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# INFLUENCE OF MULCHING AND FERTILIZERS ON GROWTH, YIELD AND QUALITY OF SUGAR BEET

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## Abstract

An experiment was carried out during the period from October 2022 to April 2023 to investigate the effect of different mulching materials and fertilizers on sugar beet growth, yield, and quality. The experiment consisted of mulch materials: no mulch, black polythene mulch, and rice straw mulch; and four fertilizer treatment: control (no fertilizer), 100% RCF (recommended chemical fertilizer), 100% vermicompost @ 10 t/ha and 50% vermicompost @ 5 t/ha + 50% RCF. Treatment with 50% vermicompost + 50% inorganic fertilizer (RCF) produced significant results than other treatments. Among the mulch materials, black polythene performed better than the other mulch materials. Accordingly, 50% vermicompost + 50% inorganic fertilizer and black polythene mulch may be recommended to obtain better sugar beet yield and quality.

**Keywords:** Black polythene, Rice straw, Sugar beet, Vermicompost.

## Introduction

Tropical sugar beet, scientifically known as *Beta vulgaris* (L.), is a biennial, herbaceous tuber crop grown in temperate climates that yields sugar. It is one of the most widely grown crop in the Chenopodiaceae family (Chawla *et al.*, 2016). The current production of sugar in Bangladesh meets about 5% of total demand and 20% of total requirement covers with jaggery mainly from sugarcane and the rest 75% sugar demand is fulfilled by import (Rahman *et al*., 2016). The area under cane cultivation is drastically reduced due to pressure of cereals and other short-duration crops, which cause lower amount of sugarcane production. Sugar beet has got many benefits compared to sugarcane due to its short duration with high sucrose contents (Paul *et al*., 2018).

Soil fertility is being depleted due to increased cultivation in the country driven by population growth, while the use of mineral fertilizers to restore nutrients has drawbacks such as high costs and harmful effects on soil health and the environment (Abd-Elrahman, 2017). Fertilizers, both organic and inorganic, may influence the growth and development of crops. Imbalanced nutrition is one of the important constraints towards higher productivity and other quality parameters of crops. According to Islam *et al.* (2016), an integrated strategy to fertilizer management might significantly reduce leaching losses of nitrogen (N), phosphorous (P), potassium (K), and sulfur (S). Manures

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provide all the necessary nutrients, enhance the physical, chemical, and biological characteristics of soils, and may even aid increase agricultural yield while preserving the environment. According to Kamal *et al*. (2012), deteriorated soil can be productively restored with organic fertilizer. Integrated nutrients management have a major impact on tomato (*Lycopersicon esculentum* L.) agronomical growth and crop yield (Chopra *et al.*, 2017). Mulching, particularly polyethylene mulch, which raises soil temperature and modifies the microclimate (Malik *et al*., 2018), can improve the available soil moisture condition by capturing micro efficient or ineffective precipitation, decreasing soil evaporation, and limiting runoff (Chen *et al*., 2019). Mulching is essential for improving crop productivity by raising soil temperature, conserving moisture, and reducing weed infestation, particularly in winter, leading to lower costs (Chakraborty *et al*., 2008). The use of black polyethylene film mulch was also found to be superior to that of straw mulch (Moursy *et al*., 2021).

Crop yield potential can be achieved by the effective and balanced use of both organic and inorganic fertilizer sources as well as the application of appropriate agronomic package practices (Meena *et al*., 2016). A limited amount of information has been published on sugar beet production in terms of the best mulch material and suitable nutrient management. Therefore, this experiment has understood to determine the effect of mulching and nutrient management on growth and yield of sugar beet and to identify the suitable treatment combination for quality sugar beet production.

## Materials and Methods

The study was carried out at the central farm of Sher-e-Bangla Agricultural University Dhaka during November 2022 to April 2023. The farm is situated at an elevation of 8.2 meters above sea level, at latitude 23°47′ N and longitude 90°35′ E. The experiment was carried out in a Randomized Complete Block Design (RCBD) with three replications. This study was set up using a two-factorial design with Factor A: $M_0$ (No mulch), $M_1$ (Black polythene mulch) and $M_2$ (Rice straw mulch); and $F_0$=Control (no fertilizer), $F_1$=100% RCF (recommended chemical dose), $F_2$= 100% Vermicompost @ 10 t/ha, and $F_3$= 50% Vermicompost @ 5 t/ha + 50% RCF. The chemical composition of vermicompost was analyzed with the help of SRDI (Table 1). The initial soil nutrient status was also explored in the laboratory of SRDI (Table 2). In case of mulching, 15μM of black high-density polyethylene (HDPE) film was used and the thickness of rice straw mulch was maintained 4-5 cm (3t/ha) as a layer, which helped to control soil temperature and moisture. Well-decomposed vermicompost was applied 15 days before seeding. Nitrogen, phosphorus, potassium, zinc, sulfur and boron were applied in the forms of urea, TSP, MP, Zinc sulphate, gypsum and boric acid @ 260, 100, 225, 10, 100 and 20 kg $ha^{-1}$, respectively. Full dose of phosphorus was applied as basal dressing at the time of sowing. Nitrogen and potash were split into three applications: one at the base and two side dressings at 30 and 60 days after sowing (FRG, 2018). The tropical sugar beet genotype SV889 was used. Seeds treated with Vitavax-200 fungicide, were sown on November 10, 2022, in bed method, at a spacing of 50 cm × 20 cm. Sugar beets were harvested by hand when 70–80% of the leaves were dried. Irrigation was stopped 15 days before harvesting to allow the land to dry.

