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Research Article

# Effect of Nitrogen Rates and Foliar Spray of Micronutrients on Growth and Yield of Sesame (Sesamum indicum L.)

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**Abstract**:
To find out optimum nitrogen (N) and micronutrients (MNs) doses for the growth and yield of sesame the experiment was undertaken at Sher-e-Bangla Agricultural University Research field, Dhaka, during April to July 2013 with three replications in a randomized complete block design (RCBD). Three different N levels viz. $N_0$= without N, $N_1$= 60 kg $h^{-1}$, $N_2$=120 kg $h^{-1}$ and four micronutrients (MNs) levels viz. $M_0$= without MNs, $M_1$= 50 ppm MNs, $M_2$= 100 ppm and $M_3$= 150 ppm MNs. The N significantly increased morphological characters - plant height, number of leaves plant$^{-1}$, branch number plant$^{-1}$, fresh and dry weight of shoot and root; yield contributing characters- number of pod plant$^{-1}$, pod diameter, pod length, seed weight plant$^{-1}$, seed weight plot$^{-1}$ compared to control ($N_0$). The rate of application of N 60 kg ha$^{-1}$ produced the highest seed yield (1.21 t ha$^{-1}$) which is consisting with most of the vegetative growth of sesame. Foliar application of different concentration of micronutrients also improved the morphological characters and seed yield of sesame as N. Interestingly 1000-seed weight did not show any significant differences with both N and micronutrients. The maximum number of pod plant$^{-1}$, pod diameter, pod length, seed weight plant$^{-1}$, seed yield (1.14 tha$^{-1}$) significantly increased with 150 ppm micronutrients. Therefore, this experimental results suggest that the use of 60 kg Nha$^{-1}$ and 150 ppm micronutrients have produced highest seed yield of sesame by adjusting in plant morphological characters and yield contributing characters of sesame.

**Keywords**: Sesame; Nitrogen, Micronutrients; Growth and Yield
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# Introduction

Sesame is one of the most important oil crops in Bangladesh and grown in all regions. In the year 1999-2000, the crop covered an area of 96,000 acres with production of 25,000 metric tons (BBS, 2005). Recently [BBS, 2013] reported that 84,310 acres of land cultivated for sesame and production was 30,972 metric tons. The above information suggests that although the land of cultivation of sesame is decreasing whereas the production is increasing trend from 1999 to 2013. But in a view of population growth, the requirement of edible oil is increasing with high in demand than the production. It is therefore, highly expected that the production of edible oil should be increased considerably to fulfill the increasing demand. The production may be increased either by increasing cropping area under oil crop or increasing yield. But it is difficult to extent the area of oil production in our country due to over population, high demand of cereal crops etc. That is why, the farmers of the country did not get enough interest to grow oil crops. In addition, (Rahman et al., 1994) stated that sesame yield is very low in Bangladesh due to lack of proper management practices. Therefore, it is a general consensus that increasing yield per unit area is most reasonable way to increase total production of sesame. The yield of sesame may be increased by using numerous improved technologies and practices such as use of high yielding varieties and suitable practices. As practices, proper balanced supply of both macro and micronutrients are one of the most important factors to increase higher yield.

It has been reported that nitrogen (N) is one of the most important nutrient elements that accelerate the growth of the plant because it is a constituent of chlorophyll thus ensure crop growth vigorously (Dobermann and Fairhurst, 2000). The significant response of the number of leaves to N may have led to increase in photosynthetic activity thereby resulting in the improvement of morphological characters i.e. produced more branches and simultaneously enhanced pod production and thus increased yield (Shehu et al., 2009). Unfortunately, soil of Bangladesh contain very low amount of N and need to supply additional fertilizer in proper amount to make sure for better production.

Micronutrients are essential for plant growth and play an important role in crop production. Deficiency of any one of the micronutrients in the soil can limit growth, even when all other nutrients are present in adequate amounts. The beneficial influence of micronutrients might be due to the activation of various enzymes and the efficient utilization of applied nutrients resulting in increased yield components (Tiwari et al., 1996 and Shanker et al.,1999). However, their deficiencies can cause a great disturbance in the physiological and metabolic processes in the plant (Bacha et.,1995). In recent years, soil organic materials and micronutrients have been reduced because of intensive cultivation and continuous chemical fertilizers usage. Micronutrient deficiency is widespread in many Asian countries due to the calcareous nature of soils, high pH, low organic matter, salt stress, continuous drought, high bicarbonate content in irrigation water, and imbalanced application of NPK fertilizers (Narimani et al., 2010). Foliar nutrition is an option when nutrient deficiencies cannot be corrected by applications of nutrients to the soil (Sarkar et al., 2007). Foliar spraying of microelements is very helpful when the roots cannot provide necessary nutrients (Kinaci and Gulmezoglu, 2007 and Babaeian et al., 2011). Therefore, the study has been undertaken to investigate the optimum doses of

N and micronutrients on growth and yield of sesame.

# Materials and Methods

The experiment was conducted at Sher-e-Bangla Agricultural University Research Field, Dhaka, Bangladesh during April to July 2013. The seeds of BARI Til-4 were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur. The experiment was laid out Randomized Complete Block Design (RCBD) with three replications. The treatments were different levels of Nitrogen (N) in the form of Urea and micronutrients in the form of Okozym (commercial form of micronutrients as a source of Fe, Zn, Mn and Cu, marketed by Syngenta). Three levels of Nitrogen viz. $N_0$ = Without N, $N_1$ = 60 kg N ha$^{-1}$, $N_2$ = 120 kg N ha$^{-1}$ and four micronutrients levels viz. $M_0$ = Without Micronutrients $M_1$ = 50 ppm Micronutrients, $M_2$ = 100 ppm Micronutrients, $M_3$= 150 ppm Micronutrients. The unit plot was 2 m in length and 1.5 m in breadth. . The plant to plant distance was maintained as 5 cm in the row and row to row distance was 30 cm. The distance between blocks was 1 m and distance between plots was 0.5 m.

The land was ploughed with a rotary plough and power tiller for four times. After final land preparation sowing was done on 14 April, 2013. According to the layout of the experiment the entire experimental area was divided into blocks and prepared the experimental plot for the sowing of sesame seed. The recommended doses of Triple Super Phosphate (TSP), Muriate of Potash (MP), Gypsum and Boric acid were applied full dose to the experimental field during land preparation. Half of urea was applied in each plot according to treatment combination and incorporated into soil before sowing seed. Rest of the urea was top dressed after 20 days after sowing (DAS). Micronutrients were applied by foliar spray two times during 20 days after sowing (DAS) and 40 days after sowing (DAS).

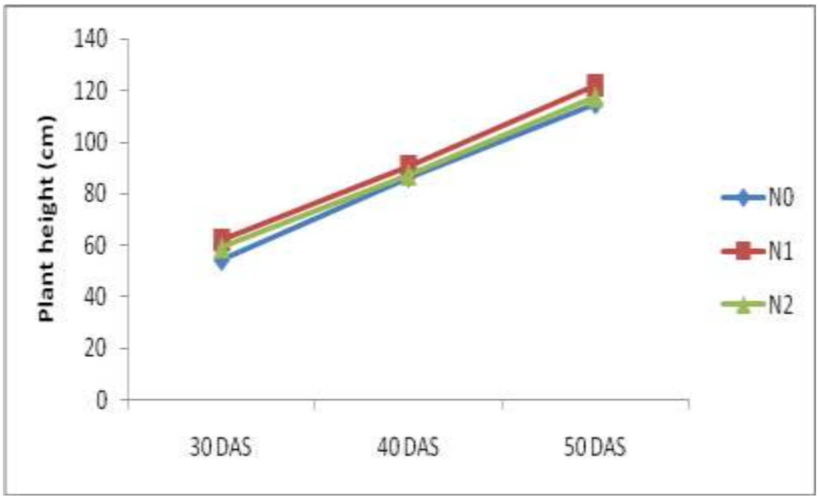
**Statistical Analysis** : All the data were statistically analyzed by using the MSTAT-C computer package program. The mean differences were tested through least significant difference (LSD) at 5% level of significance.

