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RESEARCH ARTICLE

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Impact of different combined doses of fertilizers with plant growth regulators on growth, yield attributes and yield of mustard (*Brassica campestris* cv. B_9) under old alluvial soil of Burdwan, West Bengal, India

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Abstract Field experiments were conducted with mustard (*Brassica campestris* cv. B_9) consecutively for three years (2005, 2006 and 2007) in the Crop Research and Seed Multiplication Farm of Burdwan University, Burdwan, West Bengal, India. In the first year, varietal screening of mustard under recommended dose of chemical fertilizer (100:50:50) were performed with seven mustard varieties during November 2005 to February 2006. In the second year, two experiments were conducted to study the effects of six different combined doses of chemical fertilizer and biofertilizer and six different levels of growth retardant cycocel. In the third year, six different levels of compost along with the best screened dose of growth retardant (CCC-300 ppm) and the best combined dose of biofertilizer and chemical fertilizer (3/4thchemical fertilizer:1/4th biofertilizer) from the previous year were applied to study the effects on agronomic traits and growth attributes of mustard, and the field data were analyzed statistically. The variety B_9 recorded a significant higher seed yield along with other yield contributing factors, which was found to be superior to other varieties under old alluvial soil of Burdwan, West Bengal, India, in 2005. In 2006 and 2007, seed yield was found to be the best for CCC-300 ppm treatment and the best combined dose of biofertilizer and chemical fertilizer was found to be 3/4th chemical fertilizer:1/4th biofertilizer. In 2007, the best yield was given by the treatment of $7.5\ t\cdot hm^{-2}$ compost along with the best dose of growth retardant cycocel and the best combined dose of biofertilizer and chemical fertilizer.

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1 Introduction

India is the third largest producer of oil seeds in the world. The production of oil seed groups next to food crops holds sizable share of the countries gross cropped area (13%). It accounts for 19% of the world's area and 9% of the global production (Sinha, 2003). Mustard (*Brassica campestris* cv. B_9), as a Rabi Crop, is an important oil seed crop next to sunflower, with 30%–45% protein content, high nutritive value, relatively cool temperature, and a fair supply of soil moisture during the growing season and a dry harvest period.

The introduction of a superior variety may accomplish the same objectives as the evaluation of a superior variety through breeding programs. Newly introduced variety may excel the out dated local variety in terms of increased yield per unit area. Similarly, fertilizers play an important role in the environmental influences on crop production. Research workers have reported differential responses of different genotypes to fertilizer application (Rashid and Khan, 2008). Several factors responsible for low yield are poor soil, out dated varieties and lack of modern technologies used for cropping. The application of suitable fertilizers in appropriate doses is considered as one of the most important factors for increasing crop yield per unit area. *B. campestris* and *B. juncea* were found to be the basic raw materials for the breeders due to their higher number of siliquae per plant and higher number of seeds per siliquae. These characteristics have been observed to be the important yield attributes associated with their higher yield expression, providing suitable criteria in high yield breeding of this crop (Nagalakhsmi, 1992).

Chemical fertilizers have contributed significantly toward the pollution of water, air and soil. Therefore, the current trend is to explore the possibility of supplementing chemical fertilizers with organic ones that are eco-friendly and cost effective.

Biologic nitrogen fixation by living nitrogen fixers will help to minimize the amounts of N fertilizer to be added, improve plant growth and decrease the production cost and environmental risk (Aly et al., 1999; El-Hawary et al., 1998). Bacterial fertilization provided for nonlegume crops by nitrogen fixing bacteria has shown great importance in recent years. The effect of inoculation has a remarkable influence on the growth of plants to increase yield. This increase might be due to the effect of nitrogen produced by bacterial species, which, in addition to some growth regulators, can stimulate crop growth. Abo-El-Goud (2000) reported that root fresh and dry weights, foliage fresh, and dry weights, as well as the leaf area index of folder beet significantly responded to biofertilizer treatments.

Growth retardants are chemical compounds that are able to change crop architecture, leading to better crop yield. Foliar application of cycocel in mustard increased the yield attributes and seed yield up to 50% (Saini et al., 1987). Parmer et al. (1994) reported the increase in seed yield and seed oil content when sprayed with growth retardant cycocel in mustard.

Higher seed yield and stover yield with the highest level of organic matter enrichment along with biofertilizer was reported by Chaudhury and Kabi (2003). Similar findings were reported by Chaturvedi et al. (2008). According to a field experiment conducted by Chand et al. (2006), it was found that integrated supply of plant nutrients through FYM (farmyard manure) and fertilizer, N, P, and K along with *Sesbania* green manuring played a significant role in sustaining soil fertility and crop productivity.

Therefore, our objectives of this current study were to screen the best variety among all the available varieties under recommended dose of chemical fertilizer and subsequently assess the impact of combined exposure of growth retardant, chemical fertilizer, biofertilizer, and compost on agronomic traits and seed yields of mustard (*Brassica campestris* cv. B_9) as well as the screening of the best dose of growth retardant cycocel, combined dose of chemical and biofertilizer, and compost in terms of yield and productivity under this agroclimatic conditions of old alluvial soil zone of Burdwan, West Bengal, India.