**Table 1.** Nutrient composition of vermicompost

| Sample | Chemical composition | | |
|---|---|---|---|
| Vermicompost | N (%) | P (%) | K (%) |
| | 1.32 | 1.16 | 1.27 |

**Table 2.** Initial soil fertility status of the experimental plot

| Soil characters | Value |
|---|---|
| pH | 6.7 |
| Organic matter | 1.35 |
| Nitrogen | 0.11% |
| Phosphorus | 20 ppm |
| Potassium | 0.12 meq/100 g soil |
| Sulphur | 44 ppm |
| Boron | 0.19 ppm |
| Zink | 8.52 ppm |


**Fig. a.** Research field with treatment combination

**Fig. b.** Sugar beet data collection

## Measurement of growth parameters

Five plants in each treatment and replication were used to measure different growth parameters. The height of the plant, length of leaf petiole, length of leaf blade, width of leaf blade, root length was measured with the help of a measuring tape and root diameter measured by a slide caliper. Plant height and no. of leaves data were taken on the dates of harvest as well as at 30, 60, 90 and 120 DAS. Number of leaves were counted individually. Root length and root diameter were measured on the dates of 60 DAS to harvest.

## SPAD value

The initial fully inflated leaf content was measured using a Minolta, Tokyo, Japan, SPAD-502 chlorophyll meter. All treated and control plants had measurements made from the middle of the leaf lamina.

## Measurement of yield and yield attributes

### Sugar beet yield

Five plants were randomly counted from each plot, and the mean weight of shoot and root was recorded (g) using a digital electric balance. The shoot and root were dried for 48h at 70ºC in a convection oven, then transferred into desiccator and allowed to cool down at room temperature, final weight was recorded (g) as shoot and root dry weight.

Sugar beet yield was calculated using the formula:

$$Sugar\ beet\ yield\ (t/ha) = \frac{Beet\ yield\ (kg/plot)}{1000\ x\ Net\ plot\ size}\ x\ 10000$$

### Sugar yield

Sugar yield was calculated using the formula:

$$Sugar\ yield\ (t/ha) = \frac{Sucrose\ \%}{100} x\ beet\ yield\ (t/ha)$$

## Measurements of quality attribute

### TSS

By using a hand refractometer (Hanna Instruments, HI96801, Romania) at room temperature, the percentage of brix was measured after harvest.

### Sucrose %

Pol or percent sucrose is the only sucrose content in the juice measured by polarimeter. Pol percent juice was measured by using automatic polarimeter (Model AP-300, Atago Co., Ltd., Japan).

### Purity%

Apparent purity percentage was determined as a ratio of sucrose % divided by TSS% of roots as the method outlined by Carruthers and Old Field (1960). The purity percentage was calculated from the data of brix and sugar percentage by using the following formula:

$$Purity\ \% = \frac{Sucrose\ \%}{TSS\ (Brix\ reading)}\ X\ 100$$

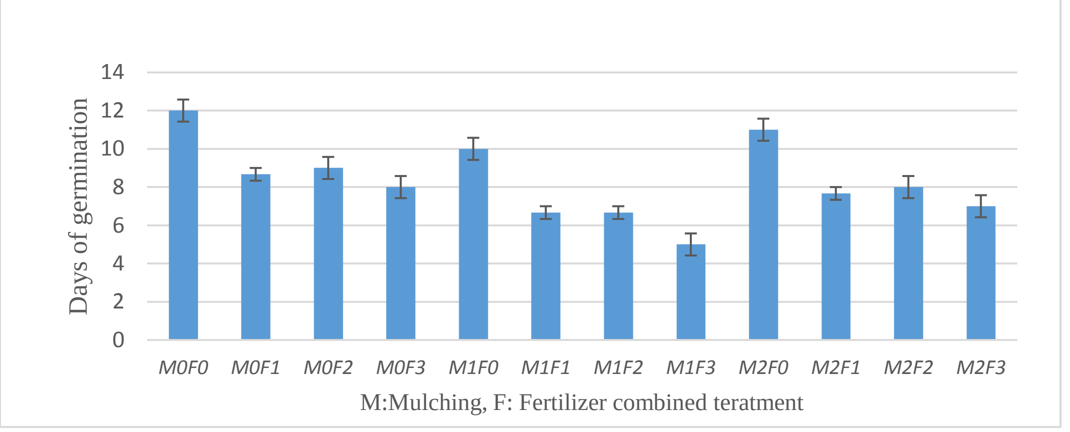
## Statistical analysis

The collected data were analyzed statistically by using the “Statistix 10” computer package. Least Significant Difference (LSD) technique at 0.05% level of significance was used to compare the mean differences among the treatments (Gomez and Gomez, 1984).

## Results and Discussion

### Seed germination

The use of mulching improved nutrient availability, soil structure, reduce nitrate leaching, improved the physical characteristics of the soil, increased biological activity, supply organic matter, regulate temperature and water retention, and lessen erosion (El-Beltagi *et al*., 2022). The combined use of mulching and fertilizers significantly ($P \leq 0.05$) increased the days of seed germination (Figure 1). The shortest beet root germination time (5 days) was achieved with black polythene mulch and a mixture of 50% vermicompost and 50% RCF. Treatments $M_1F_1$ and $M_1F_2$ both resulted in germination within 6.67 days, while the slowest germination (12 days) occurred with no treatment. Ferdousi *et al*. (2010) reported similar results in potato seed germination (maximum time 17.00 days), where organic and inorganic fertilizers combined with black polythene mulch sped up the process.