# Results and Discussion

**Plant Height (cm)**

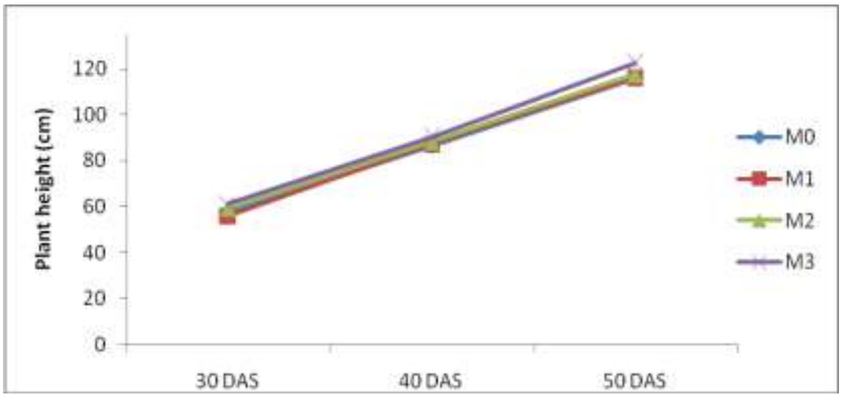
Nitrogen had stimulatory effect on plant height throughout the growth period. Different levels of nitrogen (N) fertilizer showed significant effect on plant height of sesame at 30, 40 and 50 days after sowing (DAS) (Fig. 1 and App. I). At 30 DAS, the highest plant height (62.01 cm) was observed from the $N_{1,}$ 60 kg Nha$^{-1}$ which was statistically similar with $N_2$ (59.25 cm) and the lowest (54.23 cm) was observed from $N_0$, 0 kg Nha$^{-1}$. At 40 DAS, the highest plant height (90.68 cm) was observed from the $N_{1,}$ 60 kg Nha$^{-1}$ and the lowest (86.41 cm) was observed from $N_0$ which was statistically similar with $N_2$ (87.38 cm) 120 kg Nha$^{-1}$. At 50 DAS, the highest plant height (122.0 cm) was observed from the $N_1$ which was statistically similar with $N_2$ (122.3 cm) whereas the lowest (118.0 cm) was observed from $N_0$. So the highest plant height at 30 DAS, 40 DAS and 50 DAS was from $N_1$ (60 kg ha$^{-1}$ N) which was similar to obsereved by Pathak *et al*. (2002), Patra (2001) and Alam (2002).

Micronutrients had significant effect on plant height of sesame at 30, 40 and 50 DAS (Fig. 2). At 30 DAS, the highest plant height (61.24 cm) was observed from the $M_{3,}$ 150 ppm MNs and the lowest (56.00 cm) was observed from $M_1$, 50 ppm MNs which was statistically similar with $M_0$ (57.46 cm), 0 ppm MNs. At 40 DAS, the highest plant height (90.47 cm) was observed from the $M_3$,150 ppm MNs and the lowest (86.62 cm) was observed from $M_0$ which was statistically similar with $M_1$, 50 ppm and $M_2$, 100 ppm MNs. At 50 DAS, the highest plant height (122.65 cm) was observed from the $M_3$ and the lowest (116.04 cm) was observed from $M_0$ treatment which was statistically similar with $M_1$ and $M_3$. These findings are in agreement with those of Salwa *et al.* (2010), Ali and Ahmed (2012) and Bameri *et al.* (2012).




$N_0$ – Without nitrogen, $N_1$ – 60 kgha$^{-1}$ nitrogen, $N_2$– 120 kgha$^{-1}$ nitrogen, DAS (days after sowing)

**Fig. 1** Effect of different levels of N at different DAS on the height of sesame plant

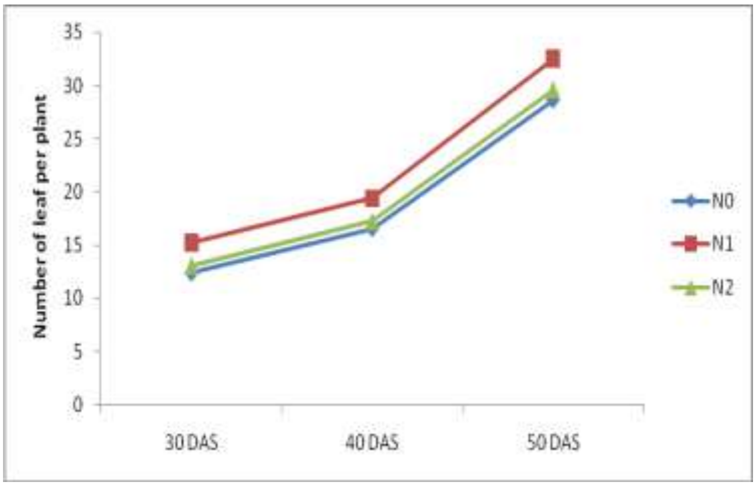



$M_0$ – Without MNs, $M_1$ – 50 ppm MNs,
$M_2$ – 100 ppm MNs, $M_3$ –150 ppm MNs
DAS (days after sowing)

**Fig. 2** Effect of different levels of MNs at different DAS on the height of sesame plant

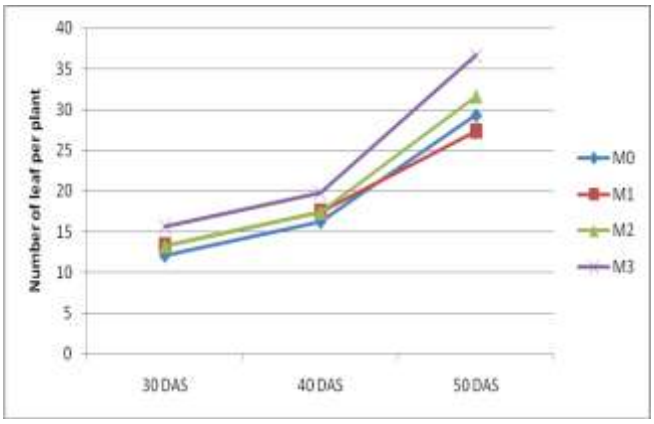
Number of Leaves Plant$^{-1}$

Nitrogen fertilizers had significant effect on number of leaves plant$^{-1}$ of sesame at 30, 40 and 50 DAS (Fig. 3 and App. II). At 30 DAS, the highest number of leaves plant$^{-1}$ (15.25) was observed from the $N_1$ and the lowest (12.41) was observed from $N_0$. At 40 DAS, the highest number of leaves plant$^{-1}$ (17.25) was observed from the $N_1$ and the lowest (14.92) was observed from $N_0$. At 50 DAS, the highest number of leaves plant$^{-1}$ (32.50) was observed from the $N_1$ and the lowest (28.67) was observed from $N_0$ which was statistically similar with $N_2$ (29.58). These findings were similar to Okpara *et al.* (2007), who reported that increased in such growth characters of sesame due to applied N. Leaf number of sesame plant increased with the increased application of nitrogen fertilizer up to a certain limit was stated by Patra (2001).