2 Materials and methods

2.1 Collection of seeds

Field experiments were conducted during the winter season of 2005, 2006, and 2007 at the agricultural farm of Burdwan University, India (latitude 87°50'51"E and longitude 23°15'12"N). In 2005, crop varieties viz., B9, B-54, TWC-3, Panchali, Malek-2, Sanjukta and Nathsona were collected from the Crop Research and Seed Multiplication Farm, Burdwan University, West Bengal, India. Chemical fertilizers were applied at the recommended dose (100:50:50) by the Directorate of Agriculture, Government of West Bengal for Mustard.

2.2 Experimental treatments

During the winter season (2006), we conducted two field experiments. In the first experiment, six different combinations of biofertilizer and chemical fertilizer were applied in field as separate treatments, including T_1: recommended dose of chemical fertilizer (100 : 50 : 50), T_2: 1/2 chemical fertilizer:1/2 biofertilizer, T_3: 3/4th chemical fertilizer: 1/4th biofertilizer, T_4: 3/4th biofertilizer:1/4th chemical fertilizer, T_5: recommended dose of biofertilizer and, T_6: control-without any chemical fertilizers. In the second experiment, mustard seeds were soaked overnight in the solution of growth retardant and cycocel at six different levels viz., CCC-100 ppm, CCC-200 ppm, CCC-300 ppm, CCC-400 ppm, CCC-500 ppm, and control (without any growth retardant),were sown in the field 24 h after soaking. In 2007, six different levels of compost (control-without any compost, 4.5 $t\cdot hm^{-2}$, 6.0 $t\cdot hm^{-2}$, 7.5 $t\cdot hm^{-2}$, 9.0 $t\cdot hm^{-2}$, and 10.5 $t\cdot hm^{-2}$) were used along with the best screened dose of combined doses of biofertilizer, chemical fertilizer, and growth retardant cycocel in 2006.

2.3 Experimental design

The experiments were conducted in randomized block design with three replications within individual plot sizes of 5 m×5 m, row to row spacing of 50 cm and plant to plant spacing of 15 cm. The land was mechanically ploughed and harrowed during land preparation after plot setting. Irrigation channels in 0.5 m wide were in between the replications to ensure the easy and uninterrupted irrigation of the individual plots independently until crops grew up to the maturity stage. Simultaneously, the observations on agronomic traits including seed growth attributes, seed yield attributes, and seed yield were recorded at different stages (30 d, 45 d, and 60 d after sowing) of crop growth.

2.4 Data collection

Plant samples were collected at intervals of 15 d after sowing from three randomly selected locations in each plot up to the 60 d of crop growth. Ten plant samples were uprooted randomly from each plot under different treatments to determine the growth attributes (root and shoot length, primary branches per plant, secondary branches per plant) and yield attributes (length of siliquae, number of siliquae per plant, number of seeds per siliquae, 1000-seed weight, and oil content).

Similarly, 10 plants from each plot were randomly selected. The length of shoots was recorded from the base above the ground to the tip of the stem using a scale, and the root length was recorded by uprooting the plants from the soil with great care in order to avoid any tear-out of roots and then measured using the scale from the base stem up to the highest length of tap root. Total numbers of primary and secondary branches were counted from 10 randomly selected plants. The height of the 10 plants was recorded by measuring from the ground level to the tip of plants. The total number of filled siliqua per plant was recorded at harvest, while the total number of seeds per siliqua was recorded by random selection of 10 siliquae from each plant per plot at harvest. Thousand seed weight was recorded in grams (g). The seed grain yield of each 1 m $\times$1 m plot segmented from the 5 m$\times$5 m plot was recorded by harvesting plants, followed by sun-drying, threshing, and cleaning on the threshing floor. The seed yield was recorded in $g \cdot m^{-2}$. The total weight of harvested plants after sun-drying and before threshing was recorded in order to obtain the stover yields by deducting the seed weight. The percentage of oil content of rapeseeds was determined using Soxhlet's Ether Extraction method (AOAC, 1975).

2.5 Statistical analysis

All the replicated data of mustard from the three successional years were analyzed statistically by one-way Anova and Duncan's Multiple Range Test (DMRT). For statistical interpretation of the observed tabulated data, Panse and Sukhatme (1967) together with Gomez and Gomez (1984) were consulted.

3 Results

3.1 Crop growth attributes

3.1.1 Shoot length and root length

During 2005–2006, the shoot length was significantly different among the seven cultivated mustard varieties ranging from 76.53 cm (V_1) to 113.1 cm (V_4), and the root length varied from 10.41 cm (V_6) and 22.83 cm (V_2). The shoot length of the field experiments conducted in 2006–2007ranged from 65.73 cm (T_5) to 79.31 cm (T_3) for the first experiment and from 63.25 cm (T_5) to 77.95 cm (T_2) for the second experiment. In 2007–2008, it varied from 73.15 cm (T_3) to 81.55 cm (T_2). The root length of two experiments in 2006 and 2007 varied from 10.88 cm (T_1) and 14.25 cm (T_4), from 10.21 cm (T_1) to 13.55 cm (T_3), and from 10.12 cm (T_6) to 13.75 cm (T_4) (Tables 1–4). The statistical data from 2006 and 2007 showed significantly different shoot length in the former and significantly different root length in the latter, respectively.

