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Influence of Seed Cake as Organic Fertilizer on Growth, Dry Matter Production and Root Development of Two Cultivars of C4 Plant, Maize (*Zea mays*) under Lab Conditions

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

A pot culture experiment was conducted with the C4 plant (*Zea mays*) in the lab during the period of vegetative growth to evaluate the influence of organic fertilizer in the form of mustard oil seed cake on growth, biomass yield and root development of two maize cultivars, hybrid yellow and hybrid purple. The seed cake fertilizer treatments imposed in the experiment were control (T0), others at 2.6%, 3.5% and 4.4% of soil weight respectively against T1, T2 and T3 treatment. The results indicated moderately elevated seed cake application showed considerable improvement in vegetative growth and the plant biomass components including height and other morphological parameters as leaf numbers, length of leaves, number of node and internodal distance per plant, root yield, fresh weight and dry matter production including the root to shoot ratio of the plants, in both the cultivars and in most of the cases found highest in hybrid yellow compared to hybrid

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purple. Among the plant components, shoot, root dry weight and root to shoot ratio had the greatest decrease under fertilizer deficiency at control (T0) treatment. Among the different doses of seed cake applications, the highest values recorded at moderate treatments for most of the parameters, both at vegetative growth and post harvesting after three months of experiment.

The result shows that morphological parameters, biomass yield and its components of the plant were maximum when fertilized with seed cake at 2.6 % and 3.5% of soil weight in treatments T1 and T2, found to be the perfect doses of fertilizer for the maize vegetative growth and biomass yield compared to T0 and other treatments. So, based on the result it can be concluded that T1 and T2 treatment is the best fertilizer treatment for the hybrid yellow maize yield.

Keywords: Maize; organic fertilizer; mustard oil seed cake; growth; dry matter; root development.

1. INTRODUCTION

Bangladesh is an agrarian country, where crops especially maize (*Zea mays L*.), one of the most important, demandable and widely grown cereal crops in recent years. Globally, maize is among the three leading staple food grains. [1,2] and contains the highest genetic potential among all other grains [3]. As the leading producer, the United States, contributes to over 40% of the world's maize production [4]. It is a C4 plant, called “Queen of Cereals” ranks next to wheat and rice in context of grain production grown in irrigated and rainfed areas [5,6]. C4 plants are well suited for hot and dry climates and produce higher amount of energy than C3 plant. As a C4 plant, hybrid maize is an emerging high value cereal crop in Bangladesh. It can be harvested as fodder within 50 days, green cobs within 60-80 days and grain within 100-130 days of planting. It has one of the highest numbers of consumers not only in Bangladesh but also worldwide [7,8,9]. It has a huge commercial potential due to subtropical monsoonal climate of Bangladesh suitable for maize cultivation [10]. Maize production in Bangladesh increased significantly in between 2011- 2020, which peaked in 2019 at 17.14% before falling to 14.63% in 2020 [11,12,13]. In 2020 maize production was 9 tons per hectare with an average yearly growth rate of 2.98% [14]. Demand and production in Bangladesh would be more than doubled between 2050. Maize production is mainly concentrated in the Agro-Ecological Zones (AEZs) of Northern, western and Eastern districts of Bangladesh [15].

Maize as a potential and multipurpose cereal grain crop for human consumption with a variety of prepared food items as loaf, flat bread, bun, cornmeal, corn flex and popcorn as well as fodder and feed for animals, livestock and poultry with great nutritional value of the grain having 66.70% starch, 10% protein, 4.8% oil, 8.5% fiber, 3% sugar and 7% ash [16,17]. Besides, the use of baby corn and corn flour especially in preparing soups are increasing day by day across the country and all over the world. It grows at diverse seasons and having different types as normal yellow/white, hybrid yellow, hybrid purple, sweet corn etc.

Morphological features including growth and development are generally hampered by disruption in the cell cycle machinery including cultivation under rainfed areas with lower rainfall than the critical level to obtain optimum yield [18]. Generally loamy soil texture is suitable for producing maize. However, adding fertilizer might boosts up plant growth, where organic fertilizer is more suitable and beneficial for plant and soil health [19,20].

In a developing country like Bangladesh, the cultivated soils are generally deficient in Organic matter and major essential nutrients as nitrogen (N), phosphorus (P) and potassium (K). So low crop productivity in the mentioned country is common feature because of very low organic manure and nutrient contents, poor soil physical condition including unbalanced use of synthetic fertilizers and low nutrient-use-efficiency [21].