$N_0$ – Without N, $N_1$ – 60 kg $ha^{-1}$ N, $N_2$– 120 kg $ha^{-1}$ N

**Fig. 3** Effect of different levels of N at different DAS on the leaf number of sesame plant




$M_0$ – Without MNs, $M_1$ – 50 ppm MNs, $M_2$ – 100 ppm MNs, $M_3$ –150 ppm MNs

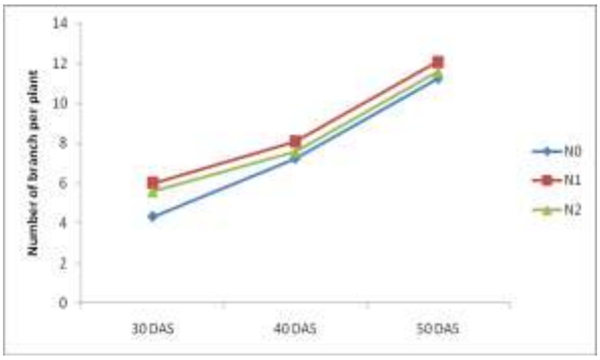
**Fig. 4** Effect of different levels of MNs at different DAS on the leaf number of sesame plant

Micronutrient was used to examine the physiological involvement on increasing of leaf number $plant^{-1}$ in sesame. Micronutrient had significant effect on number of leaf $plant^{-1}$ of sesame at 30, 40 and 50 DAS (Fig. 4 and Appendix II). At 30 DAS, the highest number of leaves $plant^{-1}$ (15.67) was observed from the $M_3$ and the lowest (12.11) was observed from $M_0$. At 40 DAS, the highest number of leaves $plant^{-1}$ (19.83) was observed from the $M_3$ and the lowest (16.27) was observed from $M_0$. At 50 DAS, the highest number of leaves $plant^{-1}$ (36.66) was observed from the $M_3$ and the lowest (23.33) was observed from $M_0$. Results showed micronutrient had significant effects and the highest leaf number per plant was observed from $M_3$, 150 ppm micronutrient and lowest from $M_0$, without micronutrient. It is reported that application of micronutrient at a rate of 150 ppm to sesame produced higher number of leaves as also suggested by Shehu (2014) .

**Number of Branches Plant$^{-1}$**

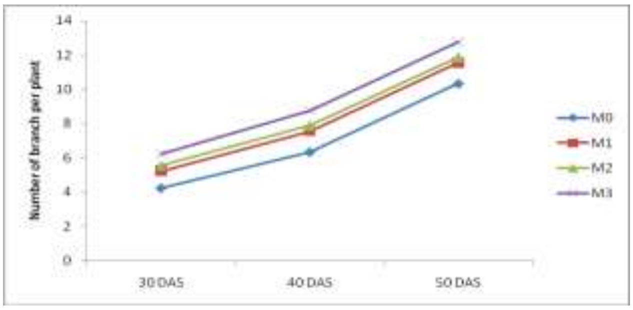
Figure 5 and Appendix III showed that nitrogen fertilizers had significant effect on number of branches plant$^{-1}$ of sesame at 30, 40 and 50 DAS. At 30 DAS, the highest number of branch plant$^{-1}$ (6.00) was observed from the $N_1$ which was statistically similar with $N_2$ (5.58) and the lowest (4.33) was observed from $N_0$. At 40 DAS, the highest number of branches plant$^{-1}$ (8.08) was observed from the $N_1$ and the lowest (7.25) was observed from $N_0$ which was statistically similar with $N_2$ . At 50 DAS the highest number of branches plant$^{-1}$ (12.08) was observed from the $N_1$ and the lowest (11.25) was observed from $N_0$ which was statistically similar with $N_2$. As the results showed highest leaf number from $N_1$, 60 kg Nha$^{-1}$ and lowest from $N_0$, 0 kg Nha$^{-1}$, so the number of branch per plant increased numerically with application of nitrogen fertilizer as observed by Sinharoy *et al*. (1990), Thakur *et al*. (1998), Pathak *et al*. (2002), Patra *et al*. (2001), Subrahmaniyan and Arulmozhy (1999).

Application of micronutrient had showed significant effect on number of branches plant$^{-1}$ of sesame at 30, 40 and 50 DAS (Fig. 6 and App. III). At 30 DAS the highest number of branches plant$^{-1}$ (6.22) was observed from the $M_3$ and the lowest (4.22) was observed from $M_0$. At 40 DAS, the highest number of branches plant$^{-1}$ (8.77) was observed from the $M_3$ and the lowest (6.33) was observed from $M_0$. At 50 DAS, the highest number of branch plant$^{-1}$ (12.77) was observed from the $M_3$ and the lowest (10.33) was observed from $M_0$. Shehu (2014) observed significant effect of micronutrient in increasing the number of branches in plant.




$N_0$ – Without nitrogen, $N_1$ – 60 kgha$^{-1}$ nitrogen applied as urea, $N_2$– 120 kgha$^{-1}$ nitrogen applied as urea

**Fig. 5 Effect of different levels of nitrogen at different DAS on the number of branches of sesame plant**



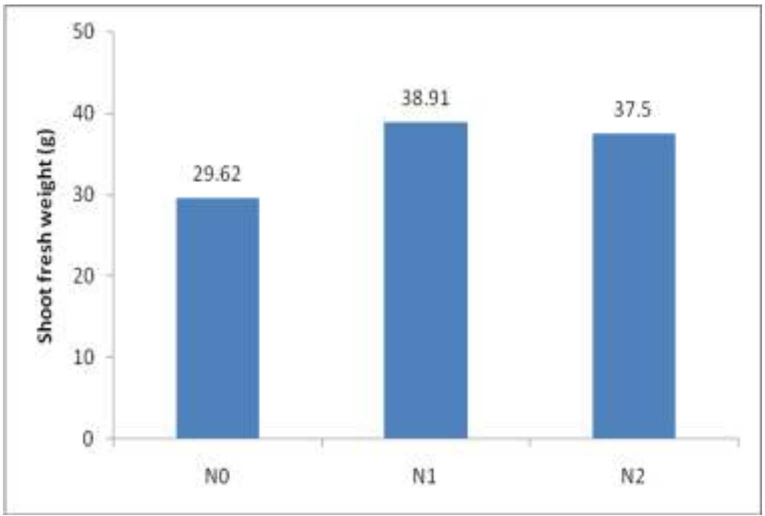

$M_0$ – Without MNs, $M_1$ – 50 ppm MNs, $M_2$ – 100 ppm MNs, $M_3$ –150 ppm MNs

**Fig 6** Effect of different levels of MNs at different DAS on the number of branches of sesame plant

Shoot Fresh Weight (g)

There was significant variation among the different levels of nitrogen fertilizer doses on shoot fresh weight (g) of sesame (Fig. 7 and APP. IV). The highest fresh shoot weight (38.91 g) was obtained from $N_1$ while the lowest result (29.62 g) was recorded from $N_0$. These results are consistent with the present morphological data of plant height, leaf and branch number plant$^{-1}$ (Figs. 1, 3, 5). The results suggest that application of N increased the shoot fresh weight of sesame plant.

Figure 8 showed different concentration of micronutrient had significant influenced on fresh shoot weight (g) of sesame. The highest fresh shoot weight (45.66 g) was obtained from $M_3$ while the lowest result (26.80 g) was recorded from $M_0$. These results are consistent with the present morphological data of plant height, leaf and branch number plant$^{-1}$ (Figs. 2, 4, 6). These results are in conformity with the findings of Masri and Hamza, (2015).




