INFLUNCE OF NITROGEN AND FOLIAR SPRAY OF MICRONUTRIENTS ON PERFORMANCE OF SESAME *(Sesamum indicum* L.*)*

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CERTIFICATE

This is to certify that the thesis entitled " INFLUENCE OF NITROGEN AND FOLIAR SPRAY OF MICRONUTRIENTS ON PERFORMANCE OF SESAME (Sesamum indicum L.)" submitted to the DEPARTMENT OF AGRICULTURAL BOTANY, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (M.S.) in AGRICULTURAL BOTANY, embodies the results of a piece of bona fide research work carried out by BIR JAHANGIR SHIRAZY, Registration. No. 08- 03001, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution.

I further certify that any help or sources of information received during the course of this investigation has duly been acknowledged.

Dated: December 2014
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DEDICATED TO
MY
BELOVED PARENTS

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ABSTRACT

The experiment was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka, during Kharif-1 season, April to July 2013 to evaluate the influence of different levels of nitrogen and foliar application of micronutrients (Fe, Zn, Mn, Cu) on performance of sesame (*Sesamum indicum* L.) variety BARI Til 4 . Treatments of the experiment were three different N levels *viz*. N_0 = 0 kg Nha^{-1}, N_1 = 60 kg Nha^{-1} and N_2 = 120 kg Nha^{-1} and four different levels of micronutrients *viz*. M_0 = 0 ppm, M_1= 50 ppm, M_2 =100 ppm and M_3 =150 ppm. The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. The total treatment combinations were 12 (3x4). Experimental results showed statistical variation among the treatments in most of the parameters which were analyzed. 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. The rate of application of N 60 $kgha^{-1}$ produced the highest seed yield (1.21 tha^{-1}) which is consisting with the vegetative growth and yield 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. The interaction effect of different levels of N and micronutrients was significantly influenced on almost all morphological parameters, yield contributing characters and seed yield of sesame. The interaction effect of N and micronutrients failed to show significant differences in branch number $plant^{-1}$ and 1000-seed weight of sesame. The highest value of yield contributing characters and seed yield of sesame was recorded with the combined dose of N_1M_3 (60 kg Nha^{-1} along with 150 ppm micronutrients) and the lowest values were obtained from control, N_0M_0 (0 kg Nha^{-1} and 0 ppm micronutrients) treatment combination. The highest seed yield (1.46 tha^{-1}) was obtained from 60 kg Nha^{-1} with 150 ppm micronutrients where as the lowest yield (0.59 tha^{-1}) found with control treatment. Therefore, this experimental results suggest that the combined use of 60 kg Nha^{-1} with 150 ppm micronutrients have produced higher seed yield of sesame by adjusting in plant morphological characters and yield contributing characters of sesame.

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LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
App.	=	Appendix
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agricultural Organization
N	=	Nitrogen
Fe	=	Ferrous
Zn	=	Zinc
Mn	=	Manganese
Cu	=	Copper
et. al.	=	And others
TSP	=	Triple Super Phosphate
MOP	=	Muriate of Potash
RCBD	=	Randomized Complete Block Design
DAS	=	Days after sowing
ha^{-1}	=	Per hectare
g	=	Gram (s)
kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
t	=	Ton
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
NS	=	Non significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of Coefficient of Variance

Chapter I

INTODUCTION

Sesame (*Sesamum indicum* L.*)* belongs to the family Pedaliaceae. It is an important oil crop next to mustard and occupying 9% of the total oil seed area in Bangladesh (BBS, 2005). It is a flower bearing annually cultivated oil crop. The wild sesame is originated from Africa and the cultivated type is originated from India which also grown in Burma, India, China, Sudan and other countries in the world including Bangladesh (Ogasawara,1988). It is widely naturalized in tropical regions around the world and is cultivated for its edible seeds. Sesame is highly tolerant to drought or any other environmental variations where other crops may fail to grow (Raghav *et al.* 1990). The world harvested about 4.76 million metric tons of sesame seeds in 2013 and the largest producer was Burma. The world's largest exporter of sesame seeds was India. Japan was the largest importer because they uses sesame seed in bakery industry (FAO, 2012). Bangladesh ranks twenty and share 0.8% in the total production of sesame in the world.

The sesame contains very high percent of oil in the range of 42-45%, 20% of protein and 14-20% of carbohydrate (BARI, 1998 and BINA, 2002) which is tasteless, nutty flavor and plays a vital role in human diet and used as a cuisine across the world. It has 47 percent oleic and 39 percent linoleic acid and is rich in Omega 6 fatty acid. The health benefits of sesame oil include its ability to improve hair and skin health, stimulate strong bone growth, reduce blood pressure, manage anxiety and depression, protect infant health, boost up dental health, prevent cancer, improve the digestive process etc. It is also used in salad and margarine. The flour that remains after oil extraction is called sesame meal which is an excellent high-protein feed for poultry and livestock (Oplinger *et al.* 2011). It has been also reported that the addition of sesame to high lysine meal of soybean produces a well-balanced animal feed (Raghav *et al.* 1990).

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 96000 acres with production of 25000 M tons (BBS, 2005). Recently BBS (2013) reported that 84310 acres of land cultivated for sesame and production was 30972 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 macronutrients 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 seed yield (Shehu *et al*. 2009). The N can contribute to increase seed yield and protein content in seed by synthesizing more protein as N is a part of protein chemistry. Nitrogen (N) has an important role in seed protein and physiological functions of the plant and supports the plant with rapid growth, increasing seed and fruit production and enhancing quality of leaf and oil seed yield (Allen and Morgan, 2009). Separately, N increases the vegetative growth but delayed maturity of seed yielding plants and excessive use of this element may produce too much of vegetative growth, thus food production may be impaired and suggesting that N management is crucial in cropping system and for normal plant growth and development (Maini *et al*. 1959 and Singh *et al*. 1972). Unfortunately, N content of Bangladesh soil is very low and need to supply N fertilizer in proper amount in available form and at appropriate time to make sure for better seed production. These results suggest that the optimum doses of Nha^{-1} for sesame seed yield is needed to examine.

Micronutrients are essential for plant growth and play an important role in balanced crop nutrition. They include Copper (Cu^{2+}), Iron (Fe^{2+}, Fe^{3+}), Manganese (Mn^{2+}), Zinc (Zn^{2+}), Molybdenum (MoO_4^{2-}), Nickel (Ni^{4+}), Boron (H_3BO_3, $H_2BO_3^-$) and Chloride (Cl^-). They are as important to plant nutrition as primary and secondary nutrients, though plants don't require as much of them. A lack of any one of the micronutrients in the soil can limit growth, even when all other nutrients are present in adequate amounts. They play an indispensable role in cell division and development of meristematic tissues, stimulate photosynthesis, respiration, energy and nucleotide transfer reactions and fasten the plant maturity (Marcher, 1998). Although micronutrients are needed in relatively very small quantities for adequate plant growth and production, their deficiencies induce a great disturbance in the different physiological and metabolic processes inside the plant. 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 as reported by Tiwari *et al*. 1998 and Shanker *et al*. 1999. Many authors reported that micronutrient found to enhance both the yield and quality of oilseed crops. However, the information on influence of foliar spray of micronutrient on growth, seed yield and oil content of sesame is very scanty. In recent years, soil organic materials and micronutrients have been reduced because of intensive cultivation and continuous chemical fertilizers usage. It is approved that continuance of these conditions lead to destruction of soil structure, loss of biological diversity and agro-ecosystem disorders (Prakash *et al.* 2003).

The term micronutrient also signifies that micronutrients are needed in small quantities for adequate plants' growth and production. However, their deficiencies cause a great disturbance in the physiological and metabolic processes in the plant (Bacha *et al.* 1997). Throughout the world microelements as Fe, Zn, Mn and Cu are added to foliar fertilizers, in order to compensate their deficiency especially in arid and semi arid regions (Kaya *et al.*, 2005). Micronutrients, especially Fe and Zn, act either as metal components of various enzymes or as functional, structural, or regulatory cofactors. Thus, they are associated with saccharide metabolism, photosynthesis, and protein synthesis (Marschner, 1995). Zinc (Zn) is known to have an important role either as a metal component of enzymes or as a functional, structural or regulatory cofactor of a large number of enzymes (Grotz and Guerinot, 2006). Manganese (Mn) is regarded as an activator of many different enzymatic reactions and takes part in photosynthesis. Manganese activates decarboxylase and dehydrogenase and is a constituent of complex PSII-protein, SOD and phosphatase. Several researches indicated a positive influence of micronutrient (Fe, Zn, Mn, Cu) application in increase of yield and quantitative parameters of crops (Mosavi *et al*. 2007) on potato, (Paygozar *et al*., 2009) on pearl millet. 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; Cakmak, 2008). Foliar spraying of microelements is very helpful when the roots cannot provide necessary nutrients (Kinaci and Gulmezoglu, 2007; Babaeian *et al*. 2011).

Considering the above proposition this study has been undertaken to investigate the growth, seed yield and physiological attributes and finally yield. Therefore, limited study has elucidated that micronutrient can modify the morpho-physiologycal attributes and yield of sesame under SAU environmental conditions.

However, to my knowledge little is known whether different doses of N along with different doses of micronutrients regulate the growth, yield of sesame using new variety of BARI Til 4 which is pest and disease resistant. In a view of above points a field experiment containing the treatments of N and micronutrients was conducted with the following objectives:

- To analyze the independent effect of N and micronutrients on morphology, yield contributing characters and yield of sesame variety BARI Til 4.
- To investigate the interaction effects of N and micronutrients on morphology, yield contributing characters and yield of sesame variety BARI Til 4.

Chapter II

REVIEW OF LITERATURE

Among the oilseed crops, sesame occupies the third positions in Bangladesh. The proper fertilizer management and foliar application of micronutrients essentially influences it's morphological characters and yield performance. Experimental evidences showed that there is a profound influence of nitrogen (N) and micronutrients (Fe, Zn, Mn, Cu) on this crop. A brief of the relevant works performed in the past are presented in this Chapter.

2.1 Effect of nitrogen (N) on morphological parameters and seed yield of sesame:

A field study was conducted by Umar *et al*. (2012) to evaluate the performance of two sesame varieties in response to nitrogen fertilizer level and intra row spacing at the Research Farm of Institute for Agricultural Research Samaru in the Northern Guinea Savanna of Nigeria, during the wet seasons of 2009 and 2010. The treatments consisting of four nitrogen levels (20, 40, 60 and 80kgNha^{-1}), three intra row spacing (5,10 and 15cm) and two varieties. The study resulted that application of 80kg Nha^{-1} at 5cm intra-row spacing produced the highest grain yield of both varieties.

Bijani *et al.* (2015) conducted an experiment to evaluate of the effects of nitrogen and biological fertilizer on sesame crop as a factorial experiment based on a randomized complete block design with three replications in the research farm of the university of Zabol. Experimental factors were nitrogen (N) fertilizer at four levels (0, 160, 240 and 320 kg ha^{-1} N as urea) and nitroxin at two levels (inoculated and non-inoculated). When 240 kg ha^{-1} of urea was applied, number of lateral branches, 1000-seed weight, number of seeds capsule^{-1}, number of capsules plant^{-1}, and protein content increased by 50, 12, 18, 45 and 11%, respectively. The interaction of treatments revealed that inoculation of seeds with nitroxin along with 75% recommended N application increases plant height, seed and oil yield, respectively, by 28, 58 and 56% compared with non-inoculated seed and non N fertilizer application.

Field trials were conducted by Haruna and Aliyu (2012) during the rainy seasons of 2005, 2006 and 2007 at the Research Farm of Institute for Agricultural Research, Samaru, Nigeria to study the yield and economic return of sesame cv. Ex-Sudan as influenced by poultry manure, nitrogen, and phosphorus application. The experiment consisted of four rates of poultry manure (0, 5.0, 10.0, and 15.0 t ha^{-1}), three levels of nitrogen in the form of urea (0, 60, and 120 kg N ha^{-1}) and three levels of phosphorus in the form of single super phosphate (0, 13.2 and 26.4 kg P ha^{-1}) applied to the treatments. Applications of 5 t poultry manure ha-^{1}, 60 kg nitrogen ha^{-1} and 13.2 of phosphorus ha^{-1} seems to be the ideal rates for sesame production at Samaru, Nigeria and is therefore recommended.

Haruna (2011) conducted a field trial during the rainy seasons of 2009 and 2010 to study the effects of nitrogen and intra row spacing on the growth and yield of sesame. In this experiment three levels of nitrogen in the form of urea (0, 50 and 100 kg N ha^{-1}) was used. Plant height, leaf area index, number of branches $plant^{-1}$, total dry matter $plant^{-1}$ and days to 50% flowering were optimized at 100 kg N ha^{-1}. Numbers of capsules $plant^{-1}$, capsule weight $plant^{-1}$, grain yield $plant^{-1}$ and grain yield ha^{-1} were optimized at 50 kg ha^{-1} of nitrogen. Maximum number capsules $plant^{-1}$, capsule weight $plant^{-1}$, grain yield $plant^{-1}$, grain yield ha^{-1} was recorded at 50 kg N ha^{-1} and planting at 15cm intra row spacing in this area.

Field experiment was conducted by Muhamman *et al.* (2010) during 2005 and 2006 rainy seasons at the Teaching and Research Farm, Faculty of Agriculture, Adamawa State University, Mubi, Nigeria to study the effect of nitrogen (N) and phosphorous (P) rates on some growth and yield characteristics of sesame. The treatments consisted of four N rates: 0, 30, 60 and 90 kg ha^{-1} and four P rates: 0, 15, 30 and 45 kg ha^{-1}. Result obtained showed a positive relationship among the characters measured which also contributed meaningfully both directly and indirectly to total seed yield $plant^{-1}$ with number of branches and plant height making the highest direct contributions, respectively.

Taylor *et al.* (2008) showed that the response of sesame to fertilizer was studied in 11 trials at four different sites, in which phosphorus was applied at rates from 0 to 26 kg ha^{-1} to the seed bed and nitrogen at rates from 0 to 60 kg ha^{-1} after thinning. Yield responses found only to the main effects of nitrogen and phosphorus, are discussed in relation to soil type and previous cropping history of the sites and used to calculate gross cash returns from fertilizer use. Seed oil content was affected by environment, but responses to nitrogen and phosphorus were inconsistent.

