2 treatment (35-day-old seedling with black polythene) and the minimum yield (321.49 g plant^{-1}) from A1T1 treatment (21-day-old seedling with non-mulch) (Table 4). Yield per hectare was significantly influenced by the different seedling age, mulching materials and combination of seedling age and mulching materials. The seedling age, maximum yield (12.19 t ha^{-1}) was observed from 35-day-old seedling followed by 28-day-old seedling (10.18 t) and the minimum yield (8.91 t ha^{-1}) from 21-day-old seedling because of older transplants were more adaptable in the field (Fig. 1C). The mulching materials, maximum yield (11.11 t ha^{-1}) was observed from black polythene followed by water hyacinth (10.90 t ha^{-1}) and minimum yield (9.80 t ha^{-1}) from non-mulch (Fig. 2C). The combination of seedling age and mulching materials, maximum yield (13.41 t ha^{-1}) was obtained from A3T2 treatment (35-day-old seedling with black polythene) and the minimum yield (8.68 t ha^{-1}) from A1T1 treatment (21-day-old seedling with non-mulch) (Fig. 3).

4 Discussion

The growth and yield of broccoli were significantly influenced by age of seedlings and mulching materials. In respect of age of seedlings, the highest fresh weight of leaves per plant, yield per hectare were recorded with 35-day-old of seedling compared to other age group seedlings due to older transplants were more adaptable in the field than younger. The possible reasons for maximum values in this treatment might be due to the older transplants ensure plant to growth properly through efficient utilization moisture, temperature, light etc. Similar reports also published by Wlazlo and Kunicki (2003). At the time of transplanting, the older transplants were heavier and taller, with a greater stem diameter and more nodes than younger transplants. Where Soniya et al. (2019) found that the highest yield was obtained from 30-day-old seedling treatment and the lowest yield was recorded from 40-day-old seedling treatment of three seedling