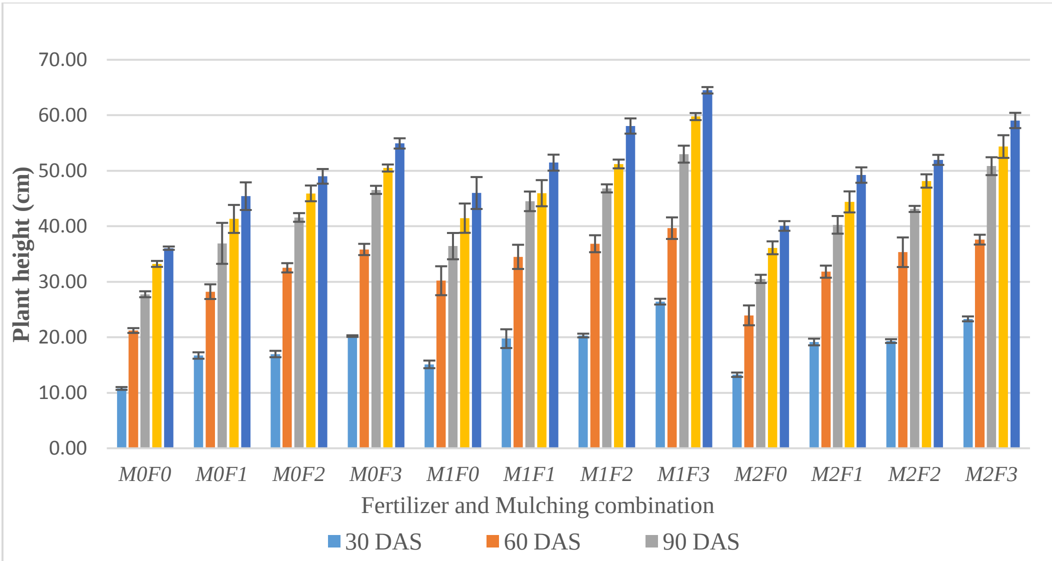



Here, $M_0$=No mulch, $M_1$=Black polythene mulch, $M_2$=Rice straw mulch, $F_0$=Control (No fertilizer), $F_1$=100% RCF (Recommended chemical fertilizer), $F_2$=100%Vermicompost @ 10 t/ha, and $F_3$=50%Vermicompost @ 5 t/ha + 50% RCF.

**Fig. 1.** Effect of mulching and fertilizer management on days to seed germination of sugar beet

### Plant height (cm)

Sugar beet plant height was significantly influenced by mulching and nutrient management. The impact of different mulching and fertilizer treatments on plant height at various growth stages (30, 60, 90, 120, and 155 DAS) is shown in Figure 2. During 30 to 155 DAS, plant height ranged from 26.43 to 64.50 cm in the $M_1F_3$ treatment and 23.33 to 59.07 cm in the $M_2F_3$ treatment. In comparison, plant height in the $M_0F_3$ treatment ranged from 20.23 to 54.93 cm, while the control ($M_0F_0$) ranged from 10.80 to 36.07 cm. The $M_1F_3$ treatment produced the tallest plants, with a maximum height of 64.50 cm at 155 DAS, followed by $M_2F_3$ at 59.07 cm and $M_1F_2$ at 58.07 cm. The shortest plants (36.07 cm) were observed in the control treatment at 155 DAS. The use of black polythene mulch with 50% RCF and 50% vermicompost @ 5 t/ha resulted in the maximum plant height of sugar beet.



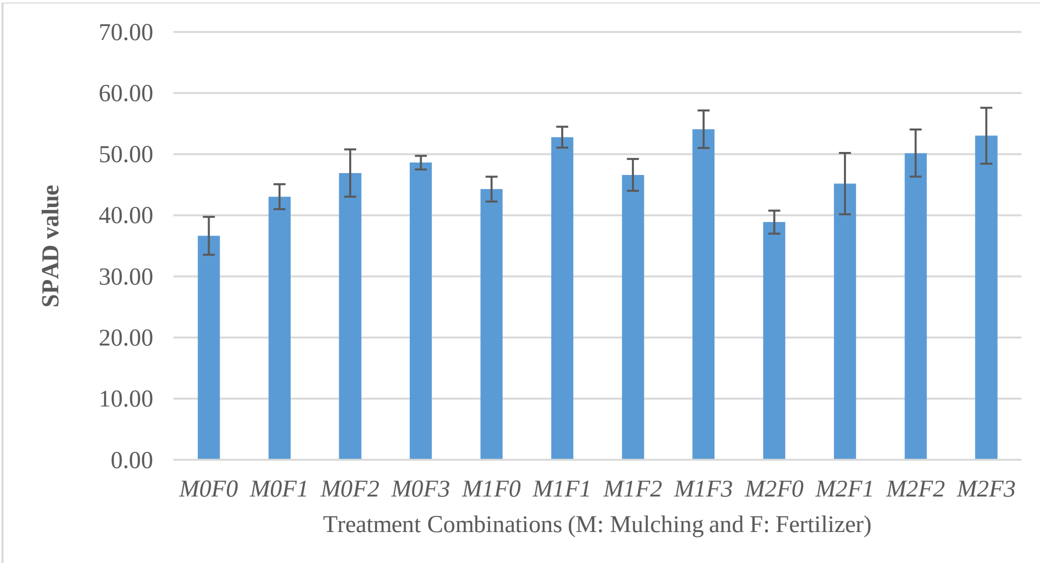

Here, $M_0$=No mulch, $M_1$=Black polythene mulch, $M_2$=Rice straw mulch, $F_0$=Control (No fertilizer), $F_1$=100% RCF (Recommended chemical fertilizer), $F_2$=100%Vermicompost @ 10 t/ha, and $F_3$=50%Vermicompost @ 5 t/ha + 50% RCF.