3.1.2 Plant height

Assessment of plant height was undertaken in the experimental fields of 2005, 2006, and 2007. In 2005, plant height was significantly influenced by the varietal performance of the seven mustard varieties. Variety V_7 Nathsona (141.68 cm) showed the greatest plant height and was significantly higher compared to that of the other varieties, whereas the lowest plant height (84.04 cm) was recorded in TWC-3 (V_4) (Table 1). In 2006, the lowest and highest plant height was recorded in T_6 (80.16 cm) and T_2 (91.03 cm) for the first field trial of different combined doses of chemical and biofertilizer, whereas the lowest and highest plant height was recorded in T_5 (63.73 cm) and T_6 (88.57 cm) treatments for the second field trial of different graded dose of growth retardant cycocel. There was a decreasing trend in the plant height of the control in 2007 that that ranged from T_1 (86.4 cm) to T_5 (97.48 cm). All the results are presented in Tables 1–4.

3.1.3 The number of primary and secondary branches per plant

The number of primary and secondary branches per plant was different from that of different varieties of mustard. The highest and lowest number of primary branches and secondary branches were recorded by V_3 (4.93), V_6(3.93), and V_3 (3.4),V_6 (0.8), respectively (Table 1). The highest number of primary branches of V_3 (B_9) per plant was not significantly higher than that of other varieties, whereas V_4 showed that the lowest number of secondary branches was significantly lower than that of V_3 (B_9). In 2006, the values of primary branches of T_6 and T_3 ranged between 4.83 and 6.67 (Table 2) in the first experiment of different combined doses of biofertilizer and chemical fertilizer, whereas the highest and lowest value of primary branches was observed in T_6 (5) and T_5 (2.67) in the second field trial of different graded doses of growth retardant cycocel (Table 3). Besides the values of the secondary branches of T_6 and T_3 in the first experiment of different combined doses of chemical and biofertilizer in 2006 ranged between 2.88 and 4.13 (Table 2), whereas those of T_5 and T_6 in the second experiment of different graded doses of growth retardant cycocel ranged between 1.33 and 3.67 (Table 3). In 2007, the values of T_1 and T_4 ranged between 4.73 and 5.53 (Table 4), and the minimum and maximum number of the secondary branches per plant were found in T_6 (4.31) and T_4 (5.03) (Table 4). The statistical data for the experimental years in 2006 and 2007 showed significantly different shoot length in 2006 and significantly different root length in 2007, respectively, with more significant plant height showed in 2006. Primary branches per plant were significant in the experiments in both 2006 and 2007.

Table 1 Growth attributes of seven mustard varieties during the winter cropping system of 2005

variety	shoot length /cm	root length /cm	plant height /cm	primary branch per plant	secondary branch per plant
V_1	76.53^{g}	12.67^{bcde}	87.52^{def}	4.10^{abcdef}	1.2^{def}
V_2	107.33^{abc}	22.83^{a}	130.82^{b}	4.53^{ab}	3.13^{ab}
V_3	80.5^{ef}	10.56^{bcdef}	93.75^{d}	4.93^{a}	3.4^{a}
V_4	113.1^{a}	15.4^{bc}	84.04^{def}	4.13^{abcde}	1.7^{d}
V_5	110.06^{ab}	15.9^{b}	91.91^{de}	4.27^{abcd}	1.6^{def}
V_6	83.17^{e}	10.41^{bcdef}	104.68^{c}	3.93^{abcdef}	0.8^{def}
V_7	102.8^{d}	14.47^{bcd}	141.68^{a}	4.5^{abc}	2.53^{c}

Note: Means followed by the same letter within a treatment are not significantly different at 5% level using Duncan's multiple range test (DMRT). Means of three replicates are taken.

Table 2 Growth attributes of B_9 mustard variety under the influence of combined dose of biofertilizer and chemical fertilizer during the winter cropping system of 2006

treatment	shoot length /cm	root length /cm	plant height /cm	primary branch per plant	secondary branch per plant
T_1	79.02^{ab}	10.88^{abcde}	89.85^{ab}	5.27^{d}	3.0^{abc}
T_2	78.97^{abc}	12.75^{ab}	91.03^{a}	6.40^{b}	3.6^{ab}
T_3	79.31^{a}	11.39^{abcde}	85.80^{abcde}	6.67^{a}	4.13^{a}
T_4	72.45^{abcde}	14.25^{a}	86.92^{abcd}	6.33^{c}	3.73^{abcd}
T_5	65.73^{abcde}	11.84^{abc}	88.17^{abc}	5.03^{e}	2.96^{abcde}
T_6	73.28^{abcd}	11.63^{abcd}	80.16^{abcde}	4.83^{f}	2.88^{abcde}

Note: Mean values followed by the same letter within a treatment are not significantly different at 5% level using Duncan's multiple range test (DMRT). Mean values of three replicates are taken.