Fumis (2004) stated that the sunflower plants were grown in vermiculite under two contrasting nitrogen supply, with nitrogen supplied as ammonium nitrate. Higher nitrogen concentration resulted in higher shoot dry matter production plant^{-1} and the effect was apparent from 29 days after sowing (DAS). The difference in dry matter production was mainly attributed to the effect of nitrogen on leaf production and on individual leaf dry matter. The specific leaf weight (SLW) was not affected by the nitrogen supply. The photosynthetic CO_2 assimilation (A) of the target leaves was remarkably improved by high nitrogen nutrition. However, irrespective of nitrogen supply, the decline in photosynthetic CO_2 assimilation occurred before the end of leaf growth. Although nitrogen did not change significantly stomatal conductance (gs), high-N grown plants had lower intercellular CO_2 concentration (Ci) when compared with low-N grown plants. Transpiration rate (E) was increased in high-N grown plants only at the beginning of leaf growth. However, this not resulted in lower intrinsic water use efficiency (WUE).

Study was conducted by Malik *et al.* (2003) during 2001 to see the influence of different nitrogen levels on productivity of sesame under varying planting geometry. The experiment comprised of three nitrogen levels (0, 40 and 80 kg ha^{-1}) and four planting methods (single row flat sowing, paired row planting, ridge sowing and bed sowing). Various growth and yield parameters of the crop were influenced differently by various nitrogen levels and planting methods. Among nitrogen levels, N_2 (80 kg ha^{-1}) treatment gave maximum seed yield (0.79 t ha^{-1}) and maximum seed oil content (45.88%) while among sowing methods bed sowing (50/30 cm) gave highest seed yield (0.85 t ha^{-1}) and seed oil contents (44.06%).

Abdel-Galil and Abdel-Ghany (2014) had reported that increasing nitrogen fertilization rates from 107.1 to 178.5 kg N ha^{-1} resulted in significant increment in yield and its attributes of groundnut and sesame crops.

In order to study the effect of nitrogen regimes on vegetative growth parameters of sesame an experiment was conducted by Haghnama *et al.* (2009) in Ramian, Golestan province, Iran. The experimental treatments were two nitrogen amount (50 and 100 kg Nha^{-1}) and two sesame row spacing (40 and 60 cm). Investigation on main effects of experimental treatments showed significant increase in leaf area index and dry weight of shoot in sesame when nitrogen level increased.

Pathak *et al.* (2002) evaluated the effect of nitrogen levels (0, 15, 30 and 45 $kgha^{-1}$) on the growth and yield of sesame. N at 45 $kgha^{-1}$ recorded the highest mean values for plant height (74.3 cm), number of branches $plant^{-1}$ (4.50), number of capsules $plant^{-1}$ (39.0) and 1000 seed weight (2.9 g). N at 45 $kgha^{-1}$ also recorded the highest value for seed yield, net return and benefit cost ratio.

Auwalu *et al.* (2007) conducted a field experiment and observed that the effect of nitrogen level (0, 30, 60 $kgha^{-1}$) on the productivity of sesame (*S. radiatum*). They suggested that the farmers should grow vegetable sesame during rainy season and apply 30 $kgha^{-1}$ N in a single dose 2 weeks after sowing. It also produced high total marketable yield.

Alam (2002) evaluated the effect of N at 45, 60 and 75 $feddan^{-1}$ on sesame cv. Giza-32 was studied. N as ammonium nitrate was applied after thinning and three weeks thereafter increasing N rate increased plant height, length of fruiting zone, number of branches and capsule $plant^{-1}$ and capsule length were highest with 60 and 75 kg/ha N $feddan^{-1}$.

Patra (2001) found out effects of N on yield and yield attributes of sesame cv. Kalika. N was applied at 0, 30, 60 and 90 $kgha^{-1}$, plant height, branch $plant^{-1}$, capsule $plant^{-1}$, 1000 seed weight and seed yield significantly increased with 60 $kgha^{-1}$ N.

Sinharoy *et al.* (1990) found that application of 30 and 60 N $kgha^{-1}$ increased plant height, number of branches $plant^{-1}$, number of capsule $plant^{-1}$ and gave average yield of 651 and 801 $kgha^{-1}$.

The increase in plant height due to application of nitrogen may be attributed to better vegetative growth of sesame. These results are in conformity with the findings of Malik *et al.* (1988) who also reported that plant height increased with increasing levels of nitrogen.

Tiwari *et al.* (1998) reported sesame cv. Co-1, Tka-9 and Tka-21 produce mean seed yield of 3.71, 3.17 and 2.57 tha^{-1}, respectively, while N rates 0, 30, 45, 60 and 75 kg/ha and produce mean yield 1.66, 2.27, 3.17, 4.19 and 4.41tha^{-1}, respectively.

Maximum number of capsules $plant^{-1}$ (97.88) was produced at the nitrogen level of 80 $kgha^{-1}$, followed by 40 kg N ha^{-1} which produced 92.50 capsules $plant^{-1}$. Minimum number of capsules $plant^{-1}$ (88.55) was recorded in control treatment. It can be attributed towards more availability of nitrogen resulting in enhanced vegetative growth, leading to improved fruiting. These results are in line with those reported by Sharma and Kewat (1995).

There is highly significant difference among nitrogen levels for number of seeds $capsule^{-1}$. Maximum number of seeds $capsule^{-1}$ (62.83) was produced when nitrogen was applied at the rate of 80 kg ha^{-1}. While minimum number of seeds $capsule^{-1}$ (61.42) was produced in N_0 (control) treatment. Increase in number of seeds $capsule^{-1}$ in N_2 (80 kg ha^{-1}) treatment might be attributed to better growth of the plant which ultimately increased number of seeds as compared to control. These results are in line with the findings of Subramanian *et al*. (1979).

The 1000-seed weight was significantly affected by nitrogen levels. The highest 1000- seed weight (3.42 g) was recorded in N_2 (80 kg ha^{-1}) treatment, followed by N_1 (40 kg ha^{-1}) treatment that resulted in 3.22 g of 1000-seeds. While control resulted in lowest 1000-seed weight (2.97 g). These results are in line with those of Mankar *et al*. (1995) who reported that 1000- seed weight increased with increasing rate of N.

Yield components such as number of capsule $plant^{-1}$, capsule yield per $plant^{-1}$, seed yield $plant^{-1}$ and seed yield $hectare^{-1}$ were all optimized at moderate N level (50 kg N ha^{-1}) and not the highest N level (100 kg N ha^{-1}) as in growth characters. This could be because excessive nitrogen has been reported to reduce fruit number and yield but enhances plant growth (Aliyu *et al*. 1996). This finding corroborated those of Gnanamurthy *et al*. (1992), Osman (1993), Okpara *et al*. (2007), Fathy and Mohammed (2009).

The response exhibited by sesame to nitrogen application as observed in increased plant height, LAI, number of branches per plant and the total dry matter per plant in all seasons could be attributed to the ability of N in promoting vegetative growth. This is in conformity with the findings of Okpara *et al.* (2007), who reported significant increase in such growth characters of sesame due to applied N. The number of days to 50% flowering was increased with nitrogen application. This could be attributed to the fact that nitrogen have been reported to increase leaf size and chlorophyll content, delayed maturity time and increased vegetative growth period (Haruna *et al*. 2011).

Yield of sesame cv. Ex-Sudan was highest at moderate rate of applied poultry manure and nitrogen (5 t ha^{-1} and 60 kg N ha^{-1}) and not the highest doses. This could be because excessive nitrogen has 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).

2.2 Effect of Micronutrients on morphological parameters and seed yield of sesame:

Salwa *et al*. (2010) conducted a field experiment at Ismailia Agricultural Research Station, Ismailia Governorate, Egypt for two successive summer seasons 2008 and 2009 using sesame (Giza 32) to study the effect of elemental sulphur as soil application, amino acids and micronutrients (Fe, Zn, Mn) as foliar spray and their interactions. Data indicated that, plant height (cm) significantly affected by all applied treatments. The tallest plant height (213.3 cm) achieved upon treating by A1 + 1.0 Mg $Sfed^{-1}$ + 900, 450, 450 µg g^{-1} Fe, Zn, Mn by rate of increases 48.0% over control. Data also show that there were significantly increases in the whole plant weight with increasing application of sulphur as soil application and micronutrients as foliar spray. A significantly increase in the seed sesame yields by rate of increases 89.80% over control. Generally, a combined application of amino acid with micronutrient Fe, Zn, Mn in the presence of elemental sulphur significantly increased the sesame yield.

A field experiment was conducted by Parinaz *et al*. (2012) at the Research Farm of Faculty of Agriculture, Urmia University, Urmia-Iran in 2011. Treatments were cropping systems as main plot (high, medium, low input and ecological cropping systems) and the foliar application of micro-nutrients as sub plot. Results of ANOVA showed significant effect of cropping system and foliar application on the number of seeds head^{-1} and number of heads plant^{-1} and however significant interaction effect on 1000 seed weight, seed yield and biological yield. In conclusion, use of micronutrients, foliar application caused to improve the yield of safflower, especially in medium and low input systems.

A field study was undertaken by Ali *et al*. (2012) by the randomized complete block design in split plot arrangement with three replications was conducted in 2009 and 2010 seasons at the experimental farm, Agriculture Faculty, Sebha University, Libya to evaluate the effects of nitrogen and copper application on sesame seed and oil yields as well as nitrogen use efficiency under sandy soil conditions. The obtained results show significant effects of nitrogen, copper and their interaction in all studied traits in the two growing seasons. Foliar spray by copper nutrients enhancement significantly sesame yield and yield attributes as well as nitrogen use efficiency in both seasons in favor of high copper concentration (150 ppm).

Studies were conducted by Shehu (2014) during the 2005 and to assess the effects of Mn and Zn on the growth and yield characters of sesame (*Sesamum indicum* L.) in Mubi, Northern Guinea savannah zone of Nigeria. The experiment consisted of optimum rates of N, P, and K (75 kg N, 45 kg P_2O_5 and 22.5 kg K_2O ha^{-1}) combined with two rates of Zn (0.5 and 1 kg ha^{-1}) and two rates of Mn (0.5 and 1 kg ha^{-1}) which gave 8 treatments combinations replicated 3 times giving a total of 24 plots. Results shows that there were no significant effect of Mn and Zn on stem height, number of leaves, number of branches and capsules. The different grain yield responses were associated to their differences in Mn and Zn concentrations. Sesame seed yield increased by 2 and 5% from the application of 0.5 kg Mn ha^{-1} and 0.5 kg Zn ha^{-1}, respectively. Dry matter increased by 13.2 and 2% from 1 kg Mn ha^{-1} and 0.5 kg Zn ha^{-1} rates, respectively.

Shanmughapriya and Singaravel (2002) conducted a field experiment to study the effect of manganese and zinc on the yield and nutrient uptake of sesame in a vertisol soil. Seven treatments comprising control (recommended NPK) and foliar application of Zn, Mn were replicated three times in a completely randomized block design using sesame variety TMV 3. The results of the experiment revealed that the combined application of ZnSO4 + MnSO4 was significantly superior in enhancing the growth, yield and nutrient uptake of sesame.

Sarkar *et al.*(2007) showed that a small amount of nutrients, particularly Zn, Fe and Mn applied by foliar spraying increases significantly the yield of crops.

El-Fouly *et al.* (2011) reported that foliar spraying with suspension, micronutrient induced stimulatory effects on growth parameters and nutrients uptake either before or after the salinization treatments in wheat and it has been suggested that foliar spray with micro-nutrient may have a potential role for increasing wheat tolerance to salinity stress.

Ali *et al.* (2011) and Hussanin *et al.* (2012) showed that the foliar spray of zinc, boron and copper micronutrients has been reported to be equally or even more effective as soil application to overcome micronutrients deficiency in subsoil.

Boorboori *et al.* (2012) revealed that the foliar application lead to increase in grain yield components and protein percentage in seed; for instance wheat, maize, rice, barley and sorghum showed increase in yield components by application of micronutrients especially in wheat, improved yield and yield components were found after foliar application of zinc, boron and copper.

Abid *et al*. (2012) conducted a field experiment at B.Z. University, Multan. Number of tillers, number of grains panicle, 1000-grain weight and grain yield increased significantly with the application of Zn, Fe and Mn alone or in various combinations in rice.

Bameri *et al*. (2012) undertaken an experiment to study the effects of foliar micronutrient application on growth and yield of wheat during 2010 growing season. Different treatments of micronutrient foliar including, F1=Fe 2.5 lit/1000 form Iron sulphate, F2= Zn 2.5 lit/1000 form Zinc sulphate, F3= Mn 2.5 lit/1000 form Mn sulphate, F4= Fe+Mn 1.5 lit/1000, F5= Zn+Mn 1.5 lit/1000, F6= Fe+Zn 1.5 lit/1000, F7= Fe+Zn+Mn 1lit/1000, F8= Fe 4 lit/1000 form Iron sulphate and F9= control were applied. The results showed that micronutrient application significantly affected plant height, number of spike plant^{-1}, number of grain spike^{-1}, 1000-grain weight, grain yield, biological yield and harvest index. Application of Mn+Fe had the highest positive effect on yield components and grain yield. It could be concluded that micronutrient application had positive effect on wheat growth and yield.

Khalil *et al*. (2008) found that foliar spray of both amino acids and micronutrients together on onion plants could improve the onion yield and its components.

Moghadam *et al*. (2012) conducted a field experiment to study the response of wheat to foliar application of micronutrients. Treatments of these experiments were type of elements (Zinc, Boron and Copper) doses of foliar application (0, 1 and 2 lit/ha) and varieties (Gaskojen and Pishtaz). Type of elements was significant on the number of spikes per plant, grain per spike, grain in square meter, harvest index (HI%) and grain yield (kg/ha) but had no effect on thousand grain weigh. Boron and Zinc showed higher amounts in mentioned traits than Copper, although Boron in Chenaran, and Zinc in Mashhad were more effective. the number of spikes per plant, grain in square meter, and grain yield increased with raising in doses of foliar application.

Two field experiments were conducted by Masri and Hamza (2015) at the Desert Experimental Station of the Fac. of Agric., Cairo Univ. in Wadi El-Natroon, during 2012/2013 and 2013/2014 seasons to study the response of sugar beet yield and some of its attributes in three multigerm seed cultivars, *viz*. Heba, Ninagri and Halawa under drip irrigation in a split plot design to foliar application with zinc (Zn) + Manganese (Mn) + Iron (Fe) + Boron (B). The mixture of micronutrients was applied at three different concentrations, *viz.* 50 Zn + 50 Mn + 50 Fe + 500 B (C), 100 Zn + 100 Mn + 100 Fe + 1000 B (C) and 150 Zn + 150 Mn + 150 Fe + 1500 B (C3) in ppm/L, as well as, the control treatment of distilled water (C0). The results revealed that increasing micronutrients mixture from C0 level up to C3 level significantly increased root weight by 21.54% and 23.81%, root yield by 28.00% and 24.40% and sugar yield by 76.50% and 60.61% in the first and second seasons, respectively. The interaction between micronutrients and cultivars was significant for mean root weight, root yield, purity%, extractable sucrose% and sugar yield in both seasons.