**Fig. 2.** Effect of mulching and fertilizer management on sugar beet plant height at different days after sowing

Similar findings were reported by Jagadeesh *et al*. (2018), Maloisane *et al*. (2022) and Sarker *et al*. (2023) on sugar beet. Plant height was 10.90 to 12.33% higher with different treatments compared to the control. The combination of vermicompost, inorganic fertilizer and mulching enhanced plant growth by providing both immediate and sustained nutrient release.

## SPAD value

The revealed data showed statistically significant ($P \leq 0.05$) variations on SPAD value of sugar beet under interaction effects of different mulching and fertilizer management treatment. The combined treatments, $M_1F_3$ (BPM + 50% RCF and 50% vermicompost @5t/ha) and $M_2F_3$ (RSM + 50% RCF and 50% vermicompost @5t/ha) produced the maximum SPAD values (54.7 and 53, respectively). Meanwhile, the control treatment (No mulch + no fertilizer) gave the lowest, 36.63 SPAD value (Figure 3). SPAD value increased in fully vegetative stage that means from 60 DAS to 120 DAS.

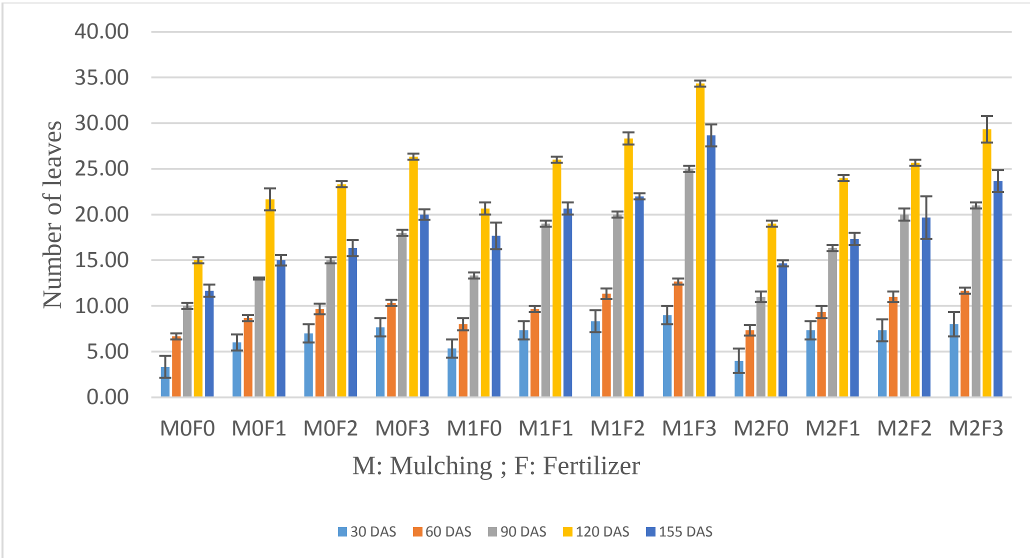



Here, $M_0$=No mulch, $M_1$=Black polythene mulch, $M_2$=Rice straw mulch, $F_0$=Control (No fertilizer), $F_1$=100% RCF (Recommended chemical fertilizer), $F_2$=100%Vermicompost @ 10 t/ha, and $F_3$=50%Vermicompost @ 5 t/ha + 50% (RCF).

**Fig. 3.** Effect of Mulching and Fertilizer management on SPAD value of sugar beet

## Number of leaves/plants

The number of leaves is one of the major growth-attributing parameters. The interaction of different mulching types and organic and inorganic fertilizer management significantly ($P \leq 0.05$) influenced the number of sugar beet leaves (Figure 4) and data were recorded from 30 DAS to 150 DAS**.** The $M_1F_3$ treatment resulted in the highest leaf count of 28.67 leaves per plant, while the control ($M_0F_0$) had the lowest at 11.67 leaves per plant. The combined treatments $M_0F_3$, $M_1F_1$, $M_1F_2$, and $M_2F_3$ also showed superior leaf numbers (20.00, 20.67, 22.00, 23.67 leaves per plant, respectively) with no significant differences among them. The result obtained shows that the number of leaves decreased at harvest due to drying of older leaves. The combined application of vermicompost and chemical fertilizer produced more leaves per plant than vermicompost alone (Zaman *et al*., 2015; Lasmini S A *et al*., 2019).

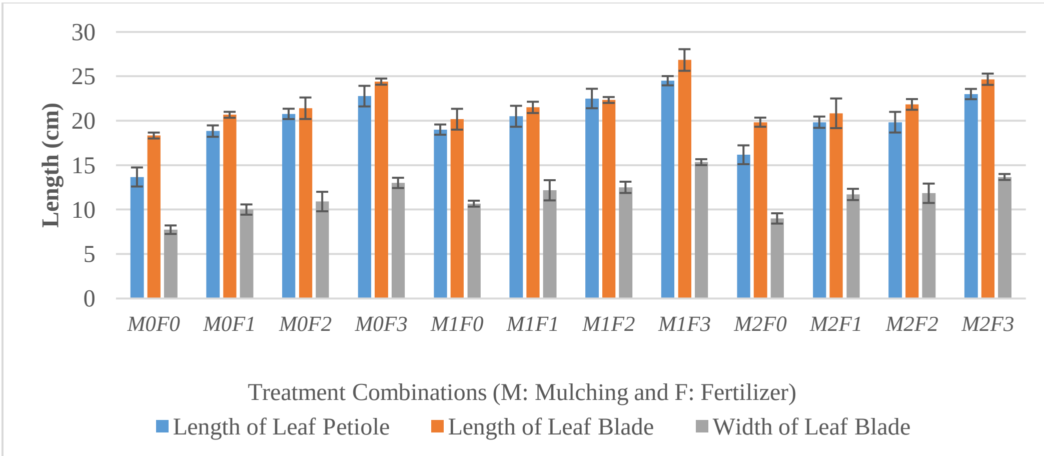



Here, $M_0$=No mulch, $M_1$=Black polythene mulch, $M_2$=Rice straw mulch, $F_0$=Control (No fertilizer), $F_1$=100% RCF (Recommended chemical fertilizer), $F_2$=100%Vermicompost @ 10 t/ha, and $F_3$=50%Vermicompost @ 5 t/ha + 50% RCF.