Table 3 Growth attributes of B_9 mustard variety under the influence of growth retardant cycocel during the winter cropping system of 2006

treatment	shoot length cm	root length cm	plant height cm	primary branch per plant	secondary branch per plant
T_1	73.90^{bcd}	10.21^{e}	79.33^{b}	4.00^{abc}	2.33^{d}
T_2	77.95^{a}	11.47^{d}	75.1^{bc}	4.33^{ab}	3.00^{c}
T_3	75.64^{abc}	13.55^{a}	72.77^{bcd}	4.67^{a}	3.33^{b}
T_4	71.60^{de}	13.47^{ab}	70.77^{bcd}	3.33^{abcd}	1.67^{e}
T_5	63.25^{f}	12.70^{c}	63.73^{e}	2.67^{abcde}	1.33^{f}
T_6	75.65^{ab}	10.05^{f}	88.57^{a}	2.64^{abcde}	3.67^{a}

Note: Mean values followed by the same letter within a treatment are not significantly different at 5% level using Duncan's multiple range test (DMRT). Mean values of three replicates are taken.

Table 4 Growth attributes of B_9 mustard variety under the influence of compost, biofertilizer, and growth retardant cycocel during the winter cropping system of 2007

treatment	shoot length /cm	root length /cm	plant height /cm	primary branch per plant	secondary branch per plant
T_1	73.32^{abcde}	12.0^{e}	86.4^{e}	4.73^{abcde}	4.27^{abcde}
T_2	81.55^{a}	10.68^{cd}	95.4^{ab}	5.12^{abc}	4.42^{abc}
T_3	73.15^{abcde}	11.21^{cd}	90.06^{d}	5.3^{ab}	4.81^{ab}
T_4	77.86^{ab}	13.75^{a}	93.42^{abc}	5.53^{a}	5.03^{a}
T_5	75.28^{abcd}	13.28^{ab}	97.48^{a}	4.94^{abcd}	4.39^{abcd}
T_6	76.96^{abc}	10.12^{cd}	89.23^{d}	4.80^{abcde}	4.31^{abcde}

Note: Mean values followed by the same letter within a treatment are not significantly different at 5% level using Duncan's multiple range test (DMRT). Mean values of three replicates are taken.

3.2 Crop yield attributes

3.2.1 Siliquae per plant, length of siliquae, number of seeds per siliquae, and 1000-seed weight

In 2005, out of the seven varieties undertaken for the trial, the lowest siliquae per plant was observed in V_7 (56.57) and the highest in V_3 (153.8) (Table 5). In the first experiment of 2006, the lowest and highest number of siliquae was 139.12 in T_6 and 163.33 in-T_3, respectively (Table 6), and in the second experiment of 2006, the lowest and highest number of siliquae was 150.99 and 178.33, respectively, recorded in T_6 and T_3 (Table 7). In 2007, the number of siliquae per plant ranged between 162.33 (T_1) and 191.77 (T_4) (Table 8). The statistical data for the aforesaid years showed significant results in case of the first experiment of 2006 and 2007.

In 2005, variety V_3 (6.05 cm) recorded the highest length of siliquae, while the smallest length of siliquae was reported in variety V_7 (4.1 cm), indicating a significant difference between different varieties. In the first experiment of 2006, the value of the length of siliquae ranged between 5.22 cm (T_6) and 6.28 cm (T_3), and in the second experiment of 2006, the value ranged between 6.11 cm (T_6) and 7.14 cm (T_3). In 2007, the values ranged between 6.72 cm (T_1) and 7.52 cm (T_4). The above results indicated a statistical significance in the first experiment of 2006. The number of seeds per siliquae was also significantly affected by the varietal performance of the seven mustard varieties in 2005. The maximum and minimum number of seeds per siliquae was reported in V_3 (22.77) and V_7 (10.37), respectively (Table 5). The number of seeds per siliquae ranged between 18.67 (T_6) and 25.67 (T_3) (Table 6) in the first experiment of 2006 and between T_6 (18.66) and T_3 (23.67) in the second experiment of 2006–2007 (Table 7). In 2007, the values ranged between 22.4 (T_1) and 34.63 (T_4) (Table8). The maximum and minimum 1000 seed weight were recorded in B_9 (5.88 g) and Nathsona (3.41 g), respectively, during 2005 (Table 5). The highest 1000-seed weight was 6.34 g for the first experiment in 2006 (Table 6), 6.82 g for the 2nd experiment in 2006 (Table 7) and 6.70 g in 2007 (Table 8), respectively.

3.2.2 Seed yield

The seed yields ($g \cdot m^{-2}$) obtained from different plots were computed in all the field experiments of 2005, 2006 (the first and second experiments) and 2007 which revealed that, in varietal performance, the best yield was obtained in V_3 (B_9) (Table 5).In the first experiment of 2006, the best yield was obtained in the treatment T_3 (3/4th biofertilizer:1/4th chemical fertilizer)(Table 6), and in the second experiment of 2006, the best yield was obtained in treatment T_3 (300 ppm cycocel) (Table 7). In 2007, the best yield was obtained in case of treatment T_4 ($7.5\ t \cdot hm^{-2}$ + T_3-3/4th biofertilizer: 1/4th chemical fertilizer + T_3- 300 ppm) (Table 8). The general trend of higher seed yield was that application of biofertilizer, chemical fertilizer, and growth retardant (cycocel) along with compost application showed positive role in increasing seed yield of this crop under such agroclimatic condition of Burdwan district, West Bengal.