Habib (2012) conducted a field experiment on clay-loam soil at Parsabad Moghan region, Iran during 2009 to 2010 to investigate the effect of foliar application of zinc, iron and urea on wheat yield and quality at filling stage. The experimental design was a randomized complete block design with three replication. The SAS software package was used to analyze all the data and means were separated by the least significant difference (LSD) test at $P < 0.01$. In this study, parameters such as wheat grain yield, 1000 kernel weight, ear length, plant height, seed Zn, Fe, Cu and Mn concentrations were evaluated. Results show that foliar application of Zn and Fe increased seed yield and its quality when compared with the control.

Chapter III

MATERIALS AND METHODS

The experiment was undertaken during Kharif-1 season, April to July 2013 to evaluate the response to different levels of nitrogen (N) and micronutrients (Fe, Zn, Mn, Cu) on performance of sesame variety BARI Til-4.

3.1 Experimental site

The experiment was carried out at Sher-e-Bangla Agricultural University Farm, Dhaka-1207, Bangladesh. It is located at $90^{0}22^{'}$ E longitude and 23°4l′ N latitude at an altitude of 8.6 meters above the sea level. The land belongs to Agro-ecological zone of Modhupur Tract, AEZ-28.

3.2 Climatic condition

The experimental area is under the sub-tropical climate that is characterized by less rainfall associated with moderately low temperature during rabi season, (October-March) and high temperature, high humidity and heavy rainfall with occasional gusty winds during kharif season (April-September).

3.3 Soil condition

The soil of experimental area situated to the Modhupur Tract (UNDP, 1988) under the AEZ no. 28 and Tejgoan soil series (FAO, 1988). The soil was sandy loam in texture with pH 5.47 to 5.63. The physical and chemical characteristics of the soil have been presented in Appendix I.

3.4 Materials

3.4.1 Seed

A pest and disease resistant and high yielding variety of sesame, BARI Til 4 developed by the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur was used as the experimental material. The seed was collected from the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Before sowing of the seed in the experimental plot, germination test was done in the laboratory and results of percentage of germination was over 90%.

3.4.2 Fertilizers

The recommended doses of Triple super phosphate (TSP) as a source of phosphorus (P), Muriate of Potash (MP) as a source of Potash (K), Gypsum as a source of Sulpher (S) and Boric acid as a source of Boron (B) were added to the soil of experimental field along with different levels of Nitrogen (N) in the form of Urea and Micronutrient in the form of Okozym according to the treatment of the experiment.

3.5 Methods

3.5.1 Treatments

Factor A: 3 levels of N (kgha^{-1}) as a source of Urea	**Factor B: 4 levels of micronutrients (ppm) as a source of Okozym**
N_0 = Without N	M_0 = Without micronutrients
N_1 = 60 kg Nha^{-1}	M_1 = 50 ppm micronutrients
N_2 = 120 kg Nha^{-1}	M_2 = 100 ppm micronutrients
	M_3= 150 ppm micronutrients

3.5.2 Treatment combinations

There were 12 treatment combinations of different N and Micronutrient doses used in the experiment under as following:

1. N_0M_0
2. N_0M_1
3. N_0M_2
4. N_0M_3
5. N_1M_0
6. N_1M_1
7. N_1M_2
8. N_1M_3
9. N_2M_0
10. N_2M_1
11. N_2M_2
12. N_2M_3

3.5.3 Design and layout

The experiment consisted of 12 treatment combinations and was laid out in a Randomized Complete Block Design (RCBD) with 3 replications. The total plot number was 12 × 3 = 36. The unit plot size was 2 m × 1.5 m = 3 m^2. The distance between blocks was 1 m and distance between plots was 0.5 m and plant spacing was 30 cm × 5 cm. The layout of the experiment is presented in Appendix II.

3.5.4 Land preparation

The land was ploughed with a rotary plough and power tiller for four times. Ploughed soil was then brought into desirable fine tilth and leveled by laddering. The weeds were clean properly. The final ploughing and land preparation were done on 2 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. In addition, irrigation and drainage channels were made around the plot.

3.5.5 Fertilization

In this experiment fertilizers were used according to Bangladesh Agricultural Research Institute (BARI) Information which is given under as follows:

Name of Nutrients	**Name of Fertilizers**	**Rate of Application (kgha^{-1})**
Nitrogen (N)	Urea	As per treatment
Phosphorus (P)	Triple Super Phosphate	140
Potash (K)	Muriate of Potash	45
Sulpher (S)	Gypsum	105
Boron (B)	Boric acid	10

The amounts of fertilizer as per treatment in the forms of urea, triple super phosphate, muriate of potash, gypsum and boric acid required plot^{-1} were calculated. The triple super phosphate, muriate of potash, gypsum and boric acid was applied during final land preparation. Half of urea was applied in each experimental unit 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).

3.5.6 Micronutrients

In this experiment micronutrients Iron, Zinc, Manganese and Copper as a commercial form of Okozym was applied through foliar spray in each experimental unit plot according to treatment. It was applied two times during 20 days after sowing (DAS) and 40 days after sowing (DAS).

3.5.7 Sowing of seed

Sowing was done on 14 April, 2013 in rows 30 cm apart. Seeds were sown continuously in rows at a rate of 7.5 kgha^{-1}. After sowing, the seeds were covered with the soil and slightly pressed by hand, and applied little amount water for better germination of seeds.

3.5.8 Thinning and weeding

The optimum plant population, 60 plants m^{-2} was maintained by thinning excess plant at 15 DAS. The plant to plant distance was maintained as 5 cm in the row. One weeding with khurpi was given on 25 DAS.

3.5.9 Irrigation

Two irrigations were given as plants required. First irrigation was given immediate after topdressing and second irrigation were applied 60 DAS with watering can. After irrigation when the plots were in zoe condition, spading was done uniformly and carefully to conserve the soil moisture for proper growth and development of plants.

3.5.10 Crop protection

As per preventive measure seed was treated with a fungicide Vitavex 200 @ 2 g kg^{-1} before showing. As a preventive measure of fungal disease, Diathen M 45 EC @ 2 ml litre $^{-1}$ of water was applied twice first at 25 DAS and second at 50 DAS.

3.5.11 General observation of the experimental field

The field was investigated frequently in order to reduce losses with weeds competition and insects infestation and diseases infection.

3.5.12 Harvesting and threshing

Previous randomly selected ten plants, those were considered for the growth analysis was collected from each plot to analyze the yield and yield contributing characters. Rest of the crops was harvested when 80% of the pod in terminal raceme turned grayish in color. After collecting sample plants, harvesting was started on 12 July and completed on 17 July 2013. The harvested crops were tied into bundles and carried to the threshing floor. The crop bundles were sun dried by spreading those on the threshing floor. The seeds were separated from the plants by beating the bundles with bamboo sticks.

3.5.13 Drying and weighing

The seeds thus collected were dried in the sun for couple of days. Dried seeds of each plot was weighted and subsequently converted into yield tha^{-1}.

3.6. Data collection

Ten (10) plants from each plot were selected as random and were tagged for the data collection. Some data were collected from 30 days after sowing with 10 days interval and some data were collected at harvesting stage. The sample plants were uprooted prior to harvest and dried properly in the sun. The seed yield $plot^{-1}$ was recorded after cleaning and drying those properly in the sun. Data were collected on the following parameters:

1. Plant height (cm)
2. No. of leaves $plant^{-1}$
3. No. of branches $plant^{-1}$
4. Fresh and dry weight of shoot (g)
5. Fresh and dry weight of root (g)
6. No. of pod $plant^{-1}$
7. Pod length (mm)
8. Pod diameter (mm)
9. Seed weight $plant^{-1}$ (g)
10. Seed weight $plot^{-1}$ (g)
11. Weight of 1000 seeds (g)
12. Yield (tha^{-1})

3.6.1 Plant height (cm)

Plant height was measured three times at 10 days interval such as 30, 40 and 50 DAS. The height of the plant was measured by scale considering the distance from the soil surface to the tip of the randomly ten selected plants and mean value was calculated for each treatment.

3.6.2 Number of leaves plant^{-1}

Number of leaves plant^{-1} was counted three times at 10 days interval such as 30, 40, 50 DAS. Mean value of data were calculated and recorded.

3.6.3 Number of branches plant^{-1}

The number of primary branches plant^{-1} was counted three times at 10 days interval such as 30, 40 and 50 DAS of sesame plants. Mean value of data were calculated and recorded.

3.6.4 Shoot fresh and dry weight (g)

The shoot fresh weight of ten plants was taken by weight balance on fresh condition. After sun drying of fresh shoot, it was kept in oven for 72 hours at 80^{o}c for each treatment then dry weight was taken by balance. Mean of shoot fresh and dry weight was calculated and expressed in g.

3.6.5 Root fresh and dry weight (g)

The root fresh weight of ten plants was taken by weight balance on fresh condition after removing the soil properly from root. After sun drying of fresh root, it was kept in oven for 72 hours at 80^{o}c for each treatment then dry weight was taken by balance. Mean weight of fresh root and dry root was calculated and expressed in g.

3.6.6 Number of pod plant^{-1}

The number of pods of main inflorescence from ten plants were counted and calculated as plant^{-1} basis.

3.6.7 Pod length (mm)

Pod length was taken by Slide calipers from ten plants for each treatment. The mean length of pod of sesame was calculated and expressed in mm.

3.6.8 Pod diameters (mm)

Pod diameter was taken by Slide calipers from ten plants for each treatment. The mean diameter of pod of sesame was calculated and expressed in mm.

3.6.9 Seed weight plant^{-1} (g)

Total pod were collected from each of sesame plant. The pods were cut, threshed and dried. The dried seeds were weighed. Then the weighed seed yield was converted to g.

3.6.10 Seed weight plot^{-1} (g)

Total sesame plants were collected from each plot. The plants were cut, threshed and dried. The dried seeds were weighed. Then the weighed seed yield was converted to g.

3.6.11 Thousand seed weight (g)

A composite sample was taken from the yield of ten plants. The thousand seeds of each plot were counted and weighed with a digital electric balance. The thousand seed weight was recorded in gram (g).

3.6.12 Yield (tha^{-1})

After threshing, cleaning and drying, total seed from harvested area were recorded and was converted to tha^{-1}.

3.7 Data analysis

The data collected on different parameters were statistically analyzed to obtain the level of significance using the MSTAT computer package program developed by Russell (1986). The mean differences were tested through, least significant difference (LSD) method.

Chapter IV

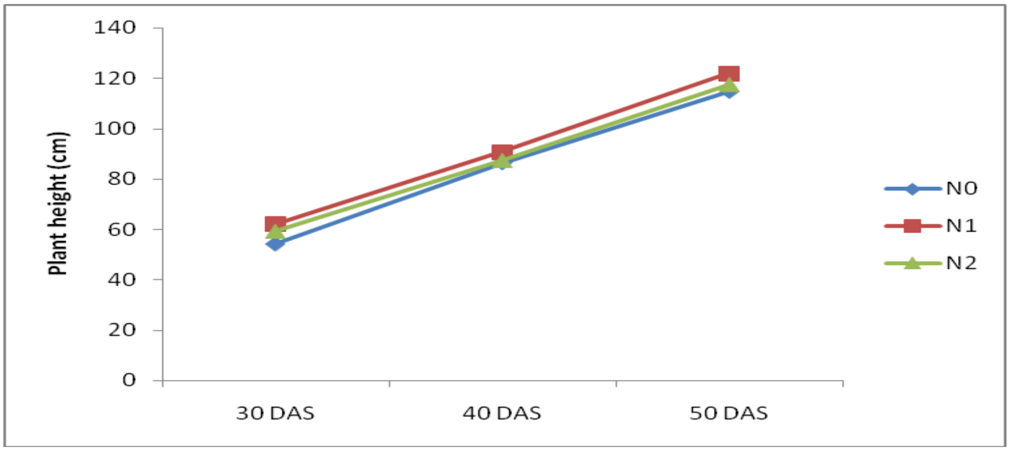
RESULTS AND DISCUSSION

The results obtained with different levels of nitrogen (N) and micronutrient and their combinations are presented and discussed in this chapter. Data about morphological parameters, yield contributing characters and seed yield of sesame have been presented in both Tables and Figures and analyzes of variance and corresponding degrees of freedom have been shown in Appendix.

4.1 Plant height (cm)

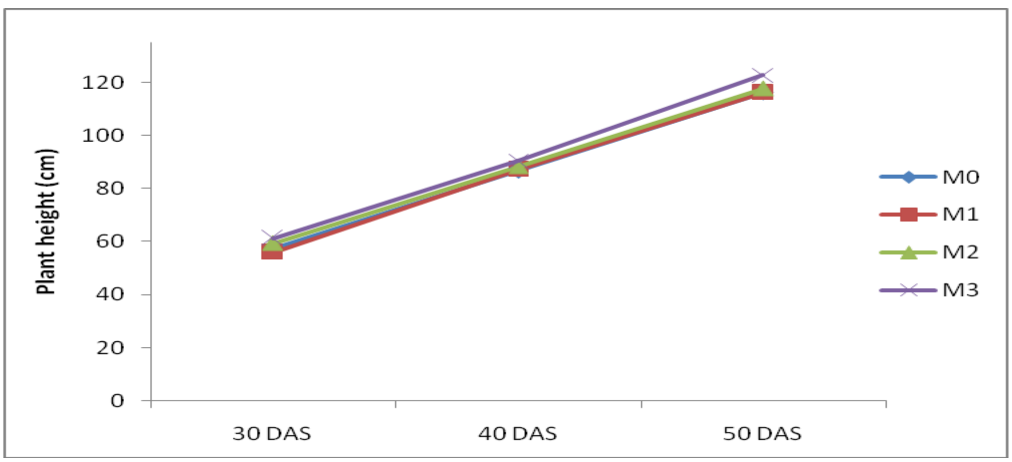
Nitrogen had stimulatory effect on plant height throughout the growth period. Different levels of nitrogen (N) fertilizer showed significant effect on plant height of sesame at 30 days after sowing (DAS), 40 DAS and 50 DAS (Fig. 1 and Appendix III). At 30 DAS, the highest plant height (62.01 cm) was 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 N/ha. 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 $kgha^{-1}$ N) which was similar to obsereved by Pathak *et al*. (2002), Patra (2001) and Alam (2002).