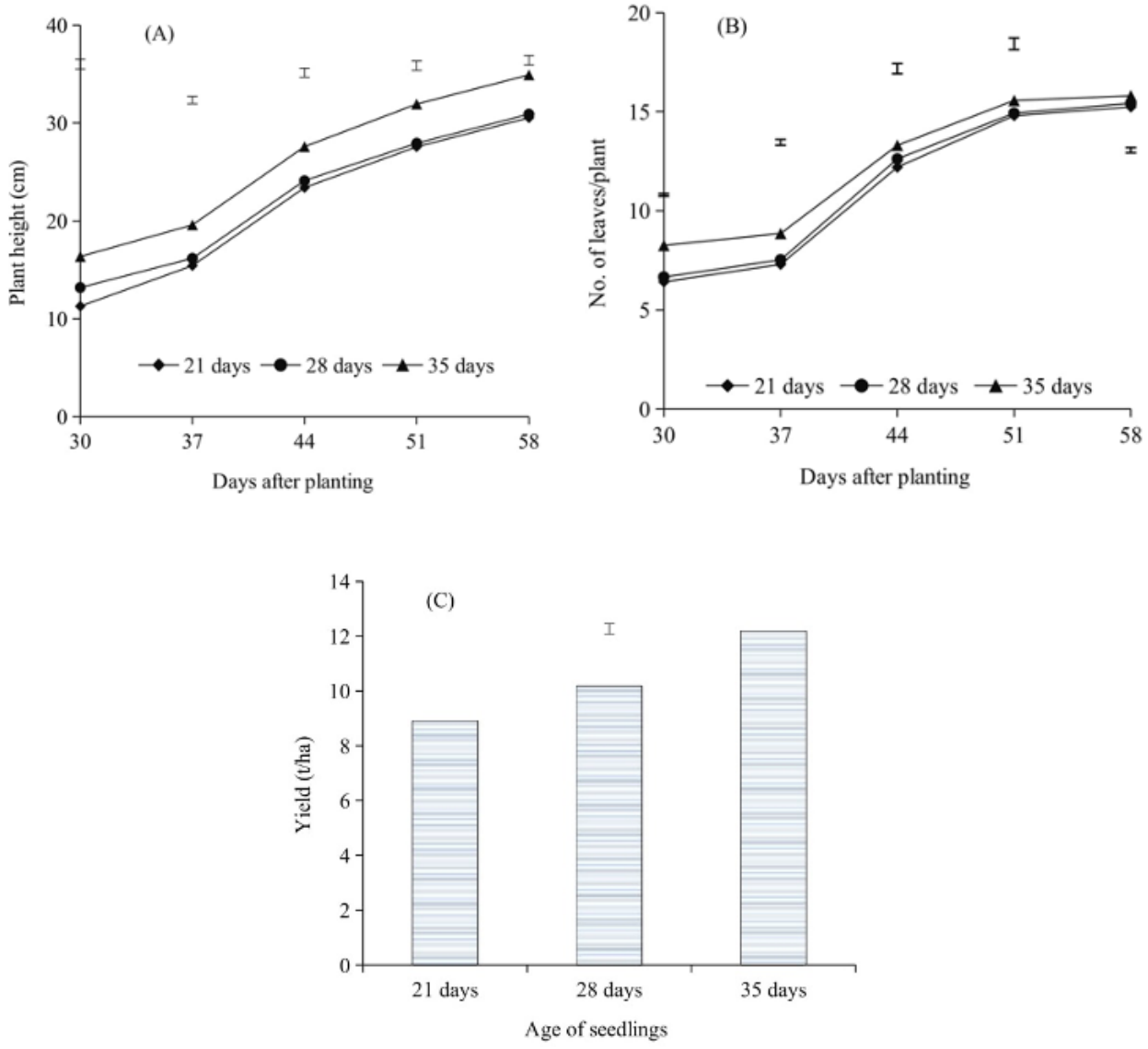

Figure 1. Effect of seedling age on plant height (A), number of leaves (B) and yield (C) of broccoli. The vertical bars represent LSD at 1% level of significance.