**Fig. 4.** Effect of mulching and fertilizer management on no. of leaves of sugar beet at different days after sowing

## Leaf characters

The combined application of mulching and fertilizer have significant ($P \leq 0.05$) effect on the leaf characters (length of leaf petiole, length of leaf blade and width of leaf blade) of sugar beet and the results are showed in the Figure 5. The longest leaf twig length and leaf blade length were 24.5 cm and 26.83 cm, recorded from $M_1F_3$ treatment. The lowest length of leaf petiole 13.67 cm and length of leaf blade was 18.33 cm, recorded from $M_0F_0$ (control) treatment. The results are in agreement with the finding of Ruksun *et al.* (2022) in spinach. Similarly, the largest leaf blade width of 15.33 cm was recorded in the $M_1F_3$ treatment, while the second largest, 13.67 cm was observed in the $M_2F_3$ treatment. The smallest width, 7.73 cm, was recorded in the control ($M_0F_0$) treatment. Similar results were found by Dulal *et al*. (2021) in radish.

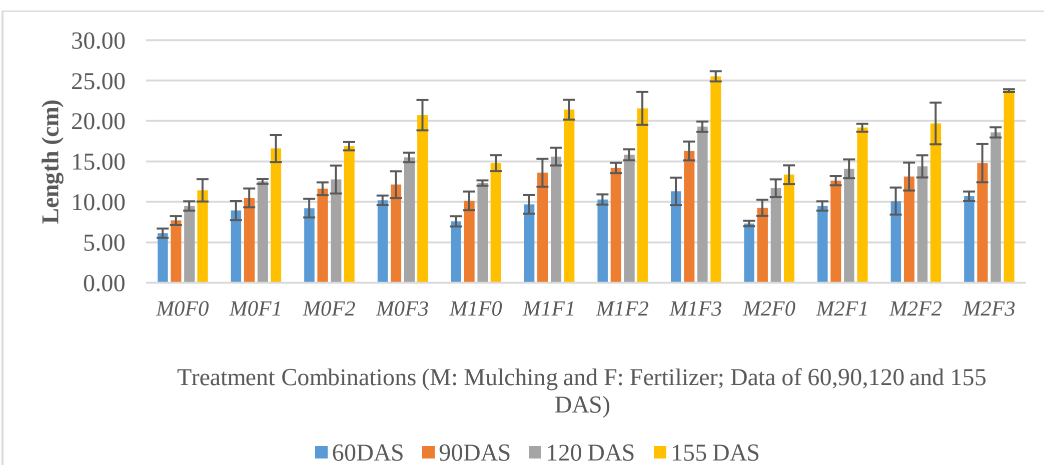



Here, $M_0$=No mulch, $M_1$=Black polythene mulch, $M_2$=Rice straw mulch, $F_0$=Control (No fertilizer), $F_1$=100% RCF (Recommended chemical fertilizer), $F_2$=100%Vermicompost @ 10 t/ha, and $F_3$=50%Vermicompost @ 5 t/ha + 50% RCF

**Fig. 5.** Effect of mulching and fertilizer management on leaf characters of sugar beet

## Root length (cm)

The interaction of mulching and nutrient management significantly ($p<0.05$) influenced root length (Figure 6). The longest root (25.53 cm) was obtained with black polythene mulch and $M_1F_3$. Treatments $M_1F_1$ and $M_1F_2$ had similar lengths (21.40 cm and 21.57 cm, respectively). The shortest beet root length (11.43 cm) was observed in the $M_0F_0$ treatment (no mulch, no fertilizer). Similar results were reported by Maloisane *et al*. (2022) in sugar beet.

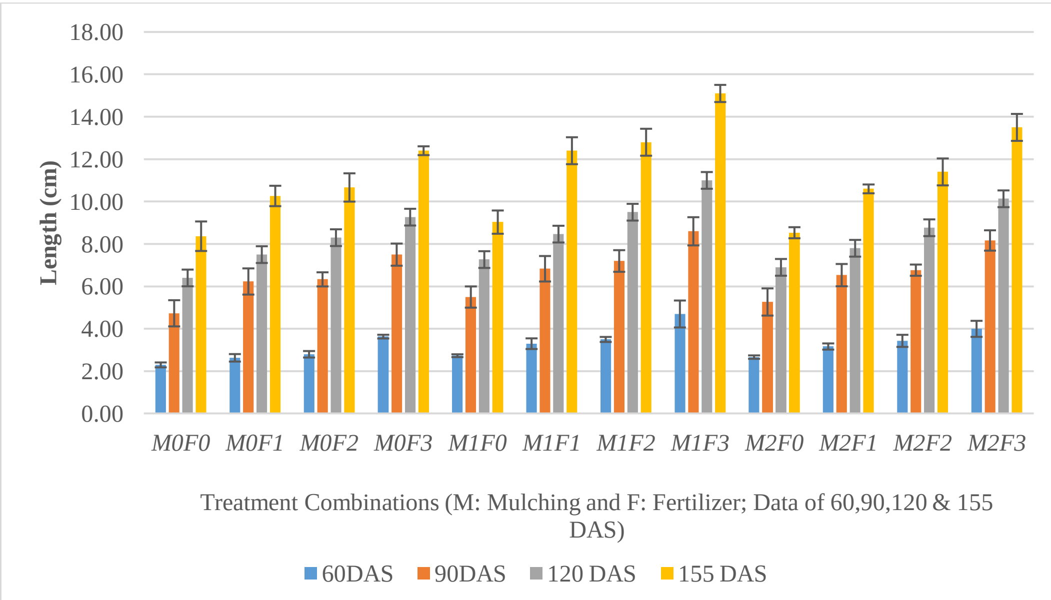



Here, $M_0$=No mulch, $M_1$=BPM, $M_2$=RSM, $F_0$=Control (No fertilizer), $F_1$=100% RCF (Recommended chemical fertilizer), $F_2$=100%Vermicompost @ 10 t/ha, and $F_3$=50% Vermicompost @ 5 t/ha + 50% RCF.