Micronutrient had significant effect on plant height of sesame at 30 DAS, 40 DAS and 50 DAS (Fig. 2 and Appendix III). At 30 DAS, the highest plant height (61.24 cm) was observed from the $M_{3,}$ 150 ppm micronutrient and the lowest (56.00 cm) was observed from M_1, 50 ppm micronutrient which was statistically similar with M_0 (57.46 cm), 0 ppm micronutrient. At 40 DAS, the highest plant height (90.47 cm) was observed from the $M_{3,}$150 ppm micronutrient 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 micronutrient. 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 applied as urea ,
N_2– 120 $kgha^{-1}$ nitrogen applied as urea, DAS (days after sowing)

Fig. 1. Effect of different levels of nitrogen at different days after sowing DAS on the height of sesame plant



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

Fig. 2. Effect of different levels of micronutrients at different days after sowing (DAS) on the height of sesame plant

Table 1. Combined effect of nitrogen and micronutrient on the plant height of sesame

Treatment	Plant height (cm)		
	30 DAS	40 DAS	50 DAS
$N_0 M_0$	53.59	84.46 d	111.66 g
$N_0 M_1$	53.36	85.40 cd	115.33 ef
$N_0 M_2$	54.00	87.60 b	114.00 f
$N_0 M_3$	56.00	88.20 b	117.96 d
$N_1 M_0$	60.13	91.13 a	120.26 c
$N_1 M_1$	57.93	88.40 b	117.96 d
$N_1 M_2$	64.00	90.66 a	122.80 b
$N_1 M_3$	66.00	92.53 a	127.00 a
$N_2 M_0$	58.66	84.26 d	116.2 e
$N_2 M_1$	56.70	87.83 b	115.33 ef
$N_2 M_2$	59.90	86.73 bc	116.00 e
$N_2 M_3$	61.73	90.70 a	123.00 b
LSD (0.05)	2.85	2.19	1.67
Significant level	NS	**	**
CV (%)	2.84%	1.45%	0.83%

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

N_2– 120 kgha^{-1} nitrogen applied as urea, DAS (days after sowing)

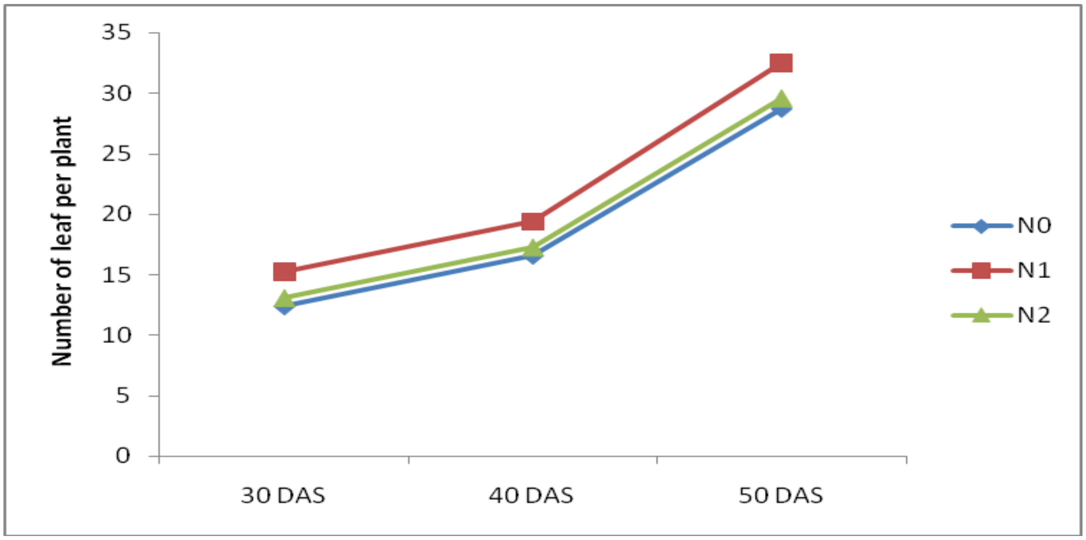
M_0 – Without micronutrient, M_1 – 50 ppm micronutrient
M_2 – 100 ppm micronutrient, M_3 –150 ppm micronutrient

CV = Co-efficient of variance, LSD = Least significant Difference, NS=Non significant,
** = Significant at 1% level

Interaction of nitrogen fertilizer doses and micronutrient doses showed no significant variation on plant height of sesame at 30 DAS but significant on 40 and 50 DAS (Table 1 and Appendix III). At 30 DAS, the highest plant height (66.00 cm) was observed from the $N_1M_{3,}$ 60 kg N/ha with 150 ppm micronutrient treatment and the lowest (53.36 cm) was observed from $N_0M_{1,}$ 0 kg Nha^{-1} with 50 ppm micronutrient treatment which was statistically similar with N_0M_0 (53.59 cm) and N_0M_2 (54.00 cm). At 40 DAS, the highest plant height (92.53 cm) was observed from the N_1M_3 treatment and the lowest (84.26 cm) was observed from N_2M_0 treatment which was statistically similar with N_0M_0 (84.46 cm). At 50 DAS, the highest plant height (127.0 cm) was observed from the N_1M_3 treatment and the lowest (111.66 cm) was observed from N_0M_0 treatment. All together these results indicate that plant height increases with the combined use of N and micronutrients.

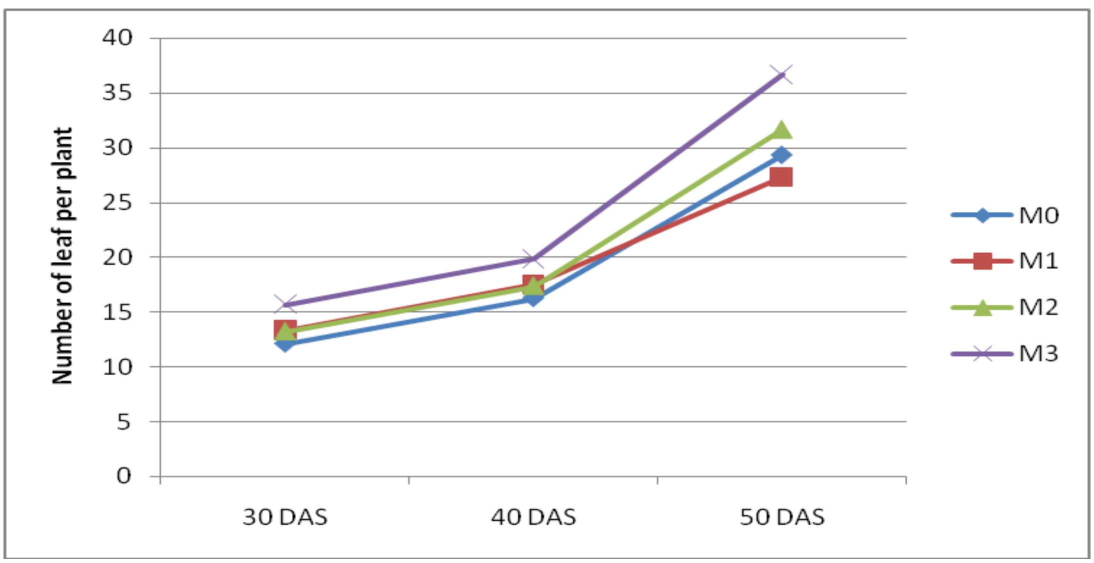
4.2 Number of leaves plant^{-1}

Nitrogen fertilizers had significant effect on number of leaves plant^{-1} of sesame at 30, 40 and 50 DAS (Fig. 3 and Appendix IV). 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 nitrogen, N_1 – 60 kgha^{-1} nitrogen applied as urea ,
N_2– 120 kgha^{-1} nitrogen applied as urea, DAS (days after sowing)

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



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

Fig. 4. Effect of different levels of micronutrients 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 IV). 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) .

The combined effect of nitrogen fertilizer and micronutrient doses showed significant variation on number of leaves plant^{-1} of sesame at 30, 40 and 50 DAS (Table 2 and Appendix IV). At 30 DAS, the highest number of leaves plant^{-1} (17.33) was observed from the N_1M_3 treatment and the lowest (10.33) was observed from N_0M_0 treatment which was statistically similar with N_2M_2 (11.33). At 40 DAS, the highest number of leaves plant $^{-1}$ (21.50) was observed from the N_1M_3 treatment and the lowest (14.50) was observed from N_0M_0 treatment which was statistically similar with N_2 M_2 (15.50). At 50 DAS, the highest number of leaves plant^{-1} (40.33) was observed from the N_1M_3 treatment whereas the lowest (22.33) was observed from N_2M_1 treatment which was statistically similar with N_0M_1 and N_1M_1 treatment.

Table 2. Combined effect of nitrogen and micronutrient on the leaf number of sesame plant^{-1} at different days after sowing (DAS)

Treatment	Number of leaves plant^{-1}		
	30 DAS	40 DAS	50DAS
$N_0 M_0$	10.33 h	14.50 h	25.00 e
$N_0 M_1$	12.33 fg	16.50 fg	24.00 ef
$N_0 M_2$	12.66 ef	16.83 ef	30.66 d
$N_0 M_3$	14.33 cd	18.50 cd	35.00 b
$N_1 M_0$	13.66 de	17.83 de	32.33 cd
$N_1 M_1$	14.33 cd	18.50 cd	23.66 ef
$N_1 M_2$	15.66 b	19.83 b	33.66 bc
$N_1 M_3$	17.33 a	21.50 a	40.33 a
$N_2 M_0$	12.33 fg	16.50 fg	30.66 d
$N_2 M_1$	13.33 def	17.50 def	22.33 f
$N_2 M_2$	11.33 gh	15.50 gh	30.66 d
$N_2 M_3$	15.33 bc	19.50 bc	34.66 b
LSD (0.05)	1.15	1.17	2.127
Significant level	**	**	**
CV (%)	4.96%	3.79%	4.10%

N_0 – No nitrogen applied, N_1 – 60 kgha^{-1} nitrogen applied as urea ,
N_2– 120 kgha^{-1} nitrogen applied as urea, DAS (days after sowing)

M_0 – Without micronutrient, M_1 – 50 ppm micronutrient
M_2 – 100 ppm micronutrient, M_3 –150 ppm micronutrient

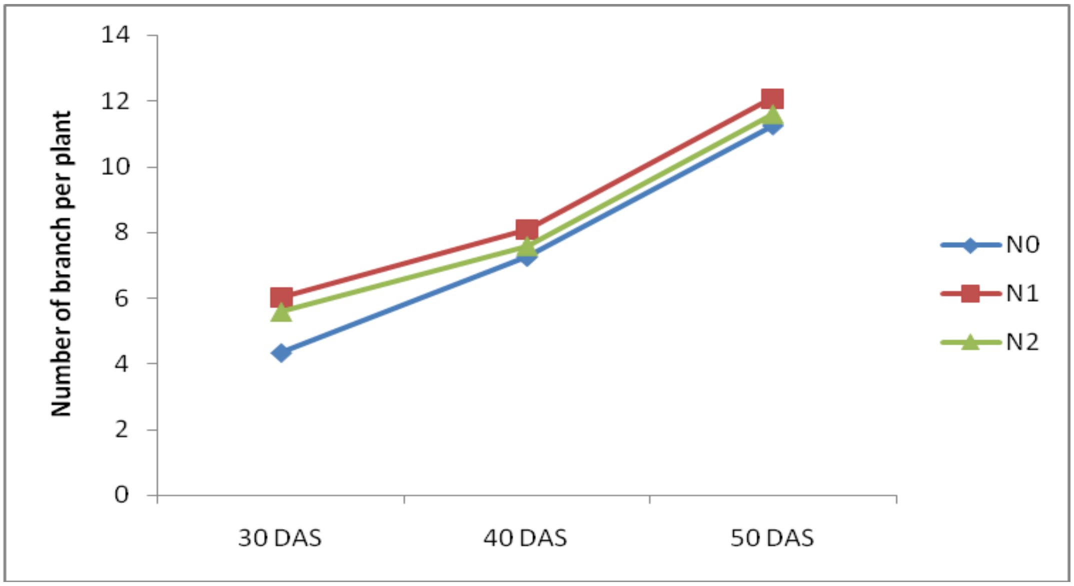
CV = Co-efficient of variance,
LSD = Least significant Difference
** = Significant at 1% level

4.3 Number of branches plant^{-1}

Figure 5 and Appendix V 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).

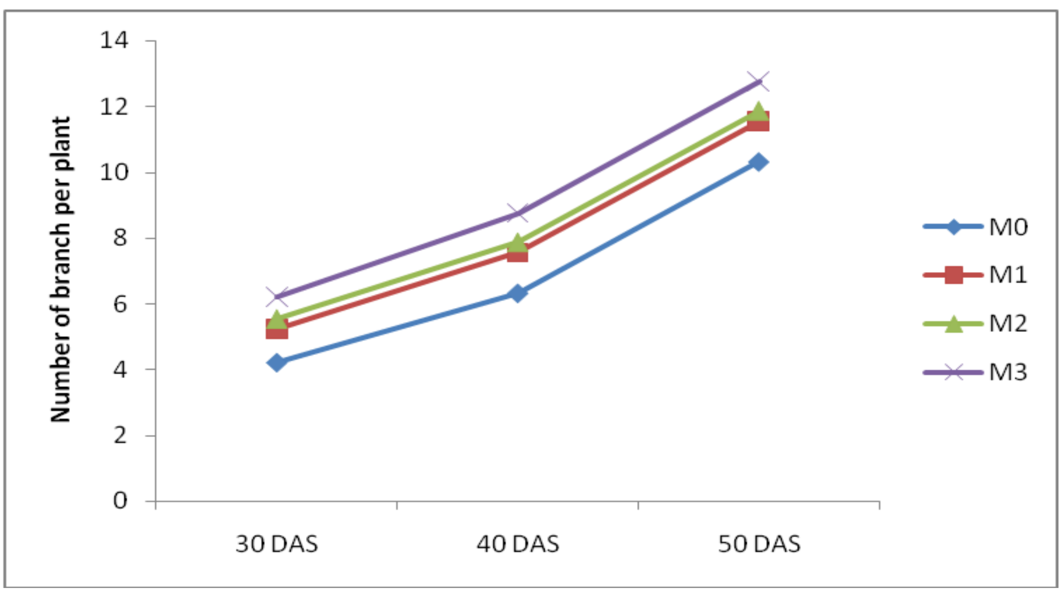
Application of micronutrient had showed significant effect on number of branches plant^{-1} of sesame at 30, 40 and 50 DAS (Fig. 6 and Appendix V). At 30 DAS the highest number of branches plant $^{-1}$ (6.22) was observed from the M_3 and the lowest (4.22) was observed from M_0. At 40 DAS, the highest 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.