$N_0$ – Without nitrogen , $N_1$ – 60 kgha$^{-1}$ nitrogen applied as urea , $N_2$– 120 kgha$^{-1}$ nitrogen applied as urea

**Fig. 7** Effect of different levels of nitrogen on shoot fresh weight of sesame plant

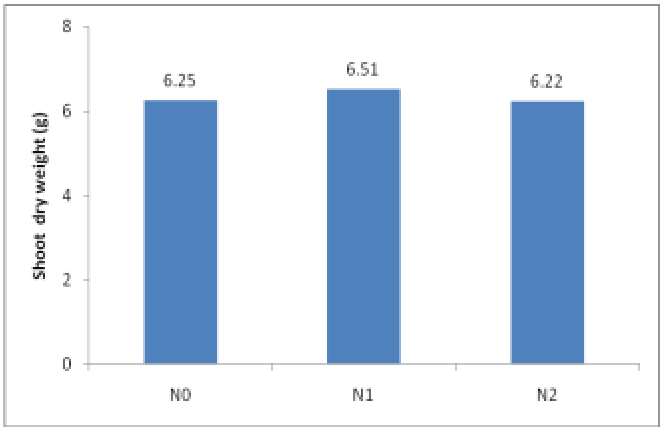

$M_0$ – Without MNs, $M_1$ – 50 ppm MNs, $M_2$ – 100 ppm MNs, $M_3$ –150 ppm MNs

**Fig. 8** Effect of different levels of micronutrients on shoot fresh weight of sesame plant

**Shoot Dry Weight (g)**

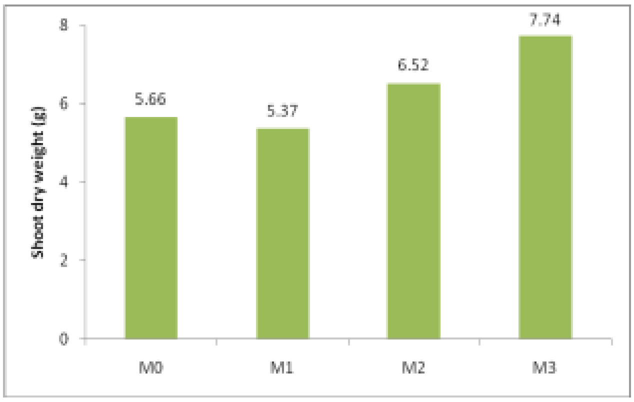
Application of different levels of nitrogen fertilizer had significant influence on dry shoot weight (g) of sesame (Fig. 9 and App. IV). The highest dry shoot weight (6.51 g) was obtained from $N_1$ which was statistically similar with $N_2$ (6.22 g) and the lowest result (6.25 g) was recorded from $N_0$. The results showed that there was not statistical variation in $N_1$, 60 kg $Nha^{-1}$ and $N_2$, 120 kg $Nha^{-1}$, so it was found that the shoot dry weight of sesame (g) increased with the increasing doses of N. The result of shoot dry weight of this study is comparable with the shoot fresh weight (Fig. 7). Tiwari *et al*. (1998) had reported that application of nitrogen fertilizer increased dry matter production in sesame.

Micronutrient at different concentrations had significant variation on shoot dry weight (g) of sesame (Fig. 10 and App. IV). The highest shoot dry weight (7.74 g) was obtained from $M_3$ while the lowest result (5.37g) was recorded from $M_1$. From the results the application of micronutrient increased of shoot dry weight (g) of sesame at greater level with $M_3$, 150 ppm micronutrient. The result of shoot dry weight of this study is similar with the shoot fresh weight (Fig. 8). Foliar spray of micronutrient at 0.1 $mgl^{-1}$ concentration had found to be more effective in increasing the total dry weight as reported by Zhao *et al*. (1997).




$N_0$ – Without nitrogen, $N_1$ – 60 $kgha^{-1}$ nitrogen applied as urea ,$N_2$– 120 $kgha^{-1}$ nitrogen applied as urea

**Fig. 9** Effect of different levels of nitrogen on the shoot dry weight of sesame plant



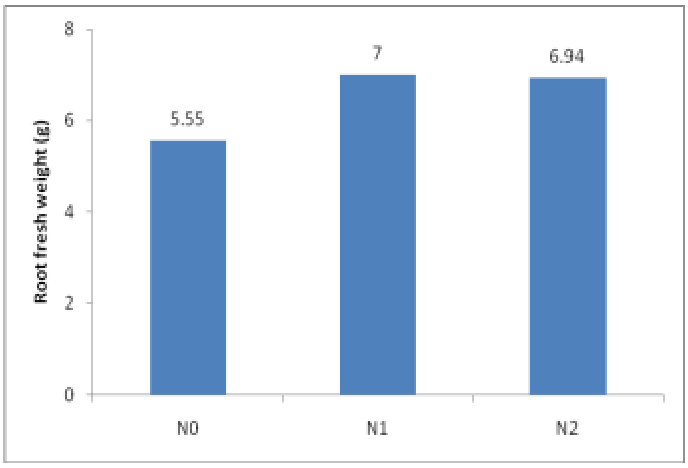

$M_0$ – Without MNs, $M_1$ – 50 ppm MNs, $M_2$ – 100 ppm MNs, $M_3$ –150 ppm MNs

**Fig. 10** Effect of different levels of micronutrients on the shoot dry weight of sesame plant

**Root Fresh Weight (g)**

The N showed (Fig. 11 and App. IV) indicated significant variation among the different doses of nitrogen fertilizer on root fresh weight (g) of sesame. The highest root fresh weight (7.00 g) was obtained from $N_1$ which was statistically similar with $N_2$ (6.94 g) treatment while the lowest result (5.58 g) was recorded from $N_0$ treatment. It can be attributed towards more availability of nitrogen resulting in enhanced vegetative growth. These results are in line with those reported by Sharma and Kewat (1995).

Application of micronutrient had significant effect on root fresh weight (g) of sesame (Fig. 12). The highest fresh root weight (8.18 g) was obtained from $M_3$ 150 ppm micronutrient while the lowest result (5.32 g) was recorded from $M_{0,}$0 ppm micronutrient which was statistically similar with $M_1$ (5.59 g). The results showed that fresh root weight (g) increased with the application of micronutrient as fresh shoot weight (g). Salwa *et al.* (2010) had found that foliar spray at micronutrient significantly increase whole plant weight of sesame.




$N_0$ – Without nitrogen, $N_1$ – 60 $kgha^{-1}$ nitrogen applied as urea , $N_2$– 120 $kgha^{-1}$ nitrogen applied as urea

**Fig. 11** Effect of different levels of nitrogen on root fresh weight of sesame plant

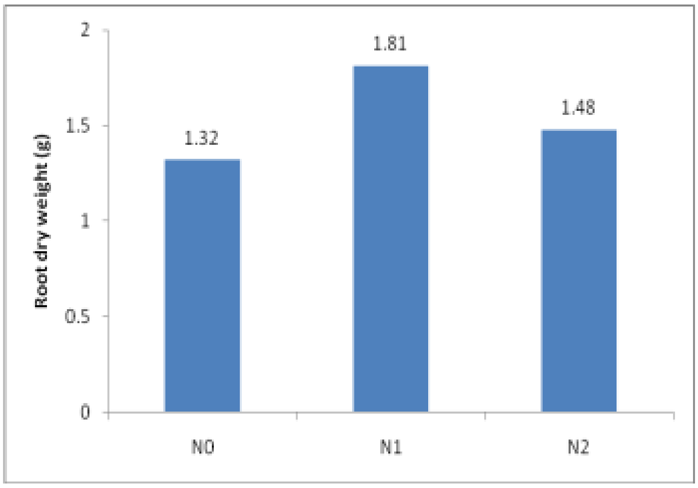

$M_0$ – Without MNs, $M_1$ – 50 ppm MNs, $M_2$ – 100 ppm MNs, $M_3$ –150 ppm MNs

**Fig. 12** Effect of different levels of micronutrients on root fresh weight of sesame plant

**Root Dry Weight (g)**

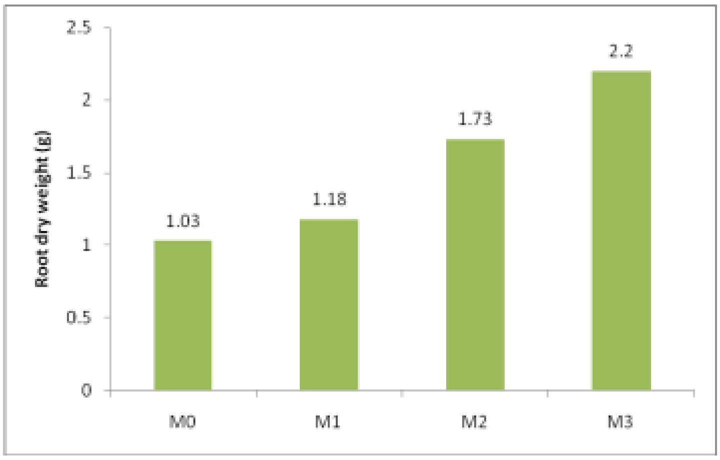
Here the results showed that nitrogen fertilizer doses had significantly effected on root dry weight (g) of sesame (Fig. 13 and App. IV). The highest dry root weight (1.81 g) was obtained from $N_1$ and the lowest result (1.32 g) was recorded from $N_0$. These results showed similarity with root fresh weight (g) (Fig. 11) and suggested that nitrogen had important role in increased of root dry weight of sesame in application at proper doses.