**Fig. 6.** Effect of mulching and fertilizer management on root length of sugar beet at different days after sowing

## Root diameter (cm)

Sugar beet root diameter increased gradually from 60 DAS to 155 DAS with both individual mulching and fertilizer treatments (Fig. 7). The largest root diameter (15.1 cm) was recorded in the $M_1F_3$ treatment, followed by 13.5 cm in $M_2F_3$. The smallest diameter (8.37 cm) was observed in $M_0F_0$ (no mulch, no fertilizer) at harvest. Similar results were reported by Dulal *et al*. (2021) in radish and Maloisane *et al*. (2022) in sugar beet.




Here, $M_0$=No mulch, $M_1$=BPM, $M_2$=RSM, $F_0$=Control (No fertilizer), $F_1$=100% RCF (Recommended chemical fertilizer), $F_2$=100%Vermicompost @ 10 t/ha, and $F_3$=50%Vermicompost @ 5 t/ha + 50% RCF.

**Fig. 7.** Effect of mulching and fertilizer management on root diameter of sugar beet at different days after sowing

## Shoot fresh and dry weight (g)

Data on Table 3 represent that, at harvest, the $M_1F_3$ treatment produced the maximum fresh shoot weight of 450 g, while the $M_0F_0$ treatment had the lowest (115.33 g). The combined effects of mulching and fertilizer management significantly influenced sugar beet shoot dry weight. Similarly, the $M_1F_3$ treatment recorded the highest shoot dry weight at 78.6 g, while the control had the lowest at 16.26 g (Table 2). These results align with Alam *et al*. (2007), who found that the best shoot dry matter was obtained with the combined application of vermicompost and chemical fertilizer.

**Table 3.** Effect of mulching and integrated fertilizer management on plant yield components of sugar beet

| Treatment | Shoot fresh weight (g) | Shoot dry weight (g) | Beet root fresh weight (g) | Root dry weight (g) |
|---|---|---|---|---|
| $M_0F_0$ | 115.33 | 16.26 | 390.70 | 40.31 |
| $M_0F_1$ | 169.00 | 28.09 | 588.00 | 101.61 |
| $M_0F_2$ | 230.00 | 32.65 | 673.70 | 119.67 |
| $M_0F_3$ | 306.00 | 45.66 | 803.70 | 173.95 |
| $M_1F_0$ | 179.33 | 28.77 | 749.00 | 109.97 |
| $M_1F_1$ | 265.67 | 37.50 | 781.00 | 168.11 |
| $M_1F_2$ | 280.67 | 40.28 | 966.70b | 159.18 |
| $M_1F_3$ | 450.00 | 78.60 | 1520.70 | 434.39 |
| $M_2F_0$ | 166.00 | 23.97 | 568.30 | 76.58 |
| $M_2F_1$ | 253.33 | 33.56 | 754.70 | 130.16 |
| $M_2F_2$ | 238.67 | 40.28 | 735.70 | 159.18 |
| $M_2F_3$ | 384.00 | 60.92 | 1176.70 | 286.95 |
| CV% | 14.29 | 9.06 | 13.01 | 10.69 |
| LSD (0.05) | 61.25 | 6.02 | 177.47 | 30.39 |

Here, $M_0$=No mulch, $M_1$: Black polythene mulch, $M_2$: Rice straw mulch. $F_0$: Control (No fertilizer), $F_1$: 100% vermicompost @ 10t/ha, $F_2$: 100% Recommended chemical dose, and $F_3$: 50% Vermicompost @ 5t/ha and 50% RCF.

## Root fresh and dry weight (g)

At harvest, the $M_1F_3$ treatment produced the highest root fresh weight of 1520.70 g, while the $M_0F_0$ treatment had the lowest at 390.7 g (Table 3). Enhancing root quality and output is mostly dependent on diet. The root dry weight (Table 2) of sugar beet was affected by the combined application of vermicompost and RCF during the cropping season. At harvest, the $M_1F_3$ treatment had the highest root dry weight at 434.39 g, while $M_0F_0$ had the lowest at 40.31 g. According to Ferdoushi *et al*. (2010), black polythene mulch and a combination of organic and chemical fertilizers produced the highest potato yields.

## Sugar beet yield (t/ha)

The combined application of mulching and fertilizer significantly ($P \leq 0.05$) increased sugar beet yield (Table 4). It is evident from the data that the highest sugar beet yield, 121.52 t/ha, was recorded in the $M_1F_3$ treatment, while the lowest, 31.25 t/ha, was in the $M_0F_0$ treatment. Gross yield was highest with $M_1F_3$, 288.86% greater than the control ($M_0F_0$). Nutrition plays an important role in improving productivity and quality of beet root (Hussain & Kerketta, 2023). The treatment 50% vermicompost and 50% NPK supplies higher macro and micronutrients to the soil and plants get it in the available from which results in better growth, yield and quality of crops (Manivannan *et al.* 2009). Moursy AMM *et al*. (2021) reported that, root yield of sugar beet increased by 16.8 and

51.6%, as well for rice straw mulch and BPFM (black polythene film mulch) treatment compared to no mulch (NM). Black polythene mulch with mineral fertilizer and vermicompost showed the best performance for growth and yield of carrot by Biswas *et al*. (2019).