Nitrogen fertilizer and micronutrient doses showed insignificant variation on number of branches plant^{-1} of sesame at 30, 40 and 50 DAS (Table 3 and Appendix V). At 30 DAS, the highest number of branches plant^{-1} (6.66) was observed from the N_1M_3 treatment which was statistically similar with N_1M_2 (6.33), N_2M_2 (6.00) and N_2M_3 (6.33) and the lowest (2.66) was observed from N_0M_0 treatment.



N_0 – Without nitrogen, N_1 – 60 kgha^{-1} nitrogen applied as urea ,
N_2– 120 kgha^{-1} nitrogen applied as urea, DAS = Days after sowing

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



M_0 – Without micronutrient, M_1 – 50 ppm micronutrient
M_2 – 100 ppm micronutrient, M_3 –150 ppm micronutrient
DAS (Days after sowing)

Fig. 6. Effect of different levels of micronutrients at different DAS on the number of branches of sesame plant

Table 3. Combined effect of nitrogen and micronutrient on the number of branches of sesame plant at different days after sowing (DAS)

Treatment	Number of branches plant^{-1}		
	30 DAS	40 DAS	50DAS
$N_0 M_0$	2.66	5.66	9.66
$N_0 M_1$	4.66	7.66	11.66
$N_0 M_2$	4.33	7.33	11.33
$N_0 M_3$	5.66	8.33	12.33
$N_1 M_0$	5.33	6.66	10.66
$N_1 M_1$	5.66	7.66	11.66
$N_1 M_2$	6.33	8.33	12.33
$N_1 M_3$	6.66	9.66	13.66
$N_2 M_0$	4.66	6.66	10.66
$N_2 M_1$	5.33	7.33	11.33
$N_2 M_2$	6.00	8.00	12.00
$N_2 M_3$	6.33	8.33	12.33
LSD (0.05)	1.10	1.15	1.11
Significant level	NS	NS	NS
CV (%)	12.17%	8.45%	5.55%

N_0 – No nitrogen applied, N_1 – 60 kgha^{-1} nitrogen applied as urea ,
N_2– 120 kgha^{-1} nitrogen applied as urea, DAS (Days after sowing)

M_0 – Without micronutrient, M_1 – 50 ppm micronutrient
M_2 – 100 ppm micronutrient, M_3 –150 ppm micronutrient

CV = Co-efficient of variance, LSD = Least significant Difference

NS= Non- significant

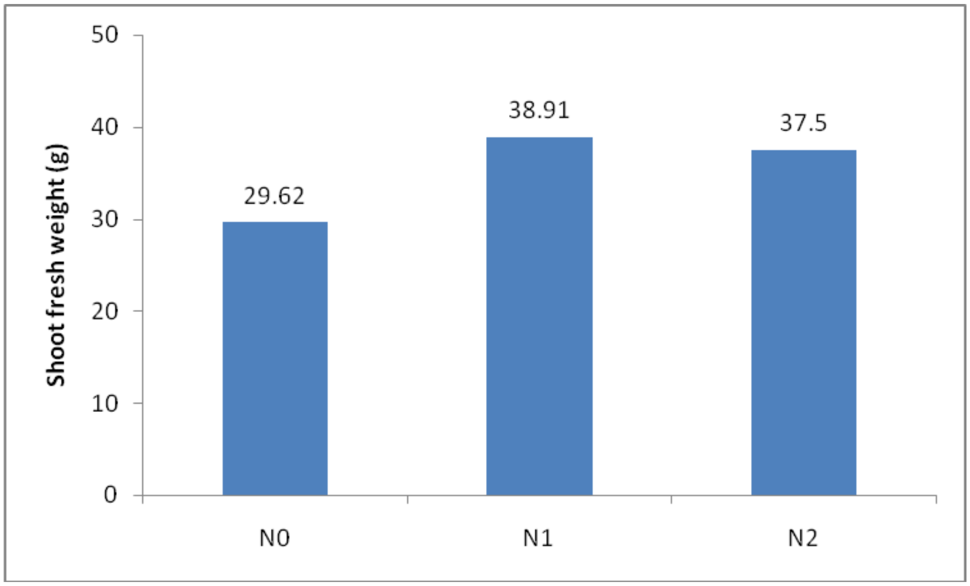
At 40 DAS, the highest number of branches plant^{-1} (9.66) was observed from the N_1M_3 treatment and the lowest (5.66) was observed from N_0M_0 treatment. At 50 DAS, the highest number of branches plant^{-1} (13.66) was observed from the N_1M_3 treatment and the lowest (9.66) was observed from N_0M_0 treatment. The lowest number of branches plant^{-1} at different DAS was found from $N_0M_{0,}$ 0 kg Nha^{-1} with 0 ppm micronutrient and highest from N_1M_3, 60 kg Nha^{-1} with 150 ppm micronutrient showed that branches increased with application of N and micronutrients.

4.4 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 Appendix VI). 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 and Appendix VI 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).

The shoot fresh weight of sesame showed a significant variation due to the combined application of nitrogen fertilizer (N) and micronutrients (Fe, Zn, Mn, Cu) doses. (Table 4 and Appendix VI). The maximum fresh shoot weight (51.00 g) was recorded for the $N_1M_{3,}$ 60 kg Nha^{-1} with 150 ppm micronutrients treatment and the lowest (23.08 g) was observed from $N_0M_{0,}$ 0 kg Nha^{-1} with 0 ppm micronutrients treatment combination.



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 micronutrient, M_1 – 50 ppm micronutrient
M_2 – 100 ppm micronutrient, M_3 –150 ppm micronutrient

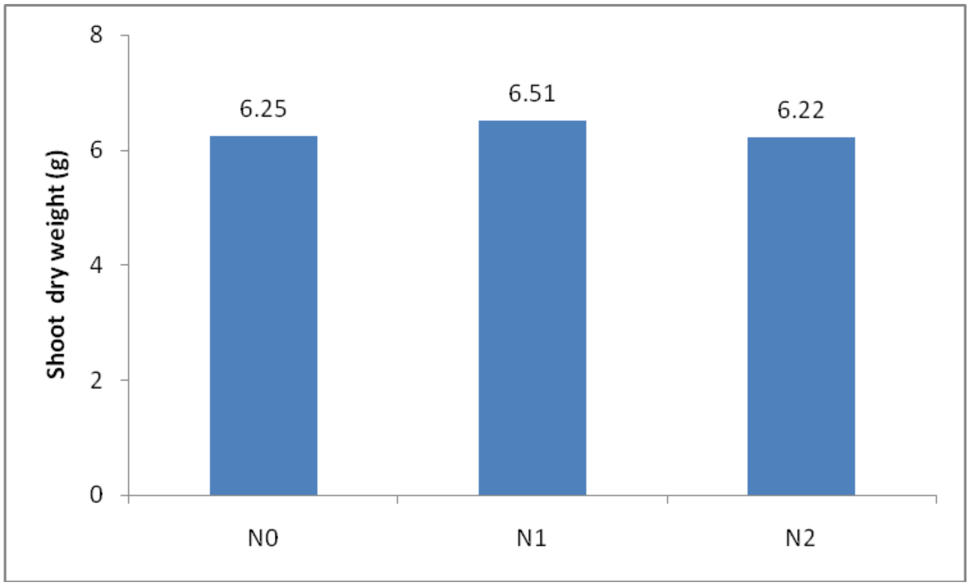
Fig. 8. Effect of different levels of micronutrients on shoot fresh weight of sesame plant

4.5 Shoot dry weight (g)

Application of different levels of nitrogen fertilizer had significant influence on dry shoot weight (g) of sesame (Fig. 9 and Appendix VI). 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 Appendix VI). 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).

Table 4 and App. VI presented the combined interaction of nitrogen fertilizer and micronutrient doses had significant effect on dry shoot weight of sesame. The maximum dry shoot weight (8.90 g) was recorded for the N_1M_3 treatment and the lowest (4.91 g) was observed from N_2M_0 treatment. The results revealed that as fresh weight of shoot increased with application of 60 kg Nha^{-1} and 150 ppm micronutrient as consistent to dry weight.



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 micronutrient, M_1 – 50 ppm micronutrient
M_2 – 100 ppm micronutrient, M_3 –150 ppm micronutrient

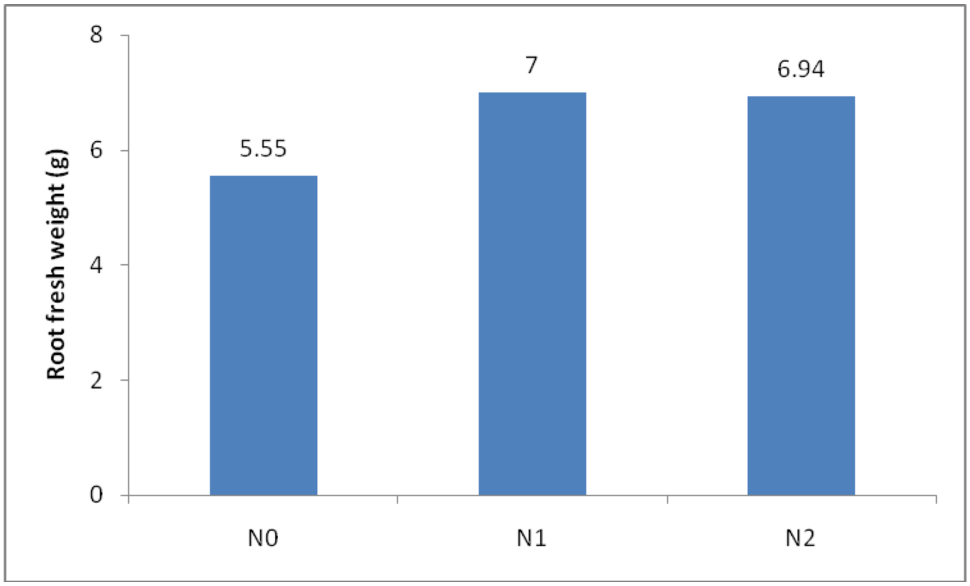
Fig. 10. Effect of different levels of micronutrients on the shoot dry weight of sesame plant

4.6 Root fresh weight (g)

The N showed (Fig. 11 and Appendix VI) 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 and Appendix VI). 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.

The combined effect of different levels of nitrogen fertilizer and micronutrient concentrations showed significant variation on root fresh weight of sesame (Table 4 and Appendix VI). The maximum fresh root weight (9.50 g) was recorded for the N_1M_3 (60 kg Nha^{-1} with 150 ppm micronutrient) treatment and the lowest (4.91 g) was observed from N_0M_0 (without N and micronutrient) treatment. Here N_1M_3 combination showed the best result at 60 $kgha^{-1}$ N with 150 ppm micronutrient.



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 micronutrient, M_1 – 50 ppm micronutrient
M_2 – 100 ppm micronutrient, M_3 –150 ppm micronutrient

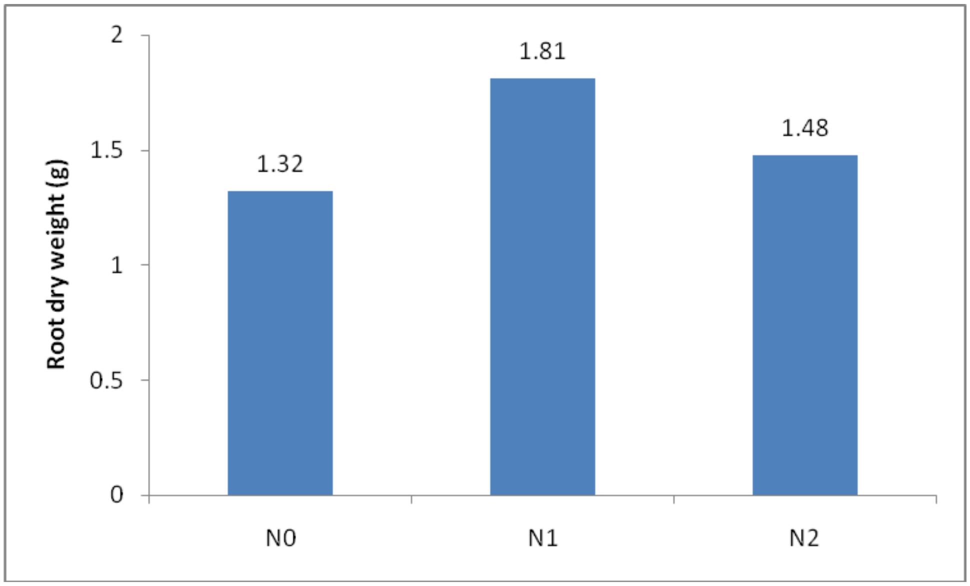
Fig. 12. Effect of different levels of micronutrients on root fresh weight of sesame plant

4.7 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 Appendix VI). 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 Appendix VI). 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.

The interaction of nitrogen fertilizer and micronutrient doses showed significant variation on dry root weight of sesame (Table 4 and Appendix VI). The maximum dry root weight (2.80 g) was recorded for the N_1M_3 (60 kg Nha^{-1} with 150 ppm micronutrient) and the lowest (0.88 g) was observed from N_0M_0 (without nitrogen and micronutrient) treatment combination. These results are in consistent with root fresh weight (Table 4).