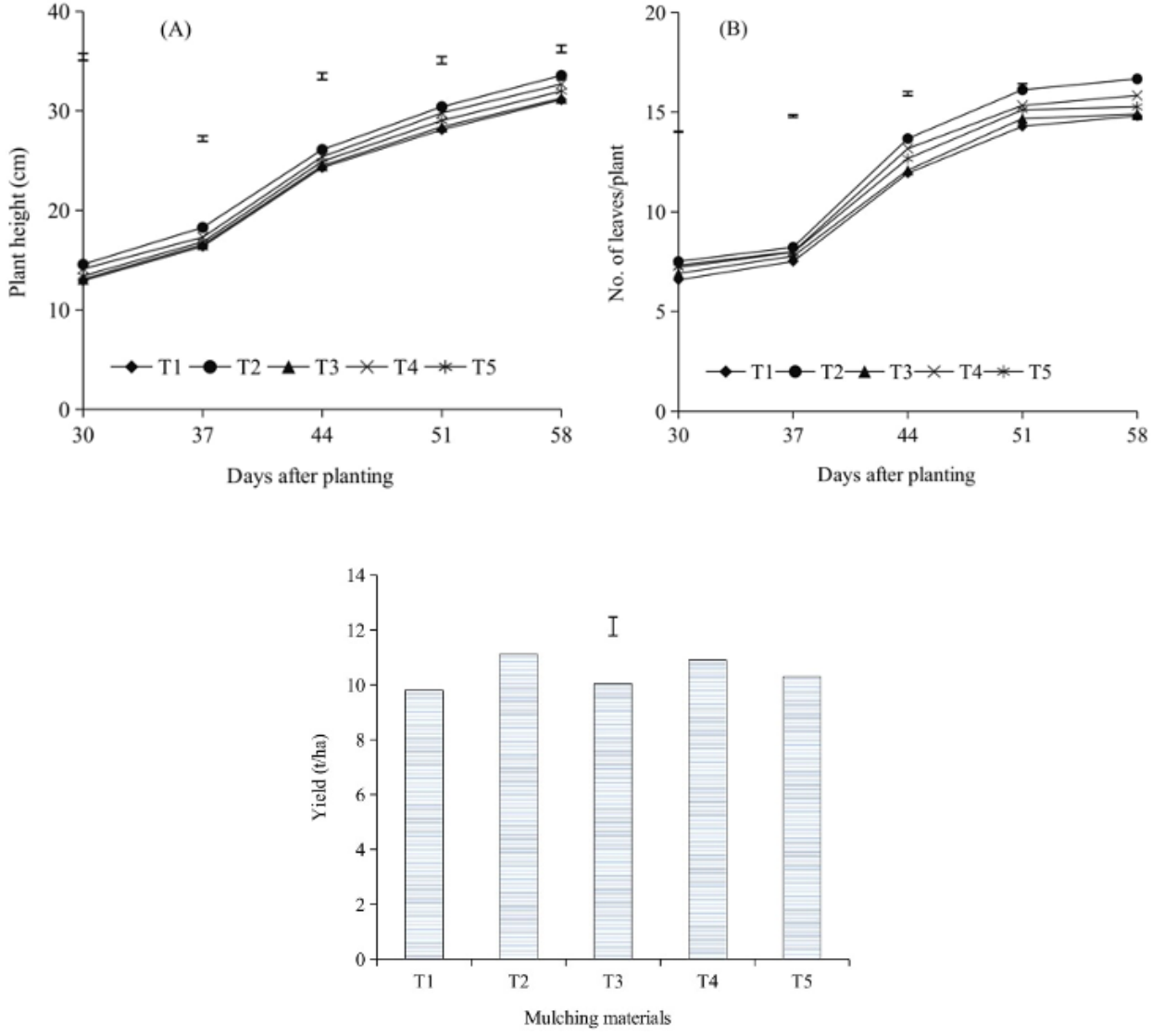

Figure 2. Effect of mulching materials on (A) plant height, (B) number of leaves, and (C) yield of broccoli. The vertical bars represent LSD at 1% level of significance. T1 = Control (Non-mulch), T2 = Black polythene, T3 = Rice straw, T4 = Water hyacinth, and T5 = White polythene.

Table 1. Combined effect of age of seedlings and mulching materials on plant height at different days after planting of broccoli

Treatment combinations		Plant height (cm) at different days after planting (DAP)				
		30 DAP	37 DAP	44 DAP	51 DAP	58 DAP
A1	T1 (Control)	10.72	14.93	22.83	26.87	29.87
(21 days)	T2 (Black polythene)	12.05	16.43	24.5	28.83	31.98
	T3 (Rice straw)	11.08	15.1	22.97	27.17	30.04
	T4 (Water hyacinth)	11.45	15.57	23.5	27.5	30.4
	T5 (White polythene)	11.2	15.13	23.27	27.43	30.38
A2	T1 (Control)	12.49	15.5	23.67	27	30
(28 days)	T2 (Black polythene)	14.08	17.47	24.8	28.93	32.08
	T3 (Rice straw)	12.59	15.8	23.83	27.27	30.14
	T4 (Water hyacinth)	13.69	16.13	24.3	28.6	31.5
	T5 (White polythene)	13.15	16	23.97	27.83	30.78
A3	T1 (Control)	15.59	18.7	26.43	30.47	33.47
(35 days)	T2 (Black polythene)	17.55	20.9	29	33.43	36.58
	T3 (Rice straw)	15.6	18.8	26.67	30.73	33.6
	T4 (Water hyacinth)	17.23	20.2	28.33	33.23	36.13
	T5 (White polythene)	15.9	19.33	27.5	31.8	34.75
$LSD_{0.05}$		0.54	0.42	0.51	0.54	0.55
$LSD_{0.01}$		0.65	0.49	0.62	0.65	0.66
Sig. level		*	**	**	**	**

* and ** indicates significant at 5% and 1% levels of probability, respectively.

Table 2. Combined effect of age of seedlings and mulching materials on number of leaves/plant at different days after planting of broccoli

Treatment combinations		No. of leaves plant^{-1} at different days after planting (DAP)				
		30 DAP	37 DAP	44 DAP	51 DAP	58 DAP
A1	T1 (Control)	5.7	7	11.67	14	14.5
(21 days)	T2 (Black polythene)	6.93	7.5	13	15.67	16.57
	T3 (Rice straw)	6.3	7.33	11.67	14.67	14.57
	T4 (Water hyacinth)	6.67	7.33	12.67	15	15.61
	T5 (White polythene)	6.5	7.33	12	14.67	14.96
A2	T1 (Control)	6.2	7.2	12	14.33	14.77
(28 days)	T2 (Black polythene)	7.13	7.83	13.67	16	16.6
	T3 (Rice straw)	6.33	7.33	12.27	14.67	14.92
	T4 (Water hyacinth)	6.87	7.67	12.83	15	15.67
	T5 (White polythene)	6.77	7.6	12.33	14.67	15.17
A3	T1 (Control)	7.87	8.33	12.17	14.5	15.17
(35 days)	T2 (Black polythene)	8.47	9.33	14.33	16.67	16.8
	T3 (Rice straw)	8.1	8.67	12.33	14.67	15.21
	T4 (Water hyacinth)	8.43	9	14	16	16.2
	T5 (White polythene)	8.37	8.97	13.67	16	15.67
$LSD_{0.05}$		0.18	0.38	0.67	0.77	0.35
$LSD_{0.01}$		0.22	0.46	0.82	0.93	0.43
Sig. level		**	**	**	**	**