## Sugar yield (t/ha)

The combined effect of mulching and fertilizer management significantly ($P \leq 0.05$) influenced sugar yield. Table 4 shows that the highest yield, 18.30 t/ha, was recorded from the $M_1F_3$ treatment (BPM + 50% VC @ 3 t/ha and 50% RCF), followed by $M_2F_3$ (13.36 t/ha). Other yields were $M_1F_2$ (10.69 t/ha), $M_1F_1$ (9.13 t/ha), and $M_0F_3$ (8.74 t/ha). The lowest (3.76 t/ha) sugar yield was recorded from control treatment. The best treatment combination ($M_1F_3$) gave 386.7% increased sugar yield compared to control. Sugar yield increased by 25.8 and 101.3% as well for RSM and BPFM treatment compared to no mulch (Moursy M A *et al*., 2021).

**Table 4.** The combined effect of mulching and integrated fertilizer management on yield and quality attributes of sugar beet

| Treatment combinations | Beet yield (t/ha) | Sugar yield (t/ha) | TSS (°Brix) | Sucrose (%) | Purity (%) |
|---|---|---|---|---|---|
| $M_0F_0$ | 31.25 | 3.76 | 15.00 | 10.02 | 66.80 |
| $M_0F_1$ | 49.71 | 6.11 | 18.60 | 12.31 | 66.78 |
| $M_0F_2$ | 53.89 | 6.83 | 19.00 | 12.68 | 66.73 |
| $M_0F_3$ | 64.3 | 8.74 | 19.60 | 13.60 | 69.38 |
| $M_1F_0$ | 54.88 | 7.04 | 18.00 | 12.84 | 71.33 |
| $M_1F_1$ | 67.92 | 9.13 | 19.50 | 13.45 | 68.97 |
| $M_1F_2$ | 77.33 | 10.69 | 20.07 | 13.89 | 69.24 |
| $M_1F_3$ | 121.52 | 18.30 | 20.60 | 15.06 | 73.37 |
| $M_2F_0$ | 44.13 | 5.49 | 18.00 | 12.45 | 69.16 |
| $M_2F_1$ | 55.31 | 6.89 | 18.80 | 12.47 | 66.32 |
| $M_2F_2$ | 58.85 | 8.17 | 19.30 | 13.86 | 71.81 |
| $M_2F_3$ | 94.13 | 13.36 | 20.17 | 14.20 | 70.64 |
| CV% | 13.01 | 13.05 | 2.95 | 0.14 | 0.19 |
| LSD (0.05) | 14.19 | 1.92 | 0.94 | 0.03 | 0.22 |

Here, $M_0$=No mulch, $M_1$: Black polythene mulch, $M_2$: Rice straw mulch. $F_0$: Control (No fertilizer), $F_1$: 100% vermicompost @ 10 t/ha, $F_2$: 100% Recommended chemical dose, and $F_3$: 50% Vermicompost @ 5 t/ha and 50% RCF.

## Total soluble solid

Total soluble solid (TSS) was significantly ($P \leq 0.05$) affected by the combined application of mulching and fertilizer (Table 4). The highest TSS values were 20.60, 20.07 and 20.04°Brix, recorded in the $M_1F_3$, $M_1F_2$, and $M_2F_3$ treatments, respectively.

The lowest TSS (15°Brix) was observed in the $M_0F_0$ treatment (control). These results highlight that black polythene mulch with 50% vermicompost and 50% RCF produced the highest TSS in sugar beet. The similar result was reported by Kondal *et al*. (2024) on sugar beet.

## Sucrose (%)

The combined effects of mulching and fertilizer management significantly ($P \leq 0.05$) impacted sucrose % (Table 4). The highest sucrose level, 15.06%, was found in the $M_1F_3$ treatment, followed by 14.2% in $M_2F_3$. Other sucrose levels were $M_1F_2$ (13.89%), $M_2F_2$ (13.86%), and $M_0F_3$ (13.6%). The lowest sucrose level, 10.02%, was in the $M_0F_0$ treatment (control). Black polythene mulch with 50% vermicompost and 50% RCF yielded the highest sucrose content. These findings were in harmony with those of Moursy *et al*. (2021).

## Purity (%)

The purity (%) of sugar beet was influenced by the combined application of mulching and fertilizer, as shown in Table 4. Data show that the highest purity of 73.37% was recorded in the $M_1F_3$ treatment, followed by 71.81% in $M_2F_2$. Other treatments had purities of 71.33% ($M_1F_0$) and 70.64% ($M_2F_3$). The lowest purity, 66.32%, was found in $M_2F_1$. Black polythene mulch with 50% vermicompost and 50% RCF produced the highest juice purity. Positive effect of mulching and integrated fertilizer apply on juice quality might be due to the promotional effect metabolic process and translocation of carbohydrates from tops to roots (Helaly *et al.*, 2017).