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 micronutrient, M_1 – 50 ppm micronutrient
M_2 – 100 ppm micronutrient, M_3 –150 ppm micronutrient

Fig. 14. Effect of different levels of micronutrient on dry root weight of sesame plant

Table 4. Combined effect of nitrogen and micronutrient on the fresh and dry weights of shoot and root of sesame plant

Treatment	Shoot fresh weight (g)	Shoot dry weight (g)	Root fresh weight (g)	Root dry weight (g)
$N_0 M_0$	23.08 h	6.75 bc	4.91 e	0.88 h
$N_0 M_1$	24.75 gh	5.49 ef	4.95 e	1.13 ef
$N_0 M_2$	31.66 e	6.10 cde	5.50 de	1.36 d
$N_0 M_3$	39.00 d	6.66 bcd	6.86 c	1.90 c
$N_1 M_0$	30.00 ef	5.33 ef	5.40 de	1.02 g
$N_1 M_1$	29.00 ef	4.97 f	5.16 de	1.03 fg
$N_1 M_2$	45.66 bc	6.83 bc	7.94 b	2.40 b
$N_1 M_3$	51.00 a	8.90 a	9.50 a	2.80 a
$N_2 M_0$	27.33 fg	4.91 f	5.66 d	1.20 e
$N_2 M_1$	31.66 e	5.66 def	6.66 c	1.40 d
$N_2 M_2$	44.00 c	6.63 cd	7.23 c	1.43 d
$N_2 M_3$	47.00 b	7.66 b	8.20 b	1.90 c
LSD (0.05)	2.74	1.00	0.64	0.10
Significant level	**	**	**	**
CV (%)	4.52%	9.22%	5.77%	4.21%

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

M_0 – Without micronutrient, M_1 – 50 ppm micronutrient
M_2 – 100 ppm micronutrient, M_3 –150 ppm micronutrient

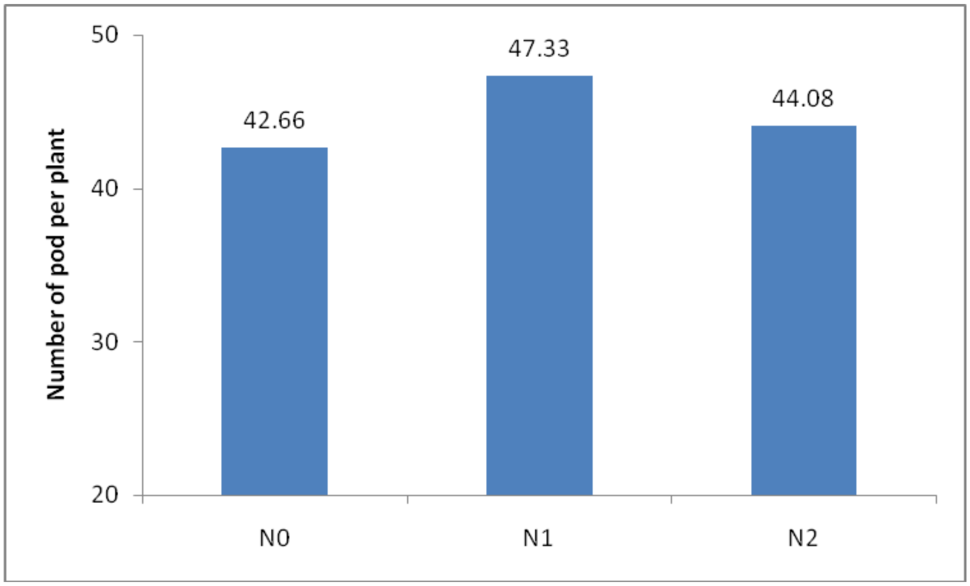
CV = Co-efficient of variance ,LSD = Least significant Difference, ** = Significant at 1% level

4.8 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 Appendix VII).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).

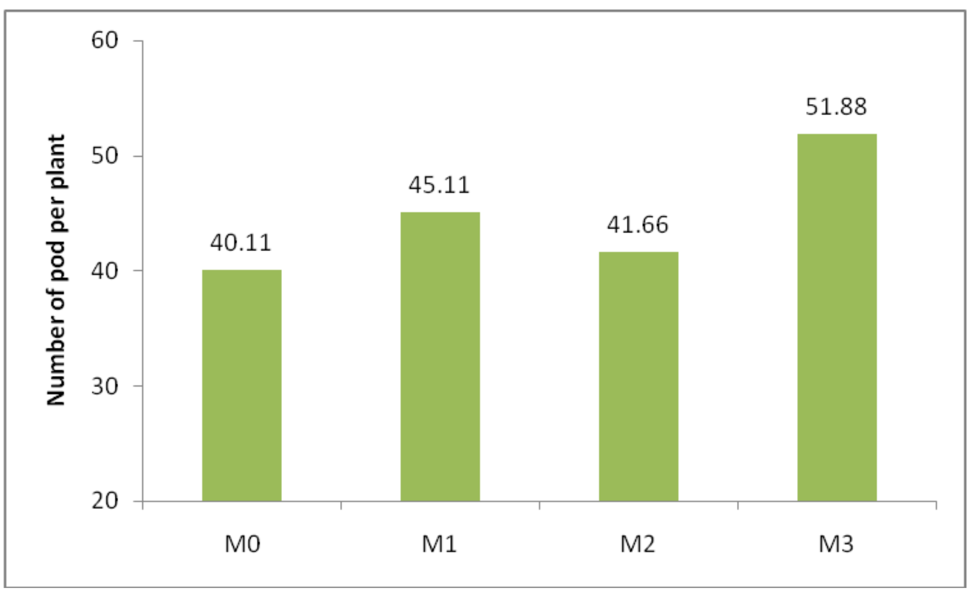
As N different concentrations of micronutrients had significant variation in the number of pods plant^{-1} of sesame (Fig. 16 and Appendix VII).The highest number of pods plant^{-1} (51.88) was recorded for the N_3 (150 ppm micronutrient) and the lowest (40.11) was observed from M_0 which was statistically 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).

The number of pods plant^{-1} of sesame significantly influenced by the combined use of nitrogen fertilizer and micronutrient (Table 5 and Appendix VII). The minimum number of pods plant^{-1} (33.33) was observed from control or N_0M_0 (without nitrogen and micronutrients) treatment combination and maximum number of pod plant^{-1} (58.00) was recorded for the N_1M_3 (60 kg Nha^{-1} and 150 ppm micronutrient) treatment combination. Here without nitrogen and micronutrient showed the lowest result and the combination of 60 kgha^{-1} N with 150 ppm micronutrient resulted best in increasing of the pod number in sesame plant. In this study, combined application of N and micronutrients produced higher number of pod plant^{-1} as a seed yield contributing character than single application of N and micronutrients (Table 5).



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 micronutrient, M_1 – 50 ppm micronutrient
M_2 – 100 ppm micronutrient, M_3 –150 ppm micronutrient

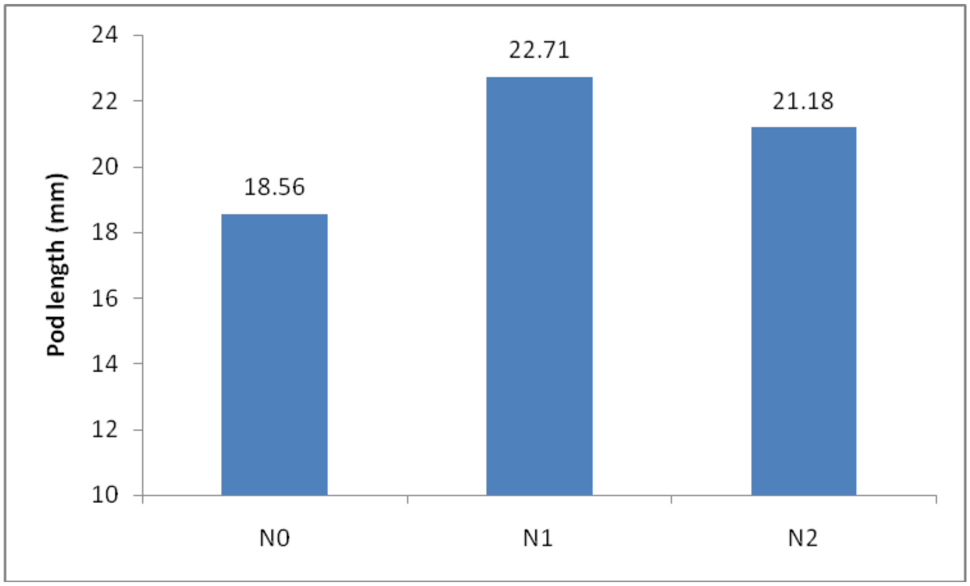
Fig. 16. Effect of different levels of micronutrients on number pod plant^{-1} of sesame

4.10 Pod length (mm):

As consistent of fruit diameter nitrogen fertilizer doses had significant influenced on fruit length (mm) of sesame (Fig. 17 and Appendix VII). 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.

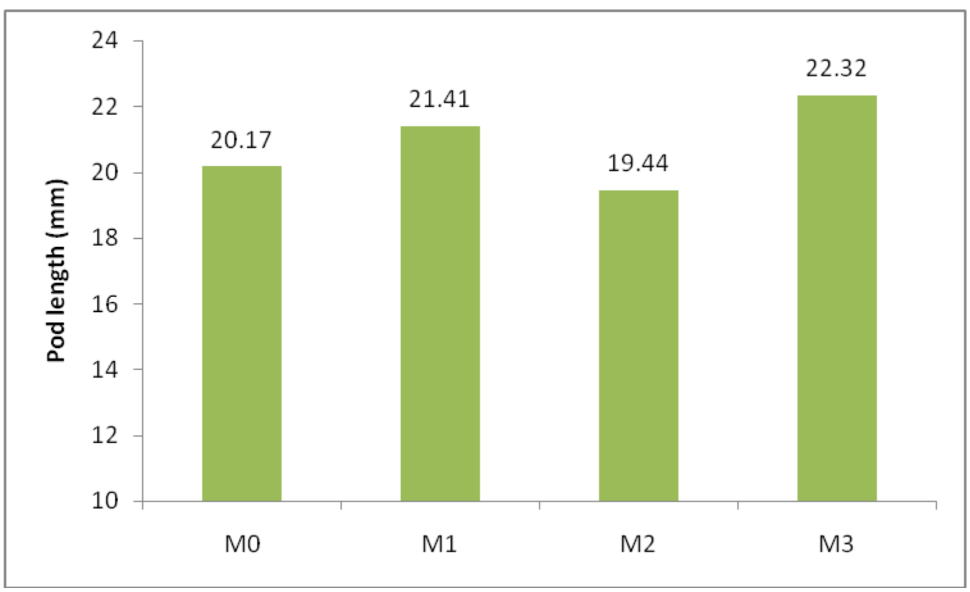
Different concentrations of micronutrient had significant influence on pod length (mm) of sesame (Fig. 18 and Appendix VII). The highest pod length (22.32 mm) was recorded from M_3 treatment while the lowest result (19.44 mm) was recorded from M_2. Here results showed that micronutrient increased ear 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.

The combined effect of nitrogen fertilizer and micronutrient was significant to pod length (mm) of sesame (Table 5 and Appendix VII). The maximum pod length (24.70 mm) was recorded for the N_1M_3 (60 kg Nha^{-1} and 150 ppm micronutrient) treatment combination and the lowest (17.28 mm) was observed from N_0M_0 (without N and micronutrient) treatment combination. Results showed that best combination (N_1M_3) of increased pod length at 60 $kgha^{-1}$ nitrogen with 150 ppm micronutrient as consistent with pod diameter in the (Table 5).



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 micronutrient, M_1 – 50 ppm micronutrient
M_2 – 100 ppm micronutrient, M_3 –150 ppm micronutrient

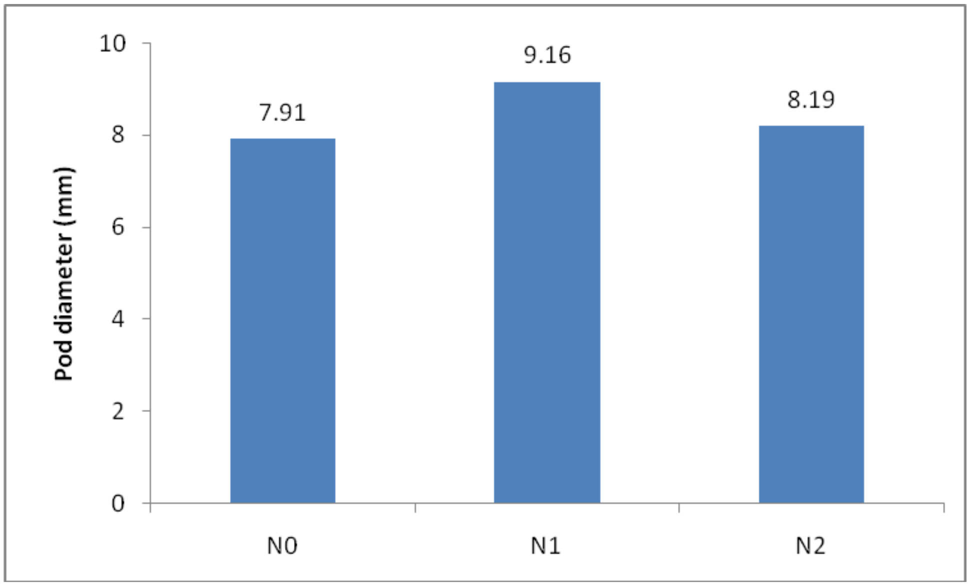
Fig. 18. Effect of different levels of micronutrients on the pod length of sesame

4.9 Pod diameter (mm)

Nitrogen fertilizer doses had significant influence on fruit diameter (mm) of sesame (Fig. 19 and Appendix VII). 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 and Appendix VII). 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).

Fruit diameter (mm) was observed significant variation due to combined application of different levels of nitrogen fertilizer and micronutrient on sesame (Table 5 and Appendix VII). The maximum fruit diameter (12.00 mm) was recorded for the N_1M_3 treatment combination and the lowest (7.26 cm) was observed from N_2M_0 treatment combination which was statistically similar with N_0M_0 (7.56 cm), N_2M_1 (7.7.66) and N_0M_2 (7.42). Here best combination resulted of increased fruit diameter (mm) from N_1M_3 at 60 kgha^{-1} of nitrogen and 150 ppm of micronutrient treatment combination.