** indicates significant at 1% level of probability.

Table 3. Combined effect of age of seedlings and mulching materials on diameter of stem, days to curd initiation, weight of primary curd of broccoli

Treatment combinations		Primary curd dia (cm plant^{-1})	Days to curd initiation	Wt. of primary curd (g plant^{1})
A1 (21 days)	T1 (Control)	11.68	64.39	270.27
	T2 (Black polythene)	13.84	58.73	281.21
	T3 (Rice straw)	12.02	61.42	272.21
	T4 (Water hyacinth)	13.32	59.3	280.21
	T5 (White polythene)	12.83	59.86	272.88
A2 (28 days)	T1 (Control)	13.61	59.87	284.57
	T2 (Black polythene)	15.5	55.2	320.17
	T3 (Rice straw)	14.22	59.5	296.4
	T4 (Water hyacinth)	14.67	57.43	311.23
	T5 (White polythene)	14.37	57.53	306.56
A3 (35 days)	T1 (Control)	15.2	58.53	331.18
	T2 (Black polythene)	15.6	51.69	410.31
	T3 (Rice straw)	15.23	56.64	340.18
	T4 (Water hyacinth)	15.47	52.2	402.57
	T5 (White polythene)	15.27	52.55	351.23
$LSD_{0.05}$		0.32	1.23	9.22
$LSD_{0.01}$		0.38	1.48	11.11
Sig. level		**	**	**

** indicates significant at 1% level of probability

Table 4. Combined effect of age of seedlings and mulching materials on fresh weight of leaves, dry matter of primary curd, root fresh weight and yield of broccoli

Treatment combinations		Leaf fresh wt. (g plant^{-1})	% dry matter of primary curd	Root fresh wt. (g plant^{-1})	Yield (g plant^{-1})
A1 (21 days)	T1 (Control)	656.36	13.89	26.28	321.49
	T2 (Black polythene)	663.83	15.74	50.07	339.58
	T3 (Rice straw)	659.86	15.36	39.98	324.73
	T4 (Water hyacinth)	663.51	15.65	49.64	336.44
	T5 (White polythene)	662.19	15.47	41.07	328.02
A2 (28 days)	T1 (Control)	668.5	14.42	36.17	352.72
	T2 (Black polythene)	673.46	18.47	80.75	397.7
	T3 (Rice straw)	670.99	15.59	40.24	366.73
	T4 (Water hyacinth)	672.42	16.5	52.3	386.7
	T5 (White polythene)	671.33	16.37	51.3	381
A3 (35 days)	T1 (Control)	739.23	14.91	38.6	414.35
	T2 (Black polythene)	745.33	19.43	80.87	496.81
	T3 (Rice straw)	741.47	16.02	45.6	423.68
	T4 (Water hyacinth)	743.66	18.4	74.23	487.77
	T5 (White polythene)	741.7	16.38	54.07	435.38
$LSD_{0.05}$		1.32	0.44	2.62	9.32
$LSD_{0.01}$		1.59	0.53	3.16	11.23
Sig. level		**	**	**	**

** indicates significant at 1% level of probability

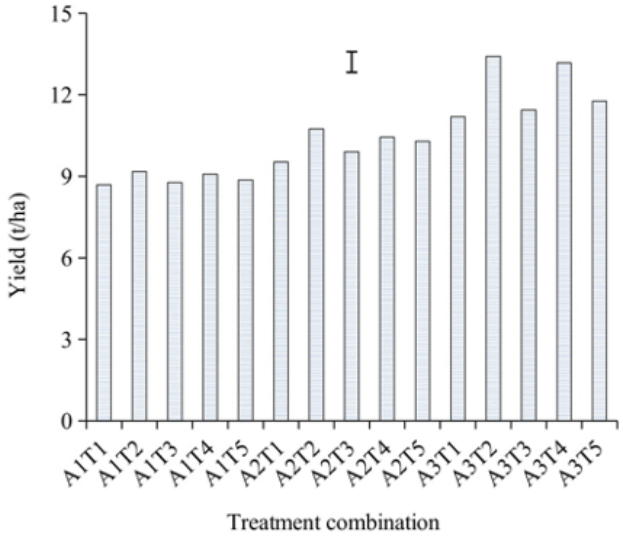

Figure 3. Combined effect of seedling age and mulching materials on yield of broccoli. The vertical bar represents LSD at 5% level of significance. A1 = 21 days, A2 = 28 days, A3 = 35 days, T1 = Control (Non-mulch), T2 = Black polythene, T3 = Rice straw, T4 = Water hyacinth, and T5 = White polythene