## Correlation matrix

In current study, a positive linear relationship between the growth and yield parameters was observed, the correlation matrix among different plant growth, yield and quality parameters have been presented in Table 5. The correlation matrix showed that plant height of sugar beet had significantly strong and positive correlation with shoot length of plant (r = 0.984***), root length (r = 0.976***), root diameter (r = 0.965***), plant weight (r = 0.941***), shoot fresh weight (r = 0.948***), root fresh weight (r = 0.920***), TSS ($^{O}$Brix) (r = 0.911***), sucrose% (r = 0.924***), root dry weight (r = 0.881**), shoot dry weight ( r = 0.924***), root yield (r = 0.928***), shoot yield of sugar beet (r = 0.949***), and sugar yield (r = 0.918***). These results indicated that root yield of sugar beet depends on plant height, shoot length, root length, root diameter, plant weight of sugar beet, shoot and root fresh weight, shoot and root dry weight of beet. Root fresh weight has a strong correlation with shoot fresh weight (0.991***). The sugar beet quality parameters, such as, brix%, pol% and purity% also correlated with root yield of sugar beet. Some pairs show moderate correlations (e.g., values between 0.5 and 0.7), indicating a weaker but still positive relationship. TSS ($^{o}$Brix) has moderate correlations with purity% (0.597**) and high correlations with pol% (0.952***). Correlation studies provides a measure of association between the characters and reveals that character that might be useful as an index for selection.

**Table 5.** Correlation matrix among different parameters of sugar beet as influenced by treatments

| Parameters | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant H | 1 | | | | | | | | | | | | | | | | | | |
| Shoot L | 0.984 | 1 | | | | | | | | | | | | | | | | | |
| Root L | 0.976 | 0.968 | 1 | | | | | | | | | | | | | | | | |
| Root D | 0.965 | 0.941 | 0.970 | 1 | | | | | | | | | | | | | | | |
| Plant W | 0.941 | 0.965 | 0.943 | 0.926 | 1 | | | | | | | | | | | | | | |
| Sh F W | 0.948 | 0.968 | 0.947 | 0.932 | 0.975 | 1 | | | | | | | | | | | | | |
| R F W | 0.920 | 0.955 | 0.918 | 0.895 | 0.991 | 0.954 | 1 | | | | | | | | | | | | |
| Brix | 0.911 | 0.908 | 0.873 | 0.869 | 0.812 | 0.830 | 0.781 | 1 | | | | | | | | | | | |
| Sucrose | 0.924 | 0.945 | 0.899 | 0.892 | 0.875 | 0.863 | 0.858 | 0.952 | 1 | | | | | | | | | | |
| R DW | 0.881 | 0.914 | 0.898 | 0.895 | 0.980 | 0.954 | 0.971 | 0.733 | 0.820 | 1 | | | | | | | | | |
| Sh D W | 0.924 | 0.947 | 0.926 | 0.929 | 0.983 | 0.978 | 0.969 | 0.789 | 0.862 | 0.989 | 1 | | | | | | | | |
| R & S | 0.943 | 0.955 | 0.943 | 0.908 | 0.943 | 0.894 | 0.933 | 0.889 | 0.923 | 0.883 | 0.887 | 1 | | | | | | | |
| RDM% | 0.922 | 0.943 | 0.933 | 0.926 | 0.994 | 0.963 | 0.987 | 0.771 | 0.850 | 0.989 | 0.986 | 0.922 | 1 | | | | | | |
| Beet Y | 0.928 | 0.954 | 0.931 | 0.914 | 0.998 | 0.959 | 0.993 | 0.796 | 0.866 | 0.977 | 0.974 | 0.948 | 0.994 | 1 | | | | | |
| Shoot Y | 0.949 | 0.968 | 0.947 | 0.932 | 0.974 | 1.000 | 0.953 | 0.831 | 0.863 | 0.953 | 0.978 | 0.893 | 0.962 | 0.958 | 1 | | | | |
| Sugar Y | 0.918 | 0.944 | 0.926 | 0.912 | 0.996 | 0.954 | 0.990 | 0.773 | 0.856 | 0.983 | 0.977 | 0.936 | 0.997 | 0.998 | 0.953 | 1 | | | |
| SPAD V | 0.891 | 0.891 | 0.902 | 0.858 | 0.839 | 0.863 | 0.790 | 0.862 | 0.880 | 0.809 | 0.841 | 0.874 | 0.811 | 0.820 | 0.864 | 0.809 | 1 | | |
| Purity | 0.597 | 0.663 | 0.606 | 0.599 | 0.679 | 0.595 | 0.700 | 0.496 | 0.736 | 0.699 | 0.693 | 0.653 | 0.694 | 0.688 | 0.594 | 0.712 | 0.582 | 1 | |
| nL | 0.960 | 0.980 | 0.964 | 0.942 | 0.979 | 0.953 | 0.969 | 0.849 | 0.927 | 0.944 | 0.956 | 0.968 | 0.969 | 0.976 | 0.953 | 0.974 | 0.881 | 0.743 | 1 |

*** Significant at 0.05% level of probability

## Conclusion

The study demonstrates that the combined application of mulching and integrated fertilizer management significantly enhances the growth, yield, and quality of sugar beet. The $M_1F_3$ treatment (black polythene mulch with 50% vermicompost and 50% RCF) produced the highest values across all growth parameters, including seed germination, plant height, number of leaves, leaf dimensions, root diameter and length, and total dry matter over the treatment combination $M_2F_3$. This treatment also yielded the highest beet production, sugar yield, TSS, purity, and sucrose percentage. Conversely, the control treatment showed the lowest values in these parameters. These findings highlighted the effectiveness of combined application of $M_1F_3$ in optimizing sugar beet production and quality.

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## Author's contribution

A. H. M. Solaiman and N. Islam were responsible for the study's conception and design; A. H. M. Solaiman verified the analytical methods; A. H. M. Solaiman, N. Islam, and S. Choudhury encouraged, investigated, and supervised the work's findings; N. Jahan collected, analyzed, and interpreted the data; and F. Hossain, S. Choudhury, and N. Jahan prepared the draft manuscript. Each author evaluated the findings, offered insightful criticism, influenced the direction of the study, and gave their approval to the manuscript's final draft.

## Conflict of Interest

The authors declare no conflicts of interest regarding publication of this manuscript.

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