3.2.3 Straw yield

Straw yield data ($g \cdot m^{-2}$) from 2005, 2006, and 2007 were analyzed statistically. The results showed a significant variation among the different varieties and different treatments. In 2005, the highest and lowest straw yield was recorded in V_3 ($223.12\ g \cdot m^{-2}$) and V_1 ($130.65\ g \cdot m^{-2}$) (Table 5). In 2006, the value ranged between $185.02\ g \cdot m^{-2}$ in T_6 and $240.55\ g \cdot m^{-2}$ in T_3 (Table 6) for the first experiment varied between $220.34\ g \cdot m^{-2}$ (T_6) and $182.67\ g \cdot m^{-2}$ (T_1) (Table 7) for the second experiment, respectively. In 2007, the minimum and maximum straw yields were found to be in T_6 ($222.18\ g \cdot m^{-2}$) and T_4 ($283.79\ g \cdot m^{-2}$) (Table 8).

3.2.4 Oil content

The oil contents were measured from different plots during varietal performance in 2005, under different combined doses of chemical and biofertilizer for the first experiment of 2006 and different graded doses of growth retardant cycocel for the second experiment of 2006 and graded doses of compost along with the best dose of biofertilizer, chemical fertilizer, and growth retardant cycocel in 2007, respectively. The highest and lowest oil contents were similarly recorded in V_3 with the highest seed yield and V_7 (Table 5) in 2005–2006, respectively, indicating significant differences in all the three years except for the second experiment of growth retardant cycocel (2006).

4 Discussion

4.1 Crop growth attributes

4.1.1 Root length and shoot length

From the experimental results, the significant variations in the root and shoot length of the seven cultivated mustard varieties could be generated at the differential growth rate of the varieties under differential assimilation capacity of photosynthate and variable translocation rate in the different parts of plants in 2005. The shoot length and root length showed a considerably increasing trend among the various treatments of both the combined doses of biofertilizers and chemical fertilizers for the first experiment in 2006 and along with the compost and growth

Table 5 Yield attributes of seven varieties of mustard during the winter cropping season of 2005

variety	No. of siliquae per plant	length of siliquae/cm	seeds per siliquae	test wt of grains/g	seed yields /(g·m^{-2})	straw yield /(g·m^{-2})	oil content/%
V_1	72.67^{ef}	4.96^{abcdef}	14.25^{cdef}	3.92^{bcdef}	36.91^{abcdef}	130.65^{abcdef}	28.49^{f}
V_2	92.57^{d}	5.39^{abcd}	15.69^{cd}	4.06^{bcd}	51.22^{abcd}	203.27^{ab}	32.28^{bcd}
V_3	153.8^{a}	6.05^{a}	22.77^{a}	5.88^{a}	78.49^{a}	223.12^{a}	39.28^{a}
V_4	119.13^{b}	5.71^{ab}	21.93^{ab}	4.31^{b}	72.05^{ab}	146.89^{abcde}	33.94^{b}
V_5	74.37^{e}	5.38^{abcde}	14.34^{cde}	3.99^{bcde}	49.31^{abcde}	187.15^{abcd}	31.62^{bcde}
V_6	118.48^{bc}	5.49^{abc}	16.76^{c}	4.24b^{c}	61.7^{abc}	128.87^{abcdef}	33.29^{bc}
V_7	56.57^{g}	4.1^{g}	10.37^{g}	3.41^{g}	33.74^{abcdef}	188.99^{abc}	26.39^{f}

Note: Mean values followed by the same letter within a treatment are not significantly different at 5% level using Duncan's multiple range test (DMRT). Mean values of three replicates are taken.

Table 6 Yield attributes of B_9 varieties of mustard under the influence of combined dose of biofertilizer and chemical fertilizer during the winter cropping season of 2006

treatment	No. of siliquae per plant	length of siliquae/cm	seeds per siliquae	test wt of grains/g	seed yield /(g·m^{-2})	straw yield /(g·m^{-2})	oil content/%
T_1	147.22^{bcd}	5.92^{d}	21.67^{cd}	5.56^{c}	78.76^{d}	219.69^{d}	34.08^{d}
T_2	152.33^{b}	6.22^{ab}	23.67^{b}	6.15^{a}	87.61^{ab}	232.88^{ab}	37.70^{ab}
T_3	163.33^{a}	6.28^{a}	25.67^{a}	6.34^{a}	90.19^{a}	240.55^{a}	37.76^{a}
T_4	149.67^{bc}	6.19^{abc}	23^{c}	6.12^{ab}	84.06^{abc}	229.01^{abc}	37.05^{abc}
T_5	144.67^{bcde}	5.49^{e}	20.77^{cd}	5.46^{c}	76.75^{d}	215.76^{d}	33.96^{de}
T_6	139.12^{bcde}	5.22^{e}	18.67^{e}	3.55^{d}	60.41^{e}	185.02^{e}	33.52^{de}

Note: Mean values followed by the same letter within a treatment are not significantly different at 5% level using Duncan's multiple range test (DMRT). Mean values of three replicates are taken.