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 micronutrient, M_1 – 50 ppm micronutrient
M_2 – 100 ppm micronutrient, M_3 –150 ppm micronutrient

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

Table 5. Combined effect of nitrogen and micronutrients on the pod number plant^{-1}, pod diameter and pod length of sesame plant

Treatment	Number of pods plant^{-1}	Pod length (mm)	Pod diameter (mm)
$N_0 M_0$	33.33 g	17.28 g	7.56 fg
$N_0 M_1$	43.33 cdef	18.38 f	7.99 defg
$N_0 M_2$	44.33 cde	18.99 ef	7.42 fg
$N_0 M_3$	49.66 b	19.60 e	8.67 cd
$N_1 M_0$	44.00 cdef	21.88 bc	7.72 efg
$N_1 M_1$	48.33 bc	23.83 a	8.03 def
$N_1 M_2$	39.00 f	20.66 d	8.90 bc
$N_1 M_3$	58.00 a	24.70 a	12.00 a
$N_2 M_0$	43.00 def	21.36 cd	7.26 g
$N_2 M_1$	43.66 cdef	22.02 bc	7.66 efg
$N_2 M_2$	41.66 ef	18.66 ef	8.36 cde
$N_2 M_3$	48.00 bcd	22.66 b	9.50 b
LSD (0.05)	5.06	0.98	0.73
Significant level	**	**	**
CV (%)	6.60%	2.77%	5.10%

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

M_0 – Without micronutrient, M_1 – 50 ppm micronutrient
M_2 – 100 ppm micronutrient, M_3 –150 ppm micronutrient
CV = Co-efficient of variance

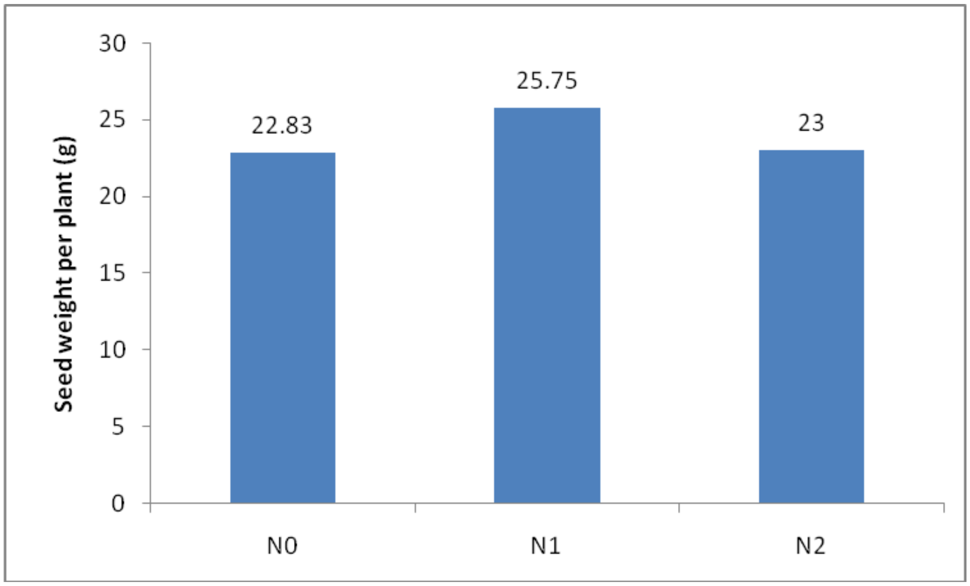
LSD = Least significant Difference,** = Significant at 1% level

4.11 Seed weight plant^{-1} (g)

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

Interaction of nitrogen fertilizer and micronutrient doses showed significant variation on seed weight plant^{-1} (g) of sesame (Table 6 and Appendix VIII). The minimum seed weight plant^{-1} (21.33 g) was observed from N_0A_0 (without N and micronutrient) treatment combination and maximum seed weight plant^{-1} (31.00 g) was recorded for the N_1M_3 treatment combination. The results showed that the best combination N_1M_3 (60 kgha^{-1} N and 150 ppm micronutrient) increased sesame seed weight plant^{-1}.



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 micronutrient, M_1 – 50 ppm micronutrient
M_2 – 100 ppm micronutrient, M_3 –150 ppm micronutrient

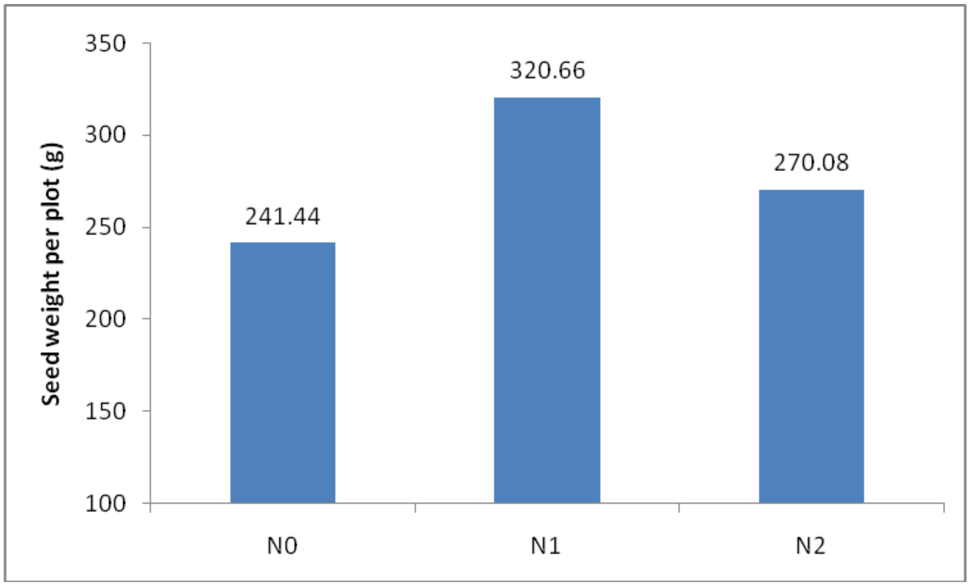
Fig. 22. Effect of different levels of micronutrients on the seed weight plant^{-1} of sesame

4.12 Seed weight plot^{-1} (g)

The Figure 23 and Appendix VIII 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).

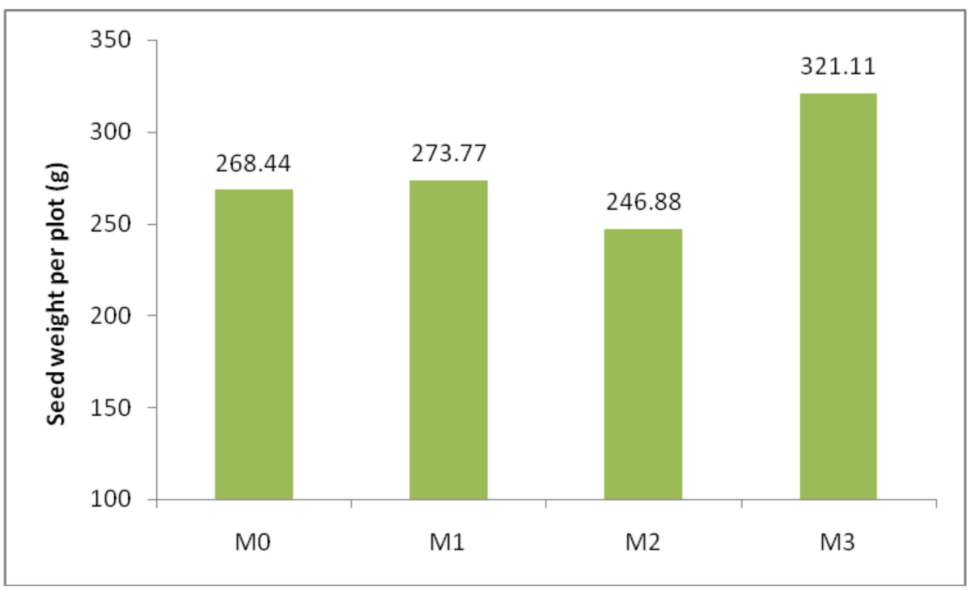
The different concentrations of micronutrient showed significant variation in the seed weight plot^{-1} (g) of sesame (Fig. 24 and Appendix VIII). The maximum seed weight plot^{-1}(321.1 g) was produced by M_3 (150 ppm) where as M_0 (without micronutrient) produced the seed weight plot^{-1} (268.4 g) 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 and Appendix VIII). 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.

Application of different levels of nitrogen fertilizer and micronutrients doses showed significant variation on seed weight plot^{-1} (g) of sesame (Table 6 and Appendix VIII). The highest seed weight plot^{-1} (366.6 g) was recorded for the N_1M_3 (60 kg Nha^{-1} and 150 ppm micronutrient) treatment combination and the lowest (223.6 g) was observed from N_0M_0 (without N and micronutrient) treatment. These results showed that application of micronutrients with different levels of nitrogen fertilizer increased the seed weight plot^{-1} (g) as consistent to combined effect on seed weight plant^{-1} (g) (Table 6) of sesame plant and the best combination (N_1M_3) found from 60 kgha^{-1} nitrogen with 150 ppm of micronutrient.



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 micronutrient, M_1 – 50 ppm micronutrient
M_2 – 100 ppm micronutrient, M_3 –150 ppm micronutrient

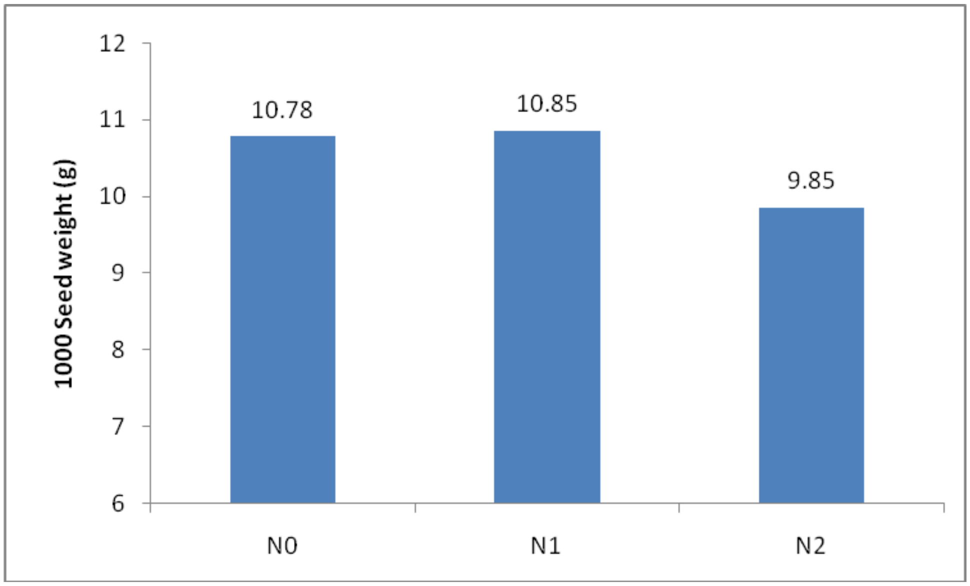
Fig. 24. Effect of different levels of micronutrients on the seed weight plot^{-1} of sesame

4.13 1000 seed weight (g)

The application of nitrogen insignificantly influenced on the thousand seed weight (g) of sesame (Fig. 25 and Appendix VIII). 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. VIII 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.

The combined interaction of different levels of nitrogen fertilizer and micronutrients doses showed insignificant variation on the 1000 seed weight (g) of sesame (Table 6 and Appendix VIII). The maximum 1000 seed weight (11.53 g) was recorded for the N_1M_3 (60 kg Nha^{-1} and 150 ppm micronutrient) treatment combination and the lowest (9.40 g) was observed from N_2M_2 treatment combination which was statistically similar with N_2M_0 (9.50 g) treatment combination. The results of this study showed the increment of 1000 seed weight (g) and the highest 1000 seed weight (g) of sesame was obtained from N_1M_3 treatment combination (60 $kgha^{-1}$ nitrogen with 150 ppm of micronutrient) which was similar to the results found in seed weight $plant^{-1}$ (g) and seed weight $plot^{-1}$ (g) (Table 6).



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

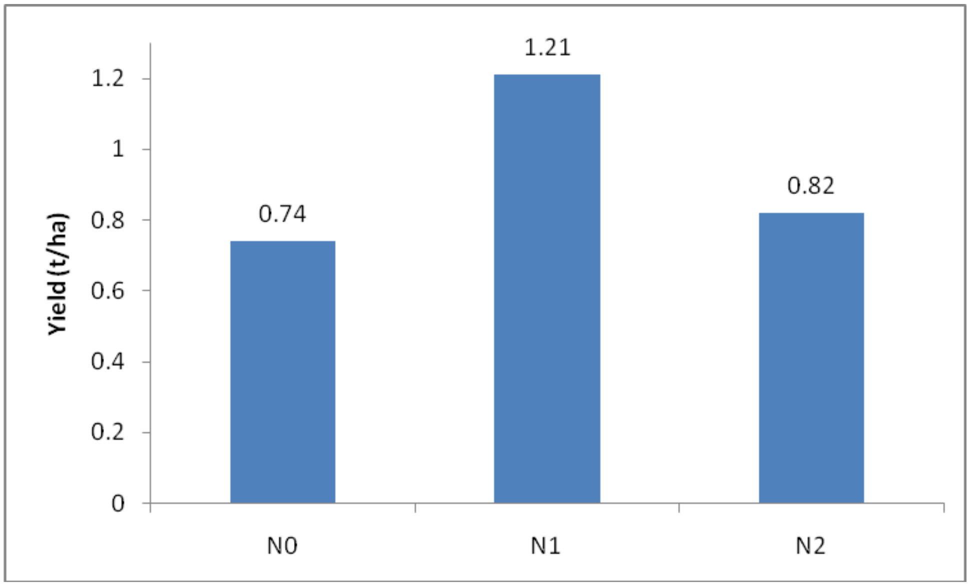
M_0 – Without micronutrient, M_1 – 50 ppm micronutrient
M_2 – 100 ppm micronutrient, M_3 –150 ppm micronutrient

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

4.14 Yield (t ha^{-1})

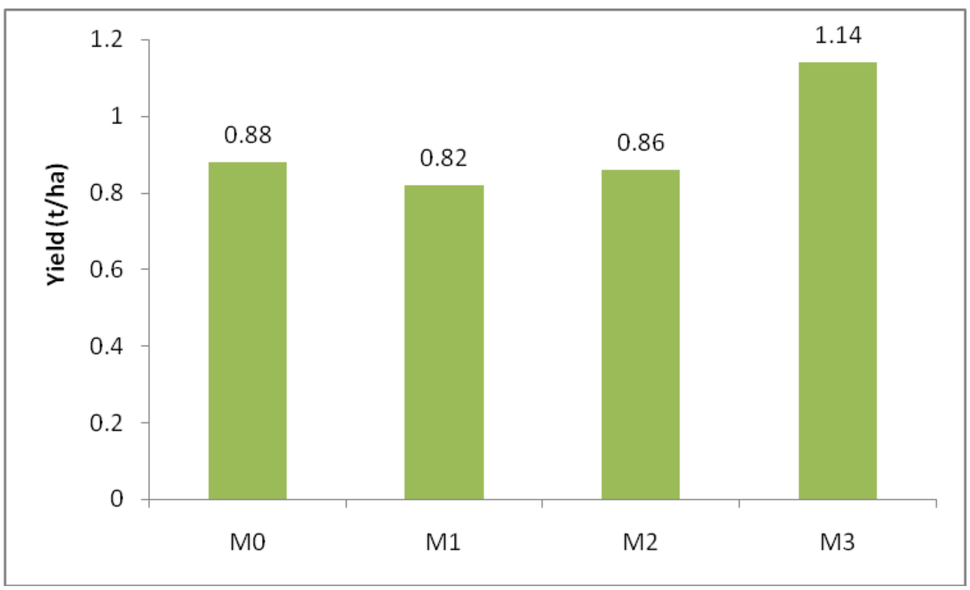
The seed yield of sesame plot^{-1} was converted into ton hectare^{-1}. The different levels of nitrogen had significant effect on the yield of sesame as consistent with number of pod plant^{-1}, pod length (mm) and pod diameter (mm), seed weight plant^{-1} (g), seed weight plot^{-1} (g), except 1000 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 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 micronutrient, M_1 – 50 ppm micronutrient
M_2 – 100 ppm micronutrient, M_3 –150 ppm micronutrient

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

There was a significant combined effect of different levels of nitrogen fertilizer and micronutrient concentrations and showed significant variation on the yield of sesame (Table 6 and Appendix VIII). The maximum seed yield (1.46 t) was recorded for the N_1M_3 (60 kg Nha^{-1} and 150 ppm micronutrient) treatment combination and the minimum (0.59 t) was observed from N_0M_0 (0 kg Nha^{-1} and 0 ppm micronutrient) treatment combination. The total yield of sesame increased by the application of different levels of N fertilizer and micronutrient concentrations and the best result from the combination of N_1M_3(60 $kgha^{-1}$ N and 150 ppm micronutrient) had found from this experiment. Previous results like pod number $plant^{-1}$, pod diameter (mm), pod length (mm), seed weight $plant^{-1}$ (g), seed weight $plot^{-1}$ (g) except 1000 seed weight (g) (Tables 5, 6) had similarity with these results. Ali and Ahmed (2012) observed that as application of 90 kg nitrogen $hectare^{-1}$ fertilizer with micronutrient at 150 ppm significantly increased the yield of sesame.