Farmers using both organic and inorganic/synthetic fertilizers in their crop fields however organic fertilizer boosts the plant growth in case of maize more than inorganic fertilizer [22]. The excessive and long-term use of chemical fertilizers deteriorate the quality and contaminate the soil including degradation of air, surface as well as groundwater through leaching of nutrients affects human body as the chemicals moves through the food chain, responsible for developing chronic diseases in humans. On the other hand, organic fertilizers

are slow releasing and beneficial for soil, plant growth but also for human health [23,24,25].

Therefore, the objective of this present research work was to assess the benefits of adding seed cake as organic fertilizer with application of different doses to investigate the growth, dry matter and root development performances and find out a suitable maize variety out of two in terms of growth, plant height, leaf number, biomass yield, root development and root to shoot ratio performances under controlled condition.

2. MATERIALS AND METHODS

A pot culture experiment was conducted from June -September, 2022 to investigate the influence of mustard oil seed cake application on maize plant growth and development, performed under controlled environment at the Laboratory, Department of Environmental Science and Management, North South University, Bangladesh. The pots were kept at a temperature of 25 °C under 14/10-hour light and dark photoperiod. The experiment was laid out in a completely randomized block design with four fertilizer levels as treatments and three replications

Seeds were sown on 170 g of soil filled in each plastic container with 5.5 inches height and 2.5 inches width. To conduct the lab trials, the treatments imposed on the soil were T0 (control), T1, T2 and T3. The fertilizer was added in 2-time intervals, one during the sowing and another after 32 days of germination.

The first doses of organic fertilizer were added in the soil during the sowing of seeds at the rate of no fertilizer (T0),1.5g/pot (T1), 2 g/pot (T2) and 2.5g/pot (T3) gm respectively and the 2nd doses on day 32 at the rate of control (T0), T1 (3 g/pot), T2 (4 g/pot) and T3 (5 g/pot). As a result, the total seed cake fertilizer added during the experiment were control and others 4.5g/pot (2.6%), 6g/pot (3.5%) and 7.5 g/pot (4.4%) by soil weight respectively against T0, T1, T2 and T3 treatments.

The experiment was done with sandy loam soil for 81 days, where the hybrid yellow and hybrid purple maize cultivars were the test crops, and mustard oil seed cake as organic fertilizer, used in this experiment to evaluate the influence of fertilizer on vegetative growth, dry matter production, and root development of the plants.

2.1 Identification of the Plant

Kingdom: Plantae, **Division:** Magnoliophyta, **Class:** Liliopsida, **Order:** Poales, **Family:** Poaceae, **Genus:** *Zea*, **Species:** *mays*

2.2 Analysis of Mustard oil Seed Cake

Total Nitrogen (N)-3.01%, Phosphorus (P)-1.15% and Potassium (K)- 1.22%

2.3 Physiochemical Properties of Soil

The soil had the following characteristics. Texture – Sandy loam. Sand- 61.26%, Silt - 32.62% and Clay – 6.12%. pH -6.9, EC - 793 µS/cm, NaCl - 1.0%, moisture content - 2%, Organic carbon (OC) -0.81%, Total Nitrogen-0.05%, Available Phosphorus – 33.84 ppm, Exchangeable potassium – 0.09 meq/100 g soil.

2.4 Instrumentation

The pH of soil sample was monitored using a pH meter (Griffin pH meter, Model No. 40), whereas Electrical Conductivity (EC) and NaCl were measured by durable and portable TDS/EC/NaCl meter (HANNA Instruments HI 9835 Model, USA). Analysis of total nitrogen, phosphorus and potassium were done by Micro kjeldahl, Spectrophotometric Molybdovanadate and Flame photometric methods respectively. Organic carbon was measured by Walkey Black wet oxidation method and exchangeable cations by Atomic Absorption Spectrophotometer (AAS) whereas Soil texture and moisture content were monitored by Hydrometer and Gravimetric methods respectively.

Mustard oil seed cake as a potential soil amendment and organic fertilizer could enhance the maize growth and biomass yield. Therefore, experiment with two varieties of maize plants were carried at lab condition to study the effects of organic fertilizer at four levels on the hybrid purple and hybrid yellow cultivars on yield components.

In these 81days' experimental periods, different parameters of plants, such as plant height, number of leaves, leaf length, number of nodes and internodal distance etc were measured from time to time and finally fresh and dry weight of shoot, root including root shoot ratio after harvesting of the plants. The results represent the average of three replications.