Significant influence on dry root weight (g) of sesame had showed by application of different concentrations of micronutrient (Fig. 14 and App. IV). The highest dry root weight (2.20 g) was observed from $M_{3,}$(150 ppm micronutrient) while the lowest result (1.03 g) was recorded from $M_0$ (0 ppm micronutrient). These results are consistent with fresh root weight (Fig. 10). Masri and Hamza (2011) had reported that foliar spray of micronutrient was found to be more effective in increasing total root weight of plant which supported these results.




$N_0$ – Without nitrogen, $N_1$ – 60 $kgha^{-1}$ nitrogen applied as urea, $N_2$– 120 $kgha^{-1}$ nitrogen applied as urea

**Fig. 13** Effect of different levels of nitrogen on root dry weight of sesame plant



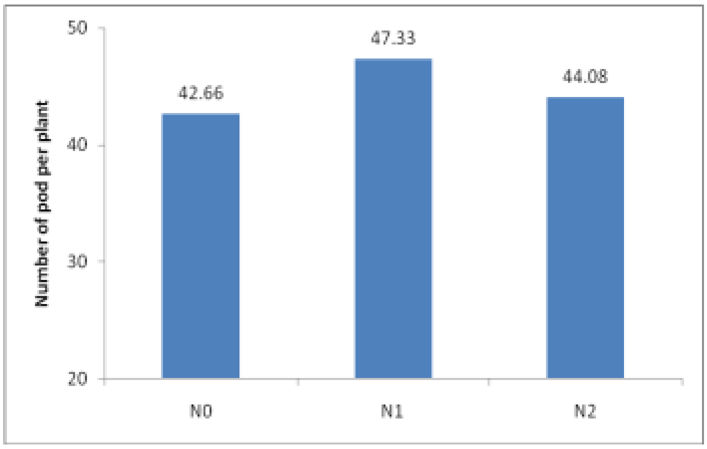

$M_0$ – Without MNs, $M_1$ – 50 ppm MNs, $M_2$ – 100 ppm MNs, $M_3$ –150 ppm MNs

**Fig. 14** Effect of different levels of micronutrient on dry root weight of sesame plan**t**

**Number of Pod Plant$^{-1}$**

A significant variation was recorded due to the different nitrogen fertilizer doses for number of pods plant$^{-1}$ of sesame (Fig. 15 and App. V).The maximum number of pods plant$^{-1}$ (47.33) was recorded for the $N_1$ treatment and the lowest (42.66) was observed from $N_0$ treatment which was statistically similar with $N_2$ (44.08). These results are in line with the findings of Subramanian *et al*. (1979). From the result it appears that pod number plant$^{-1}$ increased due to the increased rate of nitrogen fertilizer application up to certain level but excess application of nitrogen enhanced the vegetative growth instead of pod formation had reported by Alam (2002) and Pathak *et al*. (2002). These results are consistent with the vegetative characters of sesame (Figs, 1 and 3).

As N different concentrations of micronutrients had significant variation in the number of pods plant$^{-1}$ of sesame (Fig. 16 and App. V).The highest number of pods plant$^{-1}$ (51.88) was recorded for the $N_3$ (150 ppm micronutrient) and the lowest (40.11) was observed from $M_0$ which was statistically similar with $M_2$. As reported by the scientist, the number of pod plant$^{-1}$ increased significantly due to micronutrient application on various crops. The spraying of different concentrations of micronutrients had a great regulatory effect on number of pods per plant and increased the pod yield as suggested by Salwa *et al.* (2010) and Ali *et al.* (2012).




$N_0$ – Without nitrogen, $N_1$ – 60 kgha$^{-1}$ nitrogen applied as urea, $N_2$– 120 kgha$^{-1}$ nitrogen applied as urea

**Fig. 15** Effect of different levels of nitrogen on number pod plant$^{-1}$ of sesame

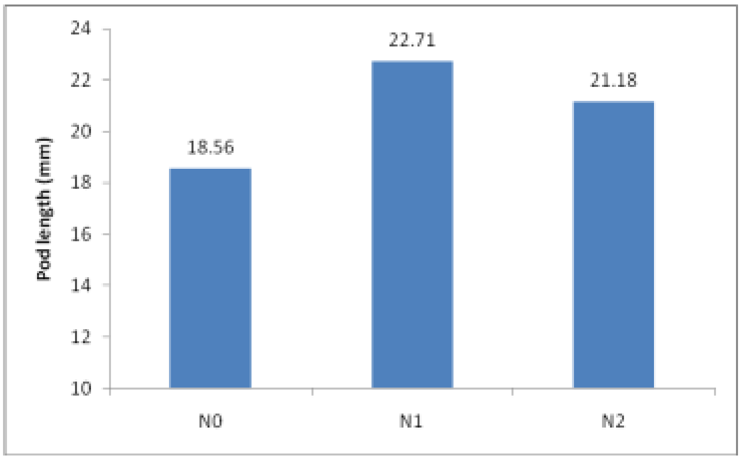

$M_0$ – Without MNs, $M_1$ – 50 ppm MNs, $M_2$ – 100 ppm MNs, $M_3$ –150 ppm MNs

**Fig. 16** Effect of different levels of micronutrients on number pod plant$^{-1}$ of sesame

**Pod Length (mm)**

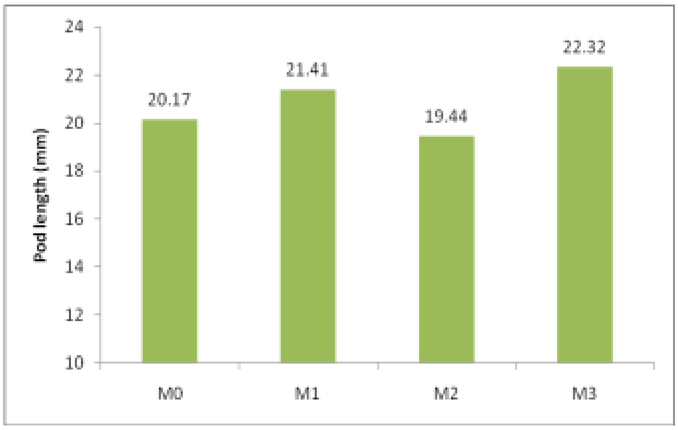
As consistent of fruit diameter nitrogen fertilizer doses had significant influenced on fruit length (mm) of sesame (Fig. 17 and App. V). The highest fruit length (22.71 mm) was obtained from $N_1$ (60 kg Nha$^{-1}$) which was statistically similar with $N_2$ (21.18 mm) while the lowest result (18.56 mm) was recorded from $N_0$ (without N). These data resulted that application of N fertilizer increased fruit length (mm) in contrast with fruit diameter (mm). Patra (2001) had reported that nitrogen fertilizer application increase the pod length of sesame.