Table 6. Combined effect of nitrogen and micronutrient on the seed weight plant^{-1} (g), seed weight plot^{-1} (g), 1000 seed weight (g) and yield (t ha^{-1}) of sesame

Treatment	Seed weight plant^{-1} (g)	Seed weight plot^{-1} (g)	1000 seed weight (g)	Yield (t ha^{-1})
$N_0 M_0$	21.33 ef	223.66 e	9.90	0.59 e
$N_0 M_1$	21.66 ef	243.66 de	10.73	0.69 e
$N_0 M_2$	22.00 ef	247.00 de	11.46	0.82 d
$N_0 M_3$	26.33 bc	253.33 de	11.03	0.86 d
$N_1 M_0$	23.66 cde	352.66 a	10.56	1.20 b
$N_1 M_1$	22.66 def	307.66 bc	11.46	1.12 bc
$N_1 M_2$	25.66 bcd	255.66 de	9.86	1.07 c
$N_1 M_3$	31.00 a	366.66 a	11.53	1.46 a
$N_2 M_0$	20.00 f	229.00 de	9.50	0.86 d
$N_2 M_1$	20.33 f	270.00 cd	10.20	0.64 e
$N_2 M_2$	23.66 cde	238.00 de	9.40	0.68 e
$N_2 M_3$	28.00 ab	343.33 ab	10.30	1.11 bc
LSD (0.05)	3.13	43.07	2.09	0.1213
Significant level	**	**	NS	**
CV (%)	7.66%	9.05%	11.62%	7.39%

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

M_0 – Without micronutrient, M_1 – 50 ppm micronutrient
M_2 – 100 ppm micronutrient, M_3 –150 ppm micronutrient

CV = Co-efficient of variance, LSD = Least significant Difference

**= Significant at 1% level, NS=Non-significant

Chapter V

SUMMARY AND CONCLUSIONS

The experiment was undertaken during Kharif-1 season, April to July 2013 to examine the response to different levels of nitrogen (N) and micronutrient (Fe, Zn, Mn, Cu) on morphology, yield and yield attributes of sesame variety BARI Til 4. In this experiment, the treatment consisted of three different N levels viz. N_0 = Without N, N_1 = 60 kg Nha^{-1}, and N_2 = 120 kg Nha^{-1}, and four different level of micronutrient viz. M_0 = Without micronutrient, M_1 = 50 ppm, M_2 = 100 ppm and M_3 = 150 ppm. The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. The amount of fertilizers in the form of urea, triple super phosphate, muriate of potash, gypsum and boric acid as a source of N, P, K, S and B, respectively were applied according to treatment and area of experimental unit plot. The collected data were statistically analyzed for evaluation of the treatment effect. Results showed that a significant variation among the treatments in respect of majority of the observed parameters.

There was significant differences among the different levels of N in respect of almost all parameters. The tallest plant height (62.01, 90.68 and 122.0 cm at 30, 40 and 50 DAS respectively) was recorded with $N_{1,}$ 60 kg N ha^{-1}. The maximum number of leaves $plant^{-1}$ (15.25, 19.41 and 32.50 at 30, 40 and 50 DAS, respectively) was produced by 60 kg Nha^{-1}. The number of branches $plant^{-1}$ showed significant variation during 30, 40 and 50 DAS and the maximum number of branches $plant^{-1}$ (6.0, 8.08 and 12.08 at 30, 40 and 50 DAS respectively) was produced by 60 kg N/ha. The highest fresh and dry shoot weight (38.91 g and 6.51 g, respectively) was obtained from 60 kg Nha^{-1}. The highest fresh and dry root weight (7.0 g and 1.81 g, respectively) was obtained from 60 kg Nha^{-1}. The maximum number of pod $plant^{-1}$ (47.33) was obtained in plots which received 60 kg Nha^{-1}. The highest fruit diameter and length (9.16 mm and 22.77 mm, respectively) was obtained from N_1 (60 kg Nha^{-1}). The maximum seed weight $plant^{-1}$ (25.75 g) was produced by N_1 treatment. The maximum seed yield $plot^{-1}$ (320.73 g) was produced by $N_{1.}$ The result showed that there was no significant variation among thousand seed weight and highest thousand seed weight (10.85 g) was produced by N_1. The maximum yield of seed $hectare^{-1}$ (1.21 t) was obtained from $N_{1,}$ 60 kg Nha^{-1}, whereas the minimum yield of seed per hectare (0.74 t) was obtained from $N_{0,}$ without N.

Plant height showed significant difference in response of foliar application of micronutrient. The tallest plant height (61.24, 90.47 and 122.65 cm at 30, 40 and 50 DAS, respectively) was produced with the M_3 (150 ppm micronutrient). The highest number of leaves $plant^{-1}$ (15.66, 19.83 and 36.66 at 30, 40 and 50 DAS, respectively) was produced with the M_3 (150 ppm micronutrient). The maximum number of branches $plant^{-1}$ (6.22, 8.77 and 12.77 at 30, 40 and 50 DAS, respectively) was produced by M_3 (150 ppm micronutrient).The highest fresh and dry shoot weight (45.66 g and 7.74 g, respectively) was obtained from 150 ppm micronutrient. The highest fresh and dry root weight (8.18 g and 2.20 g, respectively) was obtained from 150 ppm micronutrient. The maximum number of pod $plant^{-1}$ (51.88) was obtained in plots which received 150 ppm micronutrient. The highest fruit diameter and length (10.05 and 22.32 mm, respectively)) was obtained from M_3 (150 ppm micronutrient). The maximum seed weight per plant (28.44 g) was produced by M_3 treatment. The maximum seed yield $plot^{-1}$ (321.11 g) was produced by M_3 (150 ppm micronutrient). The result showed that there was no significant variation among thousand seed weight and highest thousand seed weight (10.95 g) was produced by M_3. The maximum yield of seed $hectare^{-1}$ (1.14 t) was obtained from M_3 (150 ppm micronutrient), whereas the minimum yield of seed $hectare^{-1}$ (0.82 t) was obtained from M_1, 50 ppm micronutrient.

The combinations of N and micronutrient (Fe, Zn, Mn, Cu) had significant effect on almost all parameter. The tallest plant height (66.0, 92.53 and 127.0 cm at 30, 40 and 50 DAS, respectively)) was found in N_1M_3 treatment combination. The results showed significant differences on number of leaves $plant^{-1}$ (17.33, 21.50 and 40.33 at 30, 40 and 50 DAS, respectively) in N_1M_3 treatment combination whereas number of branches $plant^{-1}$of sesame was statistically insignificant at 30, 40 and 50 DAS. The highest fresh and dry shoot weight (51.0 g and 8.90 g, respectively) and highest fresh and dry root weight (9.50 g and 2.80 g, respectively) was obtained from N_1M_3 treatment combination. The maximum number of pod $plant^{-1}$ (58.0), pod diameter (12.0 mm) and pod length (24.70 mm) was found in N_1M_3 treatment combination. The maximum seed weight $plant^{-1}$ (31.0 g), seed weight $plot^{-1}$ (366.66 g) was found in N_1M_3 treatment combination (60 kg Nha^{-1} and 150 ppm micronutrient). The highest yield of seed hectare^{-1} (1.46 tones) was obtained from N_1M_3 treatment combination (60 kg Nha^{-1} and 150 ppm micronutrient). The lowest yield of seed hectare^{-1} (0.59 tones) was obtained from N_0M_0 treatment combination without nitrogen and micronutrient.

Considering the above results, it may be summarized that morphological parameters, seed yield and yield contributing parameters of sesame are positively correlated with N and micronutrient application. Therefore, the present experimental results suggest that the combined use of 60 kg Nha^{-1} and 150 ppm micronutrient along with recommended doses of other fertilizer would be beneficial to increase the seed yield of sesame variety BARI Til 4 under the climatic and edaphic condition of Sher-e-Bangla Agricultural University, Dhaka.

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for analogy the accuracy of the experiment.
2. It needs to conduct more experiments with N and micronutrient whether can regulate the morpho-phygiology, yield and seed quality of sesame BARI Til 4.
3. It needs to conduct related experiment with other varieties of sesame.
4. Scope to conduct advance experiments how N and micronutrient physiologically increase seed yield and improve seed quality of sesame.

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APPENDICES

Appendix I. Physical and chemical characteristics of initial soil (0-15 cm depth)

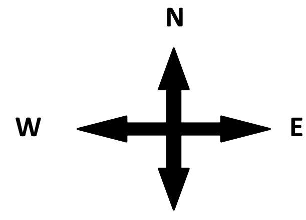
A. Physical composition of soil

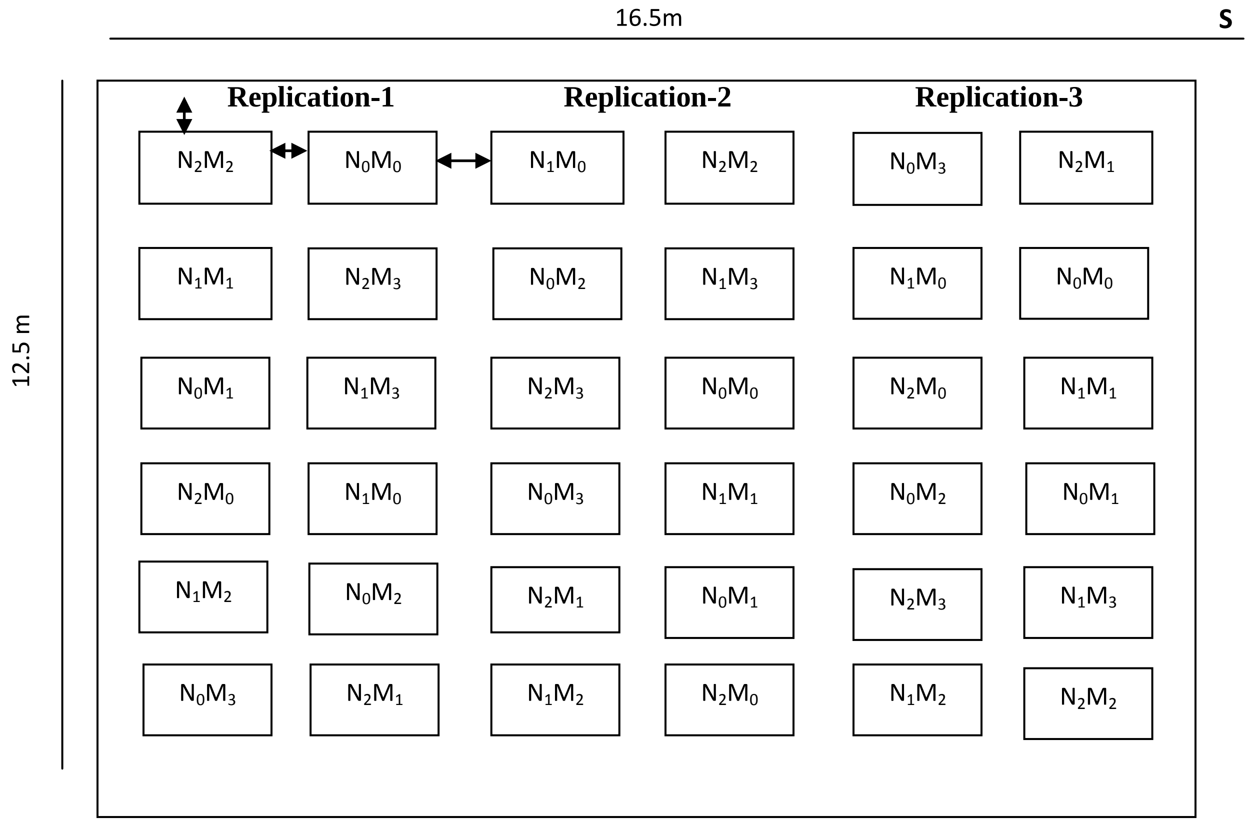
Soil separates	(%)	Methods employed
Sand	36.90	Hydrometer method (Day, 1995)
Silt	26.40	-do-
Clay	36.66	-do-
Texture class	Clay loam	-do-

B. Chemical composition of soil

SI.	Soil characteristics	Analytical data	Methods employed
1	Organic carbon (%)	0.82	Walkley and Black, 1947
2	Total N ($kgha^{-1}$)	1790.00	Bremner and Mulvaney, 1965
3	Total S (ppm)	225.00	Bardsley and Lancster, 1965
4	Total P (ppm)	840.00	Olsen and Sommers, 1982
5	Available N ($kgha^{-1}$)	54.00	Bremner and Mulvaney, 1965
6	Available P ($kgha^{-1}$)	69.00	Olsen and Dean, 1965
7	Exchangeable K ($kgha^{-1}$)	89.50	Pratt, 1965
8	Available S (ppm)	16.00	Hunter, 1984
9	P^H (1:2.5 soil to water)	5.55	Jackson,1958
10	CEC	11.23	Chapman, 1965

Appendix II. Layout of the experimental plot





Unit plot size:

2 m x 1.5 m

N = Nitrogen

M = Micronutrient

Factor A: Nitrogen

N_0= without nitrogen

N