Table 7 Yield attributes of B_9 varieties of mustard under the influence of growth retardant cycocel during winter cropping season of 2006

treatment	No. of siliquae per plant	length of siliquae/cm	seeds per siliquae	test wt of grains/g	seed yield /(g·m^{-2})	straw yield /(g·m^{-2})	oil content /%
T_1	170^{c}	6.73^{abc}	22.67^{ac}	6.59^{bc}	80.99^{bc}	182.67^{e}	33.08^{bc}
T_2	171.67^{b}	6.83^{ab}	23^{ab}	6.62^{b}	83.34^{b}	184.18^{e}	33.38^{b}
T_3	178.33^{a}	7.14^{a}	23.67^{a}	6.82^{a}	88.89^{a}	212.14^{ab}	35.46^{a}
T_4	163.33^{d}	6.38^{abcd}	21.33^{d}	5.96^{d}	76.33^{d}	204.42^{c}	32.65^{bcd}
T_5	158.92^{e}	6.13^{abcde}	20.33^{d}	5.84^{d}	72.14^{e}	198.47^{cd}	31.24^{bcde}
T_6	150.99^{f}	6.11^{abcde}	18.66^{e}	5.78d^{e}	71.79^{e}	220.34^{a}	30.89^{bcde}

Note: Mean values followed by the same letter within a treatment are not significantly different at 5% level using Duncan's multiple range test (DMRT). Mean values of three replicates are taken.

Table 8 Yield attributes of B_9 varieties of mustard under the influence of compost, biofertilizer, and growth retardant cycocel growth retardant cycocel during winter cropping season of 2007

treatment	No. of siliquae per plant	length of siliquae /cm	seeds per siliquae	test wt of grains/g	seed yield /(g·m^{-2})	straw yield /(g·m^{-2})	oil content /%
T_1	162.33^{bcd}	6.72^{de}	22.4^{d}	6.12^{abcde}	84.01^{abcde}	222.18^{e}	36.28^{abcde}
T_2	175.28^{bc}	7.01^{e}	28.97^{f}	6.32^{abc}	94.58^{abc}	253.51^{bc}	39.56^{abc}
T_3	181.97^{b}	7.46^{ab}	29.43^{b}	6.53^{ab}	96.12^{ab}	266.03^{b}	40.26^{ab}
T_4	191.77^{a}	7.52^{a}	34.63^{a}	6.70^{a}	98.04^{a}	283.79^{a}	46.79^{a}
T_5	168.9^{bcd}	6.97^{cd}	24.07^{d}	6.28^{abcd}	89.03^{abcd}	244.99^{bcd}	38.45^{abcd}
T_6	167.33^{bcd}	6.91^{de}	23.93^{d}	6.18^{abcde}	86.48^{abcde}	228.13^{e}	37.96^{abcde}

Note: Mean values followed by the same letter within a treatment are not significantly different at 5% level using Duncan's multiple range test (DMRT). Mean values of three replicates are taken.

retardant cycocel in 2007–2008. However, in the second experiment of 2006, the shoot length and root length showed a reducing trend with the increasing concentration of the growth retardant. For the first experiment of 2006 and 2007, the application of biofertilizers (*Azotobacter*, *Phosphobacter*), compost, along with chemical fertilizers increased the nutrient use efficiency of the plants as the organic fertilizer acted as an excellent source of macro and micro nutrients, and, therefore, increased the shoot and root length, which was in accordance with the findings of Asghar et al. (2006). In the second experiment of 2006, due to the antigibberellic nature of cycocel, it reduced the length of root and shoot in the present observation as was reported by Green et al. (1986). The retardant cycocels specifically can exert their influence by inhibiting cell division in the sub apical zones of shoot apex and subsequent cell enlargements resulting in cell elongation reduction. These growth retardants (often called antigibberellins) that control shoot growth by inhibiting the production of gibberellic acid are responsible for cell elongation of shoots (Franke and Hassanein, 1996; Barett, 2001).

4.1.2 Plant height

Plant height showed a significant variation among the varieties. The Nathsona recorded the highest plant height during 2005–2006. It seemed that such a variety consumed greater assimilates, thereby reducing its allocation to yield components and consequently decrease in the yield. In comparison, among the high-yield cultivars, probably more assimilates were partitioned between stems and yield components; therefore, the competition between these sinks declined. Some earlier reports (Ozer et al., 1999) also revealed positive and significant correlations between plant height and grain yield in rapeseed. Compared with the control, the plant height showed an increasing trend in all the treatments of combined doses of biofertilizer and chemical fertilizer for the first experiment of 2006 and compost along with biofertilizer, chemical fertilizer, and growth retardant in the field trial of 2007. These results were contrary to those for the second field trial of 2006–2007 with growth retardant cycocels. Due to the fact that cycocel is antigibberellic, i.e., it inhibited the effective gibberellic acid synthesis or promoted its destruction and therefore checked the excessive vegetative growth and helped in the translocation of photosynthates from leaves to pods, as was reported by Chandra (1985). Also, the decreasing trend of plant height with different doses of application of cycocels may be ascribed to the retardation of transverse cell particularly in cambium, which is the zone of meristematic activity at the base of internodes. The results of our present study were in agreement with the findings of Grossmann (1990) who opined that cycocel was an antigibberellin dwarfing agent, leading to a deficiency of the gibberellin in plants and reducing the growth by blocking the conversion of geranyl pyrophosphate to copalyl pyrophosphate as the first step of gibberellin synthesis. Therefore, the plant height reduced significantly in various treatments with respect to control in the first field trial, and in 2007–2008, the plant height showed an increasing trend probably generated by the application of biofertilizers *Azotobacter* and *Phosphobacter* species. *Azotobacter* has been found to produce the dark colored humus, which are the precursors of quinones. Quinone was reported to help the growth of crops. Similarly, it was also reported by Sprenat (1990) that azotobacterization often leads to solubilization of mineral nutrients, synthesis of vitamins, amino acids, auxins, and gibberellins, which stimulate plant growth. In 2007, the application of compost led to enhancement of the activity of *Azotobacter* population due to the increase in the population of *Azotobacter*, and, therefore, contributing toward the good crop growth in terms of increased plant height. Additionally, it was very likely that when we applied compost along with chemical fertilizers, the compost not only slowly released nutrients from itself but also prevented the losses of chemical fertilizers through denitrification, volatilization, and leaching to bind the nutrients and release nutrients with the passage of time (Arshad et al, 2003) until crop growth increased, as reported by Asghar et al. (2006).