Different concentrations of micronutrient had significant influence on pod length (mm) of sesame (Fig. 18 and Appendix V). The highest pod length (22.32 mm) was recorded from $M_3$ treatment while the lowest result (19.44 mm) was recorded from $M_2$. Here results showed that micronutrient increased ear length as reported by Habib *et al.* (2012) that application of micronutrient increased the ear length in wheat. Previous many authors reported that micronutrient plays an important role on the fruit development in many crops. All together the presented data suggest that micronutrient had positive functions on pod length (mm) of sesame.




$N_0$ – Without nitrogen, $N_1$ – 60 kgha$^{-1}$ nitrogen applied as urea, $N_2$– 120 kgha$^{-1}$ nitrogen applied as urea

**Fig. 17** Effect of different levels of nitrogen on the pod length of sesame



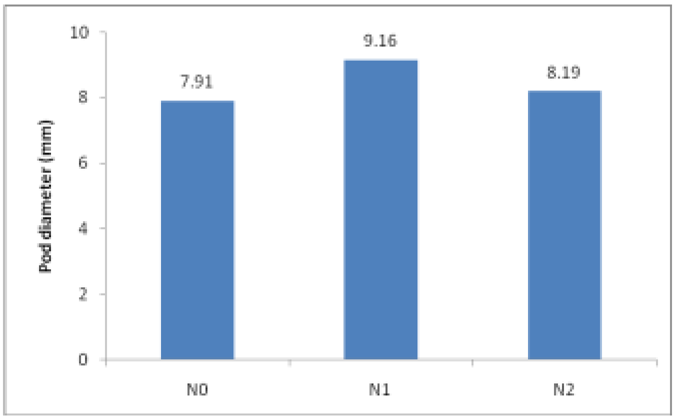

$M_0$ – Without MNs, $M_1$ – 50 ppm MNs, $M_2$ – 100 ppm MNs, $M_3$ –150 ppm MNs

**Fig. 18** Effect of different levels of micronutrients on the pod length of sesame

**Pod Diameter (mm)**

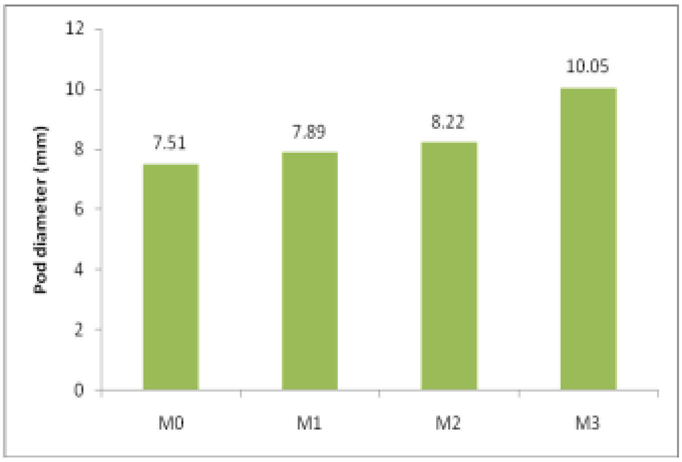
Nitrogen fertilizer doses had significant influence on fruit diameter (mm) of sesame (Fig. 19 and App. V). The highest fruit diameter (9.16 mm) was obtained from $N_1$ while the lowest result (8.19 mm) was recorded from $N_0$ which was statistically similar with $N_2$ (7.91 mm). Here results showed that without and excess nitrogen fertilizer application resulted in less pod growth in diameter for sesame plant.

A significant variation was recorded due to the different concentrations of micronutrient for fruit diameter (mm) of sesame (Fig. 20). The highest fruit diameter (10.05 mm) was obtained from $M_3$ treatment while the lowest result (7.51 mm) was recorded from $A_0$ treatment. Results showed that foliar application of micronutrient increased the fruit diameter (mm) upto a certain concentration of 150 ppm ($M_3$).




$N_0$ – Without nitrogen, $N_1$ – 60 kgha$^{-1}$ nitrogen applied as urea, $N_2$– 120 kgha$^{-1}$ nitrogen applied as urea

**Fig. 19** Effect of different levels of nitrogen on the pod diameter of sesame




$M_0$ – Without MNs, $M_1$ – 50 ppm MNs, $M_2$ – 100 ppm MNs, $M_3$ –150 ppm MNs

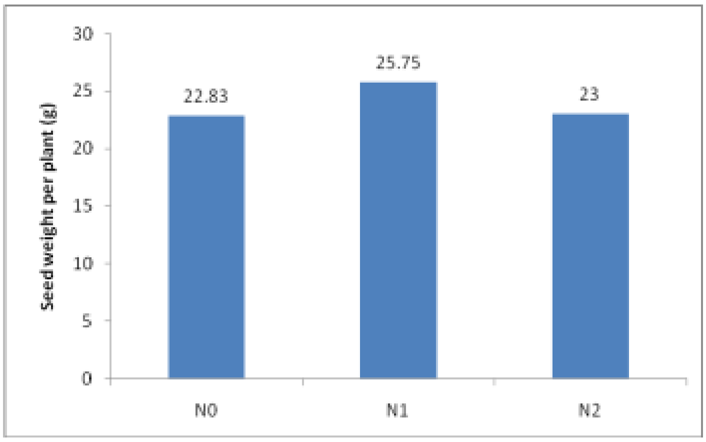
**Fig. 20** Effect of different levels of micronutrients on the pod diameter of sesame

**Seed Weight Plant$^{-1}$ (g)**

In this study N fertilizer levels showed significant variation in seed weight plant$^{-1}$ of sesame (Fig. 21

and App. VI). The maximum seed yield plant$^{-1}$ (25.75 g) was produced by $N_1$ (60 kg Nha$^{-1}$) whereas $N_0$ produced the minimum seed weight plant$^{-1}$ (22.83 g) which was statistically similar with $N_2$. This finding corroborated those of Gnanamurthy *et al.* (1992), Osman (1993), Okpara *et al.* (2007), Fathy and Mohammed (2009), Haruna *et al.* (2010). The lowest number of seed weight was found from control or without N ($N_0$). Similar findings were reported by Tiwari *et al.* (1998), Subrahmanyan and Arulmozhi (1999).

The micronutrient showed significant variation in the seed weight plant$^{-1}$ of sesame (Fig. 22 and App. VI). The highest seed yield plant$^{-1}$(28.44 g) was produced by $M_3$ (150 ppm micronutrient) and $M_1$ (50 ppm micronutrient) produced the minimum seed weight plant$^{-1}$ (21.55 g) which was statistically similar with $M_0$. The present results indicated that micronutrient at 150 ppm ($M_3$) increased seed weight plant$^{-1}$. Habib during (2011), Salwa *et al.* (2010), Parinaz et al. (2012) and Abid *et al.* (2012) had reported that micronutrient significantly increased the seed weight of plants.