Fig. 1. Seeds were soaked in water (ESM lab) Department of Environmental Science and Management, North South University

Fig. 2. 11 days old seedlings at the lab

3. RESULTS AND DISCUSSION

3.1 Morphological Features of Hybrid Yellow and Hybrid Purple Cultivars at 32 and 72 Days with Different Fertilizer Treatments at Vegetative Growth

After 32 days of germination, result shows that highest plant height was found in yellow hybrid at treatment T2 (Fig 3) followed by T3, T1 and lowest at T0, also same in case of T2 treatment at purple hybrid, which was highest followed by T1, T3 and T0 at the lowest. In both the cultivars control treatment means no added fertilizer showed lowest plant height (Fig 3).

In case of leaf length, highest value was obtained in T1 in hybrid purple followed by hybrid yellow at T3 and T2 and T3 in hybrid purple (Fig 4).

Different fertilizer treatments showed that the no of leaves was found higher at T2 and T3 and lower at T1 and T0 in both the cultivars (Fig 5).

Number of nodes per plant was found highest at T3 both in yellow and purple hybrid followed by T2, T0 but less in no at T1 in case of purple, however in hybrid yellow, it was found same at T0 and T2. Also, internodal distance was highest in T3 in both yellow and purple cultivars (Fig 6).

3.2 Morphological Parameters After 72 Days of Germination

Results after 72 days were found same as was after 32 days where plant height was highest at treatment T2 in hybrid yellow followed by T2 and T1 in hybrid purple and lowest at T0 in both the cultivars. In case of purple hybrid among the treatments found highest at T2 but was lower in comparison to hybrid purple, followed by T1 (Fig 7).

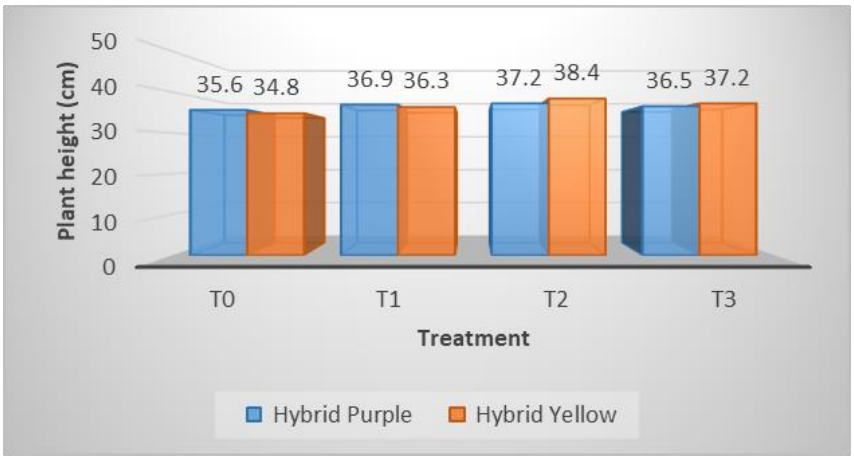

Fig. 3. Effect of fertilizer treatments on plant height

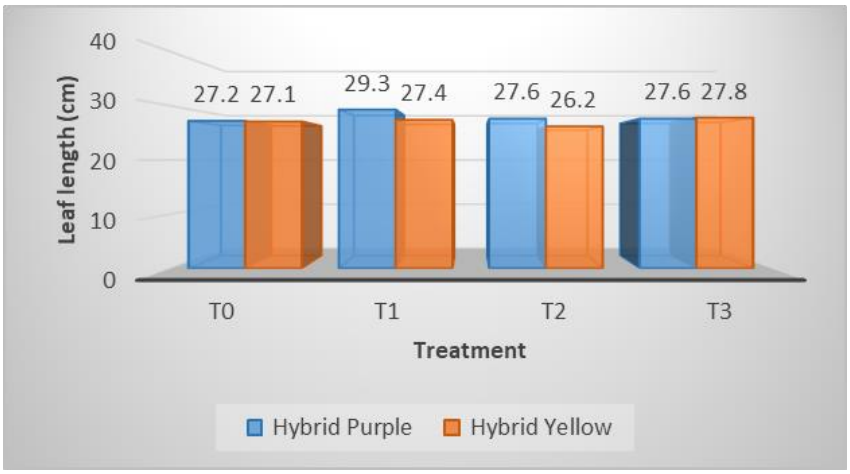

Fig. 4. Effect of fertilizer treatments on leaf length

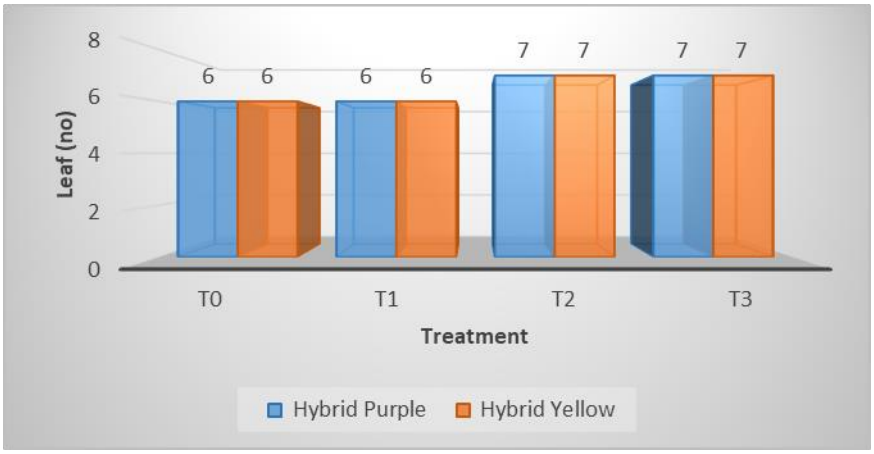

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Fig. 5. Effect of fertilizer treatments on number of leaves per plant