4.1.3 Number of primary and secondary branches

The variation in the number of primary and secondary branches per plant reflected the differential rate of vegetative growth among the seven cultivated mustard varieties. This difference in the number of primary branches per plant was due to the genetic potential of the varieties, which might contribute toward the final yields. These results were in agreement with some earlier works (Munir and McNeilly, 1986). The results regarding the number of secondary branches per plant revealed that the said trait was highly significantly affected by different varieties of mustard. Our results were corroborated with some earlier works (Sharma and Manchanda, 1997). The results of 2006 and 2007, revealed that the number of primary and secondary branches increased with respect to control in the first experiment of 2006, and in the field trial of 2007, whereas, it decreased in the second experiment of 2006–2007. The increasing trend was likely to be attributed to the inoculation with *Azotobacter* and *Phosphobacter* biofertilizers that may have secrete growth promoting substances and therefore may have contributed significantly toward the increase in the number of primary and secondary branches per plant in various combined treatments of biofertilizer and chemical fertilizer for the first field trial of 2006. In case of 2007, the combined application of growth regulator cycocel, biofertilizer, and compost gradually increased the nutrient use efficiency of the crop plant, which contributed toward the significant increase in the number of primary and secondary branches per plant. In the second experiment of 2006, the decreasing trend in the number of primary branches and secondary branches may be attributed toward the antigibberellic activity of growth regulator cycocel along with the delayed breaking of apical dominance (Rademacher, 1992).

4.2 Crop yield attributes

4.2.1 Number of siliquae per plant, seeds per siliquae, length of siliquae, and 1000-seed weight

From the current investigation, it was observed that there were considerable variations in the yield attributes and yields of the seven mustard varieties during 2005. The number of siliquae had a close relationship with grain yield in rapeseed, determined by the number of branches, buds, and flowers, as well as by the capacity of source, and the supply of nutrients and water (Allen and Morgan, 1975; Tayo and Morgan, 1975; Diepenbrock, 2000). In some earlier studies, Ali et al.(2003) observed a significant correlation between siliquae number and yield in rapeseed; Thurling, (1974b) reported that, in *B. campestris*, there was a significant correlation between yield and siliquae number and Ozer et al. (1999) suggested that the siliquae number could be a good selection criterion for increasing grain yield in rapeseed. In our study, seeds per siliquae increased due to optimum moisture level for B_9 in comparison to the other varieties, which helped produce longer siliquae, and higher number of seeds were obtained (Sultana et al., 2009). The variation between the varieties was generated by the relationship between the number of seed per siliquae and seed in one hand and plant potential for increasing siliquae or seed number on the other, as reported earlier (Miri, 2007). Regarding1000-seed weight, there was also a considerable variation among the varieties. This was probably due to the compensatory relation between yield components, as in cultivars with low grain yield, the number of pod and seed per pod was low, and available assimilates partitioned between lower number of seeds and each seed received more assimilate in comparison with high yield cultivars. Evans (1993) mentioned the seed size depended on environmental conditions, genotype, and the potential of the genotype in producing seed number. It seemed that the genotype had minor effects on seed weight in comparison with environment. In 2006, the yield attributes, viz., the number of siliquae per plant, length of siliquae, siliquae seeds, and test weight of seeds, showed an increasing trend in both the experiments of 2006 and in the field trial of 2007–2008. In the first field trial of wheat plants in 2006, the different combined doses of biofertilizer and chemical fertilizer, bacterization with *Azotobacter* and *Phosphobacter* intensified the activity of rhizospheric microflora involved in ammonification, anaerobic nitrogen fixation, nitrification, phosphate mineralization (Shende, 1965; Patel, 1969) and hence improved the nutrient use efficiency of the crop plants, leading to higher yield attributes, as was reported by Singh et al.(2006). In the second field trial of 2006 with growth retardant cycocel being antigiberellic, the excessive vegetative growth was checked and helped in the translocation of photosynthates from source (leaves) to sink (pods), as earlier reported by Singh and Sarkar in 1976, in case of pulses leading toward higher yield attributes in the mustard crop plants. Again, in 2007–2008, the application of compost along with biofertilizer and chemical fertilizer provided an adequate and balanced supply of nutrients. Plants were nourished with a large amount of nutrients throughout their growth period resulting in the maximum number of siliquae per plan. Our findings were corroborated by Khaliq (2004). The increase in the tested weight of seeds was mainly due to the balanced supply of food nutrients both from chemical fertilizer and compost throughout the grain filling and development period, which was in accordance with the findings of Rutanga et al. (1998) and Ma et al. (1999). The highest and lowest seed yield appeared in V_3 and V_7 with an overall reflection of the value of yield attributes including number of siliquae per plant, number of seeds per siliquae, and the test weight of seeds, which was previously reported by some other workers (Bharati et al., 2003).