ages which is similar to Hossain and Mohona (2018). But Solunke et al. (2011) found the broccoli transplanted on the 1st date of planting i.e. 15th September reported significantly maximum growth for height, number of leaves, stem diameter and leaf area than others. Babik (2000) found the lowest yield was obtained from 50-day-old transplants as compared with 20-day-old transplants. The report of Grabowska et al. (2014); Kaymak et al. (2009) and Das et al. (2000) are the agreement with Babik (2000).

In respect of mulching materials the highest plant height at 58 days, number of leaves per plant at 58 days, length of longest leaf per plant, fresh weight of leaves per plant, diameter of stem, diameter of primary curd, yield per plant, yield per plot and yield per hectare were recorded with T2 (black polythene) treatment as compared to other mulching materials and it is occurred due to favourable environmental condition, minimize the requirement of water and helps in retaining moisture, soil porosity and suppresses weed growth, to protect the soil surface from the influence of unfavourable factors. Most similar findings have also obtained from Verma et al. (2017) found that the highest marketable head yield was in (Polythene mulch) and it was 57% higher over the control. In this study, Black polythene gives highest result and open condition mulch gives lowest result on growth and yield of broccoli which is similar to Punetha (2020), Thentu et al. (2016), Saloom and Al-Sahaf (2016) and Kashyap et al. (2009). Singh (2005) also reported complete elimination of weeds with the use of black polyethylene in tomato crop. But Islam (2013) found the highest stem length of curd, crown length, diameter and weight of primary curd plant per plant and yield were obtained from water hyacinth mulch while the lowest from non-mulch.

The combined effect of age of seedlings and mulching materials found significant effect on plant height, number of leaves per plant, length of longest leaf per plant, diameter of stem, diameter of primary curd, weight of primary curd, percent dry matter of primary curd, number of secondary curd per plant, weight of secondary curd per plant, fresh weight of leaves per plant, percent moisture content of leaves, percent dry matter of leaves, fresh weight of root, days to curd initiation, length of root, fresh weight of root, yield per plant, yield per plot and yield per hectare on broccoli production. The combined effect of different types of seedling age and mulching materials on growth and yield of broccoli found significant except number of leaves per plant and diameter of stem. The maximum plant height, number of leaves per plant, length of longest leaf per plant, diameter of stem were obtained, when 35-day-old age seedling with black polythene mulch were applied. The maximum result of the vegetative data was obtained at 58 days after transplanting. Diameter of primary curd (14.98 cm), fresh weight of root (70.57 g), yield per plant (411.37 g), yield per plot (4.94 kg) and yield ha^{-1} (11.11 t) and the minimum days required for curd initiation (51.69 DAT) were found maximum in the treatment combination of A3T2 (35-day-old age seedling and black polythene). The lowest yield per plant (362.85 g), yield per plot (4.35 kg) and yield ha^{-1} (9.80 t) were recorded from the treatment combination A1T0 (21-day-old age seedling and non-mulch treatment). There is no previous study on combined effect of growth and yield of broccoli.

5 Conclusion

The present research work was conducted to find out the effect of different seedling age and different mulching materials on the growth and yield of broccoli. Different seedling age and mulching materials played an important role on yield contributing characters and yield of broccoli. From the results of the present investigations, it is concluded that different seedling age and mulching materials significantly influenced all the parameters studied. The appropriate combination of seedling age and mulching materials varies according to the system of land use, ecological and economic conditions. The system enhances nutrient use efficiency, maintains soil health, enhances yield and reduces cost cultivation. The maximum yield of broccoli was obtained from the treatment combination of with 35-day-old seedling and black polythene mulch. The minimum yield of broccoli was obtained from the treatment combination of 21-day-old seedling and non-mulch. The study concluded that a judicious combination strategy of using seedling age and mulching materials may be helpful in increasing the vegetable productivity.

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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