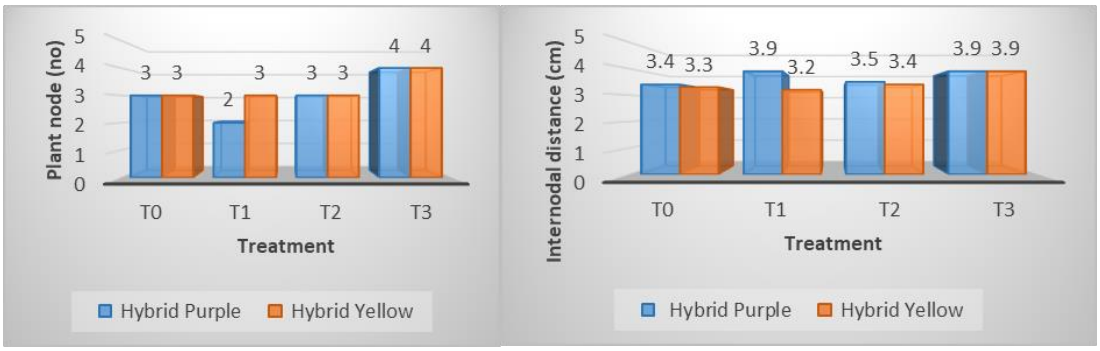


Fig. 6. Effect of fertilizer treatments on Plant node and internodal distance

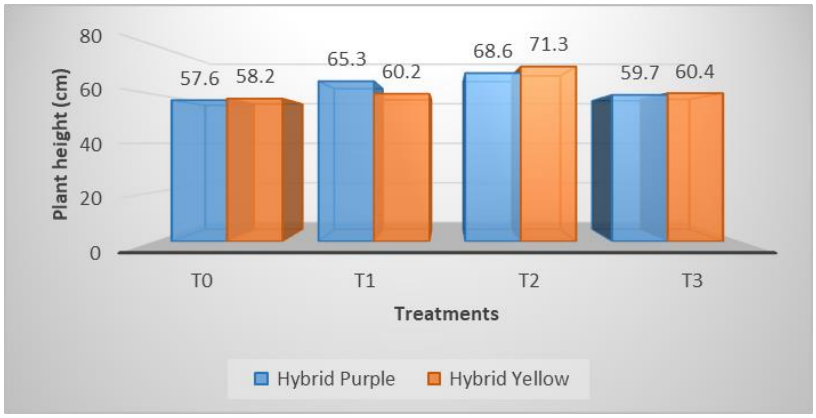


Fig. 7. Effect of fertilizer treatments on plant height

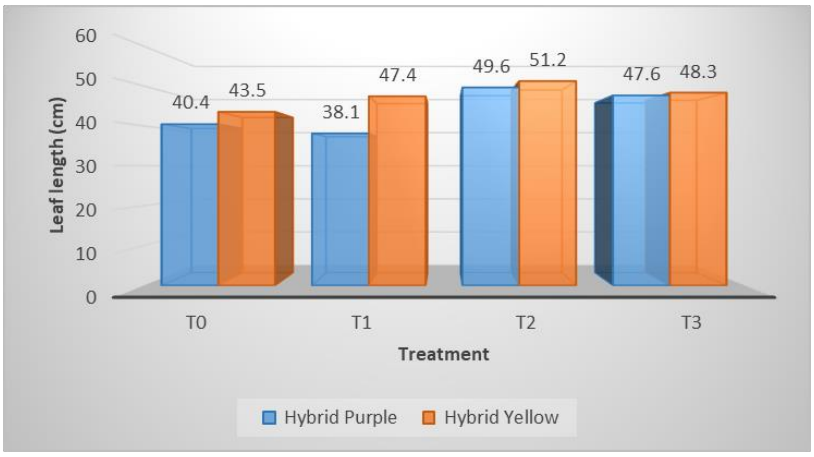


Fig. 8. Effect of fertilizer treatments on leaf length

In case of leaf length, it was found highest in yellow hybrid at T2 treatment followed by T2 in purple and T3, T1 and T0 in yellow hybrid (Fig 8).

Fertilizer treatments showed highest number of leaves in both the cultivars at T3 followed by T2 and lowest at T0 and the number of nodes per plant was found highest at T1 in yellow hybrid followed by purple at T3 and same in all others among the treatments and between the cultivars (Fig 9).

In case of internodal distance, like node no also found highest in yellow hybrid at treatment T1 followed by T3, T2 and T0, whereas found lowest in case of purple in all the treatments compared to yellow one. Purple variety showed less

internodal distance compared to yellow one (Fig 10).

3.3 Parameters After 81 Days of Germination at Harvesting

After harvesting at 81 days, shoot fresh and dry weight were found highest at T3 followed by T2 in hybrid yellow compared to hybrid purple whereas at T0 both the cultivars showing the lower performances compared to other treatments (Fig. 11).

In hybrid yellow**,** shoot fresh wt (8.99g) and dry weight (2.1g) was higher at T3 treatment followed by T2 and lowest in T0 in both the entities.

In case of root parameters, highest values were obtained in root fresh and dry weight at T3 in hybrid purple followed by T2 in hybrid yellow and lowest at control in both the cultivars (Fig. 12).

Root to shoot ratio was found highest (1.78g) in hybrid yellow at T1 treatment, followed by T2(1.76g), and T3(1.75 g) in hybrid purple whereas no differences was found in control treatment which was lowest at T0 (1.08g) in both the cultivars (Fig. 13).

Organic fertilizers improve soil health through moderating the physiochemical properties with improving the water retention capacity of soil and improves soil fertility by increasing soil organic carbon which affects positively on production of crops [26].

The results of this trial indicated organic fertilizer increased organic matter content of the soil. However moderate rates of fertilizer application is cost effective and favored vegetative growth as well as biomass including formation of strong root structure. This result also confirms the finding of [27], who found organic fertilizer as seed cake improves the nutrient availability in soil and enhances plant growth and development The incorporation of mustard oil seed cake has the ability of increasing the essential nutrient contents to improve the physiochemical properties of soil and thus aided growth as well as development of the plants. In the research investigation the fertility status of the soil justifies adding of seed case as organic low-cost soil amendment to improve fertility of soil and thus growth and biomass yield in plants.

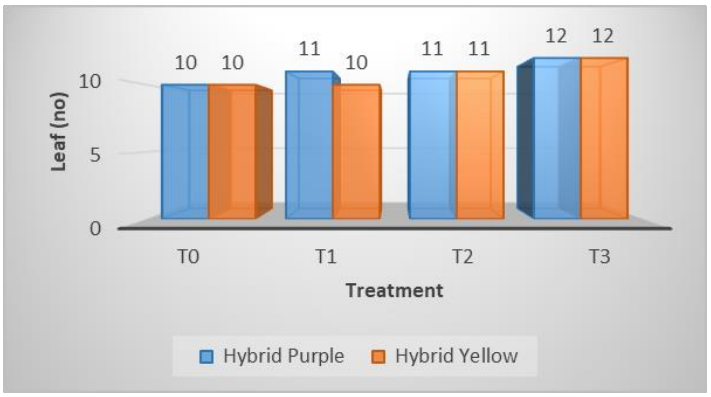


Fig. 9. Effect of fertilizer treatments on leaf number

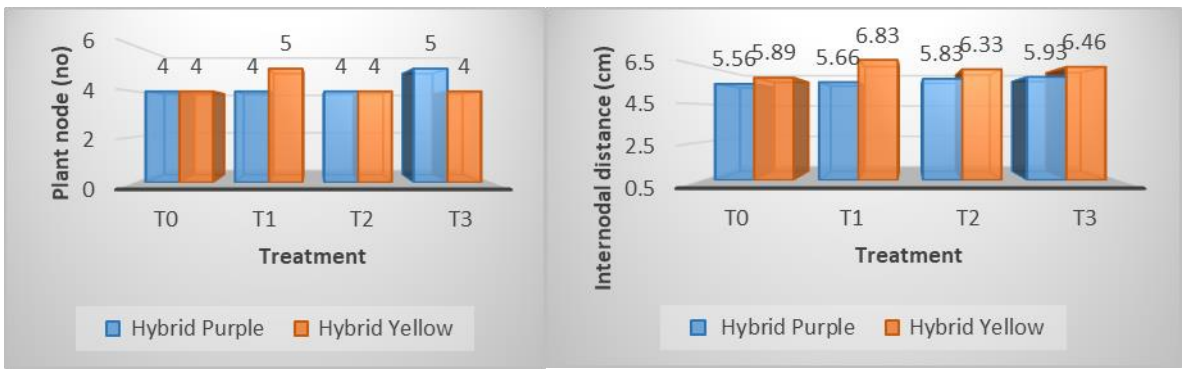


Fig. 10. Effect of fertilizer treatments on plant node and internodal distance

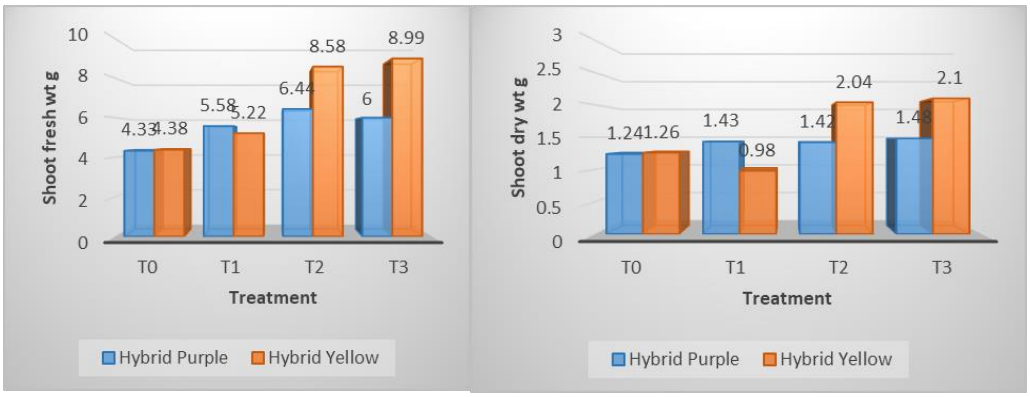


Fig. 11. Effect of fertilizer treatments on shoot fresh and dry weight

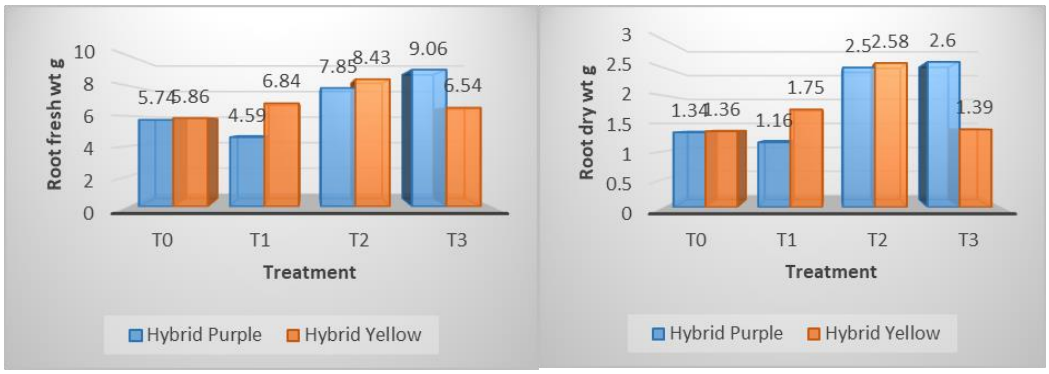


Fig. 12. Effect of fertilizer treatments on root fresh and dry weight

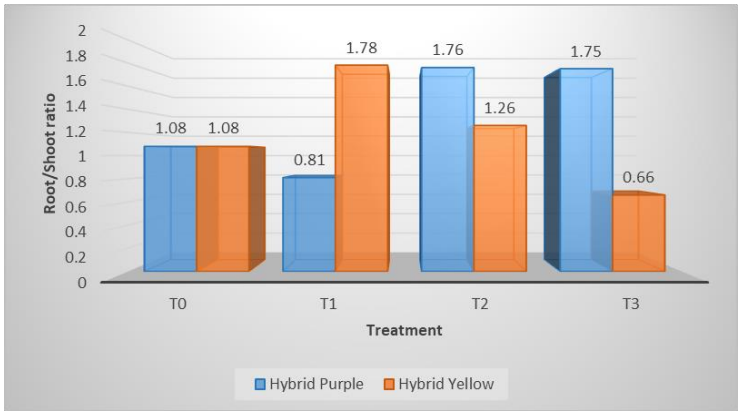


Fig. 13. Effect of fertilizer treatments on root shoot ratio

The results of this experiment are in agreement with other researchers [28,29,30,31] who found that slow releasing organic fertilizer has a positive impact more than the inorganic fertilizer to improve nitrogen use efficiency (NUE) and boost the growth, development and yield of maize crops.

In the experiment, fertilizers were applied at 2.6% and 3.5% of soil weight in Treatment 1 and 2, found to be the perfect doses of fertilizer for the maize yield compared to controlled and other treatments.

The results indicated that the application of organic fertilizer significantly affected the plant morphology as plant height, leaf length including number of node per plant and number of internodes per plant, fresh and dry weight of straw and root yield, in both the cultivars, and was found more in hybrid yellow compared to/ hybrid purple. The interaction between seed

cake (at different doses) recorded the highest values for most of the parameter at T1 and T2 during the three months of experiment at lab scale.

The result showed that under controlled environment morphological parameters and biomass yield and its components of maize were maximum when fertilized with moderately higher amount of seed cake, mostly at T1 and T2 treatments, indicated considerable increase in vegetative growth and the plant biomass components and had the greatest decrease under deficiency. However, number of leaves per plant did not show much changes under fertilizer deficiency as T0 shows some tendency of the crop to adjust with lower fertilizer levels in production of leaves for photosynthesis activities in plants.

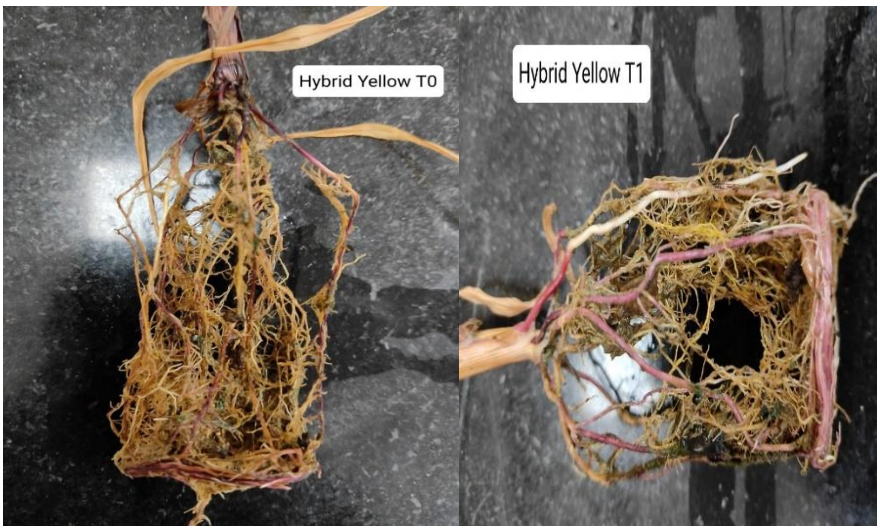
It is evident from the results that the moderate fertilizer treatments in yellow hybrid performed better in boosting the maize growth including parameters of shoot and root development. These results also confirm the finding of Islam et al. [32], who postulates that application of moderate amount of seed cake provides better performance in cereal crop compared to higher dose from both yield and economic viewpoints.

So, based on the results it can be concluded that T1 and T2 treatment is the best fertilizer treatment for the hybrid yellow maize biomass yield.

Plants of the hybrid yellow variety were found healthier compared to hybrid purple in terms of above ground and belowground parts of the plants (Fig 14).

Root structures of hybrid yellow found more stronger compared to hybrid purple (Fig 15 and 16).

Fig. 14. Harvested hybrid yellow and hybrid purple cultivar after 3 months



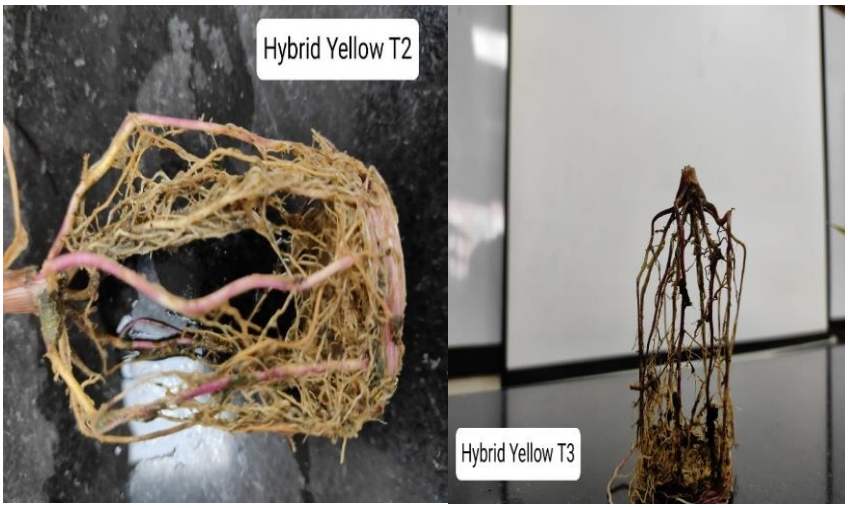


Fig. 15. Root structures of hybrid yellow with different treatments (after harvesting)

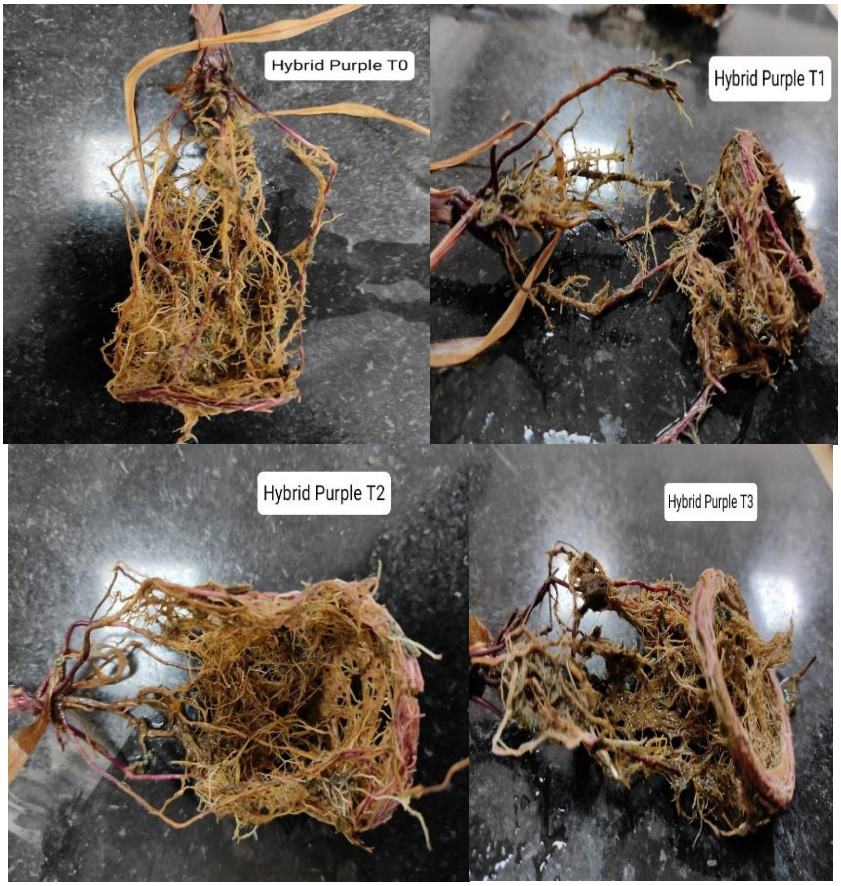


Fig. 16. Root structures of Hybrid purple with different treatments (after harvesting)

4. CONCLUSION

At fertilizer treatments T1 and T2, the cost will be reduced and production will be increased, implying the maximum benefits at a minimum cost. For this reason, it will be very helpful for the small farmers as well as the general people who want to grow maize in the pot or on rooftop gardens in an effective way. The findings will serve as a stepping stone for more studies on maize cultivation in the future that will consider our limitations and find variable solutions.

From the results it is found that organic fertilizer application can provide significant positive enhancement to maize growth and development as compared to duration especially in vegetative growth and biomass yield. It is recommended that moderate application of mustard oil seed cake as organic fertilizer should be encouraged to the farmers for vegetative growth of maize at the expanse of dry matter production. So, based on the result it could be concluded that in a developing country like Bangladesh, effective fertilizer treatment could be cost-effective with resourceful output in large agricultural areas to maintain their sustainability.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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