4.2.2 Seed yield

The seed yield showed an increasing trend in both the field trials of 2006 and the field trial of 2007. For the first field trial of 2006, the combined dose of biofertilizer and chemical fertilizer showed a significantly increasing trend in wheat yield and productivity, which was attributed toward the contribution of microelement and plant growth regulator contained in the fertilizer, as was reported by Zodape (2001), as well as toward the production of growth promoting substances due to the application of biofertilizers that had a significant effect on the morphology and development of the root, as was reported by Amellal et al. (1998). In the second field trial of growth retardant cycocel of 2006, the increased seed yield might be due to the enhancement of partitioning efficiency and better source-sink relationship in the plant by the growth regulator. Our present investigations were in conformity with the findings of Swarna (2002) who reported an increase in seed yield of moth bean by foliar spray of cycocel. The significant increase in yield among the various treatments of biofertilizer and chemical fertilizer may also be attributed toward reduced plant height and increased branching, resulting in a diversion of food material for the improvement of flowering and fruiting (Kuraishi and Muri, 1962). In 2007, the same increasing trend was observed by integrated application of compost, growth retardant, biofertilizer, and chemical fertilizer. In the combination of growth retardant cycocel along with the compost, the biofertilizers significantly increased in the yield of mustard, which, then, enhance the nutrient use efficiency by the crop plants in the presence of compost and biofertilizer on one hand and more translocation of photoassimilate toward the sink by the application of growth retardant (Nevens and Reheul, 2003) on the other hand. This indicated that reduced dose of nitrogenous and phosphatic fertilizers in combination with biofertilizer + compost + growth retardant had a remarkable effect on increasing seed yield and reducing environmental pollution. The data also showed that the maximum yield in 2007 was higher than that of all the experiments of 2006 after the addition of compost. Therefore, such agrotechnology will boost up the seed yield of mustard crop through seed treatment combinations.

Our findings confirmed the observations by Becker et al. (1991) in *Sesbania rostrata*, Aroonsri (1993) and Tangcham et al. (2000), who noted an increased yield in rice through the use of combined dose of nitrogen fertilizer and compost, El-Hawary (2002), who found higher yield in wheat through the use of biofertilizers, and Hegazi et al. (2007), who revealed a fast vegetative growth in Picual Olive trees through the use of poultry manure.

4.2.3 Straw yield

It is interesting that under the same recommended dose of chemical fertilizers, the seven cultivated mustard varieties significantly differed from one another in relation to stover yield due to their relative capability of dry matter production determined by the varietal characteristics (Chakraborty et al., 1991; Saran and Giri, 1987). With respect to straw yield, an increasing trend among different treatments in the case of the first field trial of 2006 and 2007 and a decreasing trend in the second field trial of 2006 were observed. For the first field trial of 2006, the inoculation of mustard seeds with the biofertilizer *Azotobacter* and *Phosphobacter* along with chemical fertilizers had contributed significantly toward the increase in straw yield, as was reported by El kased et al. (1996). For the second field trial of 2006, the growth retardant cycocel, arrested the vegetative growth of crop plants leading toward the decreasing trend in the straw yield. For the field trial of 2007, the straw yield showed an increasing trend due to the combined effect of biofertilizer and compost application that had nullified the effect of growth retardant cycocel.

4.2.4 Oil content

During the years of 2006 and 2007, the increase in oil content of the crop plants might be due to either the increased vegetative growth or changes in leaf oil gland population and monoterpenes biosynthesis under the influence of biofertilizers, growth retardant, and compost (Gharib et al., 2008).

5 Conclusion

Results suggested that the introduction of a high yielding crop variety with balanced application of N and P fertilizers can be recommended to the end users. Our present investigation revealed that the best variety of the seven mustard varieties under the old alluvial soil agro-climatic zone was B_9 based on the attributes of growth, morpho-physiologic and yield, in terms of yield. Therefore, B_9 can be cultivated for a better yield of mustard under old alluvial soil zone under recommended dose of chemical fertilizers. Aside from that , the highest yield of B_9 was also found in case of T_3 treatment (3/4th chemical:1/4th biofertilizer) in the first field trial of 2006, T_3 treatment ($300\,mg\cdot L^{-1}$) in the first field trial of 2006, and T_4 ($7.5\,t\cdot hm^{-2}$ compost + 3/4th chemical:1/4th biofertilizer + 300ppm growth retardant cycocel) in the field trial of 2007 that were selected as the best treatments for the respective field trials under the old alluvial soil of Burdwan District, West Bengal, India. We suggest that judicious use of biofertilizers, composts, chemical fertilizers, and growth retardants can lead toward an increase in the yield under the agroclimatic condition of the old alluvial soil of Burdwan, West Bengal, India.

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