$N_0$ – Without nitrogen, $N_1$ – 60 kgha$^{-1}$ nitrogen applied as urea, $N_2$– 120 kgha$^{-1}$ nitrogen applied as urea

**Fig. 21** Effect of different levels of nitrogen on the seed weight plant$^{-1}$ of sesame

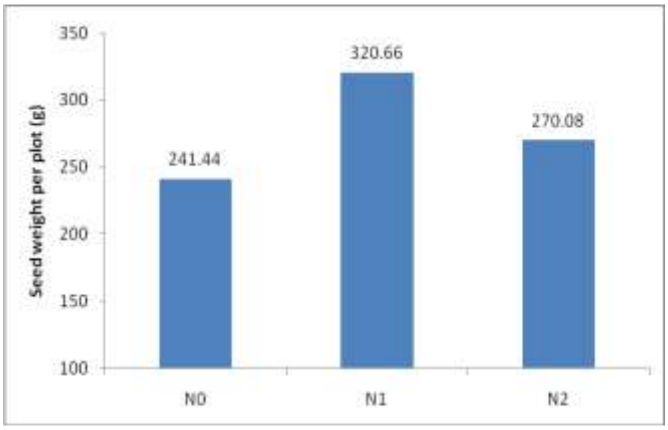

$M_0$ – Without MNs, $M_1$ – 50 ppm MNs, $M_2$ – 100 ppm MNs, $M_3$ –150 ppm MNs

**Fig. 22** Effect of different levels of micronutrients on the seed weight plant$^{-1}$ of sesame

**Seed Weight Plot$^{-1}$ (g)**

The Figure 23 and Appendix VI showed that different levels of nitrogen fertilizer had significant variation in the seed weight plot$^{-1}$(g) of sesame. The maximum seed weight plot$^{-1}$(g) (320.66 g) was produced by $N_1$ (60 kgha$^{-1}$) not from $N_2$ (120 kgha$^{-1}$) and $N_0$ (without N) produced the minimum seed weight plot$^{-1}$ (241.9 g). From the study the results found that excess nitrogen fertilizer application decrease seed weight plot$^{-1}$(g). Sesame pod number, pod length and diameter also increased with N (Figs. 15, 17 and 19) which believe to increase seed weight plot$^{-1}$ of sesame. These findings are in agreement with Pathak *et al*. (2002) and Thakur *et al*. (1998).

The different concentrations of micronutrient showed significant variation in the seed weight plot$^{-1}$ (g) of sesame (Fig. 24). The maximum seed weight plot$^{-1}$(321.1 g) was produced by $M_3$ (150 ppm) where as $M_0$ (without micronutrient) produced the seed weight plot$^{-1}$ (268.4 g) which was statistically similar with $M_2$. These results showed significant variation in seed weight plot$^{-1}$ (g) as similar effect of micronutrient to seed weight plant$^{-1}$ (g) (Fig. 22). Abid *et al.* (2012), Parinaz *et al.* (2012) and many other researchers had reported that micronutrient had a significant effect on seed yield and yield components. Taken together, these finding indicated that micronutrient can promote the seed yield of sesame as N.




$N_0$ – Without nitrogen, $N_1$ – 60 kgha$^{-1}$ nitrogen applied as urea, $N_2$– 120 kgha$^{-1}$ nitrogen applied as urea

**Fig. 23** Effect of different levels of nitrogen on the seed weight plot$^{-1}$ of sesame

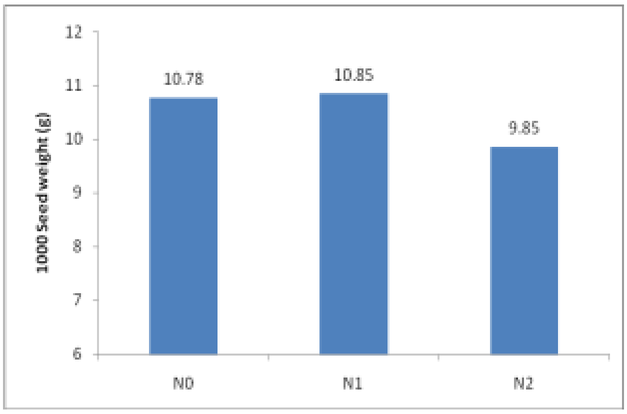

$M_0$ – Without MNs, $M_1$ – 50 ppm MNs, $M_2$ – 100 ppm MNs, $M_3$ –150 ppm MNs

**Fig. 24** Effect of different levels of micronutrients on the seed weight plot$^{-1}$ of sesame

**1000- Seed Weight (g)**

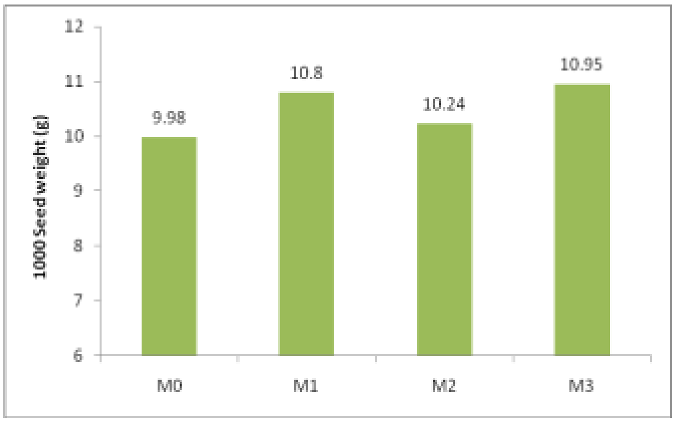
The application of nitrogen insignificantly influenced on the thousand seed weight (g) of sesame (Fig. 25 and App. VI). The maximum thousand seed weight (10.85 g) was produced by $N_1$ and $N_2$ produced the lowest thousand seed weight (9.85 g). These results showed that without application of nitrogen (N) resulted in minimum 1000 seed weight and with the application of N the 1000-seed weight increased and got highest weight from $N_1$ (60 kg $Nha^{-1}$) . These results are in line with those of Mankar *et al*. (1995) who reported that 1000 seed weight increased with increasing rate of N. Pathak *et al*. (2002) reported that 1000 seed weight of sesame increased with 45 $kgha^{-1}$ of nitrogen fertilizer application.

The Fig. 26 and App. VI showed that micronutrient had also insignificant influenced on the 1000 seed weight of sesame. The highest 1000 seed weight (10.95 g) was produced by $M_3$ which was statistically similar with $M_1$ (10.80 g) and $M_0$ produced the lowest 1000 seed weight (9.98 g). The results showed that application of micronutrient as foliar spray increased the 1000 seed weight (g) and the best result found from $M_3$ (150 ppm). Higher concentration of micronutrient on wheat and safflower increased 1000 seed weight had reported by Habib (2011) and Parinaz *et al.* (2012), respectively.




$N_0$ – Without nitrogen, $N_1$ – 60 $kgha^{-1}$ nitrogen applied as urea ,
$N_2$– 120 $kgha^{-1}$ nitrogen applied as urea

**Fig. 25** Effect of different levels of nitrogen on 1000- seed weight of sesame



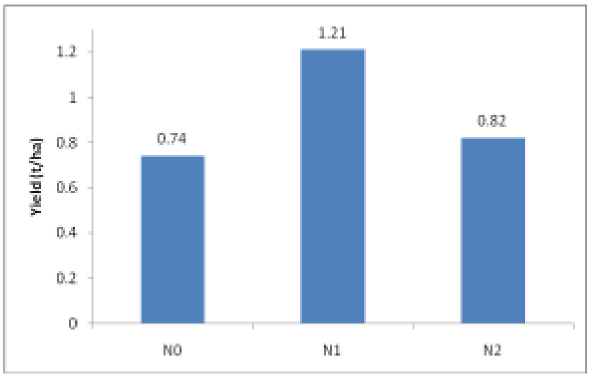

$M_0$ – Without MNs, $M_1$ – 50 ppm MNs, $M_2$ – 100 ppm MNs, $M_3$ –150 ppm MNs

**Fig. 26** Effect of different levels of micronutrient on the 1000 seed weight of sesame

**Yield (t $ha^{-1}$)**

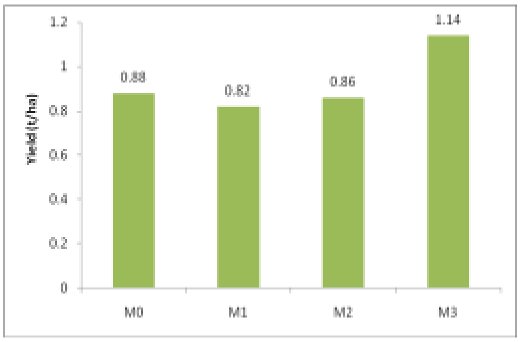
The seed yield of sesame plot$^{-1}$ was converted into ton hectare$^{-1}$. The different levels of nitrogen had significant effect on the yield of sesame (Fig. 27 and App. VI) as consistent with number of pod plant$^{-1}$, pod length (mm) and pod diameter (mm), seed weight plant$^{-1}$ (g), seed weight plot$^{-1}$ (g), except 1000 seed weight (g) (Figs. 15, 17, 19, 21, 23, 25 and 27). The maximum yield of seed hectare$^{-1}$ (1.21t) was obtained from $N_1$ (60 kgha$^{-1}$) whereas the minimum yield of seed per hectare (0.74 t) was obtained from $N_0$ (control or without N). $N_1$ (60 kgha$^{-1}$) gave the maximum yield than $N_2$ (120 kgha$^{-1}$) this could be because of excessive nitrogen had been reported to reduce fruit number and yield for sesame but enhances plant growth (Aliyu *et al*. 1996). This finding corroborated those of Bonsu (2003), Fathy and Mohammed (2009).

The different concentrations of micronutrients had significant effect on the seed yield of sesame ( Fig. 28 and App. VI) ton hectare$^{-1}$ as similar to number of pod plant$^{-1}$, pod length (mm) and pod diameter (mm), seed weight plant$^{-1}$ (g), seed weight plot$^{-1}$ (g), except 1000 seed weight (g) (Figs. 16, 18, 20, 22, 24, 26 and 28). The highest yield of seed hectare$^{-1}$(1.14 t) was obtained from $M_3$ (150 ppm). The minimum yield of seed hectare$^{-1}$ (0.82 t) was obtained from $M_1$ (50 ppm micronutrient). These results showed that the foliar application of micronutrients increased the yield of sesame. The similar findings had stated by Habib (2011), Salwa *et al.* ( 2010), Parinaz *et al.* (2012), Ali and Ahmed (2012) and Abid *et al.* (2012) had observed that foliar spray of micronutrients (Fe, Zn, Mn, Cu) in different concentration at different days of interval significantly increased the yield. Application of micronutrients (Fe, Zn, Mn, Cu) had significantly increased the yield of plant had also reported by Bameri *et al.* (2012).




$N_0$ – Without nitrogen, $N_1$ – 60 kgha$^{-1}$ nitrogen applied as urea ,$N_2$– 120 kgha$^{-1}$ nitrogen applied as urea

**Fig. 27** Effect of different levels of nitrogen on the yield of sesame




$M_0$ – Without MNs, $M_1$ – 50 ppm MNs, $M_2$ – 100 ppm MNs, $M_3$ –150 ppm MNs

**Fig. 28** Effect of different levels of micronutrients on the yield of sesame

# Conclusions

Different doses of nitrogen and micronutrients exhibited significant variation in respect of growth and yield of sesame. The rates of N and micronutrients @60 kg $ha^{-1}$ and 150 ppm is optimum for the best growth and yield of sesame variety BARI Til-4.

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**Appendix I** Analysis of variance of the data on plant height of sesame as influenced by different levels of nitrogen and micronutrient

| Sources of variation | Degree of freedom | Mean square Plant height 30 DAS | 40 DAS | 50 DAS |
|---|---|---|---|---|
| Replication | 2 | 30.19 | 9.67 | 8.54 |
| Factor A (N) | 2 | 186.47** | 60.05** | 160.61** |
| Factor B (Micronutrient) | 3 | 46.49** | 26.00** | 86.38** |
| A X B | 6 | 5.65NS | 6.79** | 9.05** |
| Error | 22 | 8.92 | 4.40 | 5.08 |

** significant at 1% level of probability,

* significant at 5% level of probability,

NS- Non significant

**Appendix II** Analysis of variance of the data on number of leaves plant$^{-1}$ of sesame as influenced by different levels of nitrogen and micronutrient

| Sources of variation | Degree of freedom | Mean square Number of leaf plant$^{-1}$ | | |
|---|---|---|---|---|
| | | 30 DAS | 40 DAS | 50 DAS |
| Replication | 2 | 0.333 | 6.33 | 2.08 |
| Factor A (N) | 2 | 26.33$^{*}$ | 26.32$^{*}$ | 48.08$^{**}$ |
| Factor B (Micronutrient) | 3 | 20.10$^{**}$ | 20.08$^{**}$ | 275.58$^{**}$ |
| A X B | 6 | 2.29$^{**}$ | 2.27$^{**}$ | 12.63$^{**}$ |
| Error | 22 | 0.746 | 0.750 | 4.07 |

** significant at 1% level of probability,

* significant at 5% level of probability,

NS- Non significant

**Appendix III** Analysis of variance of the data on number of branch plant$^{-1}$ of sesame as influenced by different levels of nitrogen and micronutrient

| Sources of variation | Degree of freedom | Mean square Number of branch plant$^{-1}$ | | |
|---|---|---|---|---|
| | | 30 DAS | 40 DAS | 50 DAS |
| Replication | 2 | 0.19 | 1.36 | 1.36 |
| Factor A (N) | 2 | 9.02$^{**}$ | 2.11$^{*}$ | 2.12$^{*}$ |
| Factor B (Micronutrient) | 3 | 6.25$^{**}$ | 9.21$^{**}$ | 9.22$^{**}$ |
| A X B | 6 | 0.58$^{NS}$ | 0.51$^{NS}$ | 0.51$^{NS}$ |
| Error | 22 | 0.78 | 0.69 | 0.69 |

* significant at 5% level of probability,

** significant at 1% level of probability,

NS- Non significant

**Appendix IV** Analysis of variance of the data on fresh and dry weights (g) of shoot and root of sesame as influenced by different levels of nitrogen and micronutrient

| Sources of variation | Degree of freedom | Mean square<br>Shoot fresh weight (g) | Shoot dry weight (g) | Root fresh weight (g) | Root dry weight (g) |
|---|---|---|---|---|---|
| Replication | 2 | 13.47 | 0.51 | 0.70 | 0.02 |
| Factor A (N) | 2 | 300.77** | 0.30** | 8.00** | 0.76** |
| Factor B (Micronutrient) | 3 | 758.15** | 10.15** | 15.60** | 2.56** |
| A X B | 6 | 19.90** | 2.35** | 1.66** | 0.41** |
| Error | 22 | 3.46 | 0.765 | 0.34 | 0.01 |

** significant at 1% level of probability,

NS- Non significant

**Appendix V** Analysis of variance of the data on pod number plant$^{-1}$, pod diameter and pod length of sesame as influenced by different levels of nitrogen and micronutrient

| Sources of variation | Degree of freedom | Mean square<br>Number of pod plant$^{-1}$ | Pod diameter (mm) | Pod length (mm) |
|---|---|---|---|---|
| Replication | 2 | 2.77 | 0.17 | 0.04 |
| Factor A (N) | 2 | 68.69** | 5.16** | 54.03** |
| Factor B (Micronutrient) | 3 | 246.32** | 11.43** | 14.77** |
| A X B | 6 | 55.43** | 1.93** | 3.76** |
| Error | 22 | 167.10 | 0.39 | 0.6 |

** significant at 1% level of probability,

NS- Non significant

**Appendix VI. Analysis of variance of the data on yield contributing characters of sesame as influenced by different levels of nitrogen and micronutrient**

| Sources of variation | Degree of freedom | Mean square<br>Seed weight plant$^{-1}$ (g) | Seed weight plot$^{-1}$ (g) | 1000 seed weight (g) | Yield (tha$^{-1}$) |
|---|---|---|---|---|---|
| Replication | 2 | 0.36 | 1044.52 | 0.52 | 0.003 |
| Factor A (N) | 2 | 32.19** | 19107.19** | 3.78NS | 0.776** |
| Factor B (Micronutrient) | 3 | 93.43** | 8804.44** | 1.87NS | 0.200** |
| A X B | 6 | 3.04** | 3652.30** | 0.99 NS | 0.039** |
| Error | 22 | 4.45 | 785.24 | 4.37 | 0.01 |

** significant at 1% level of probability,

NS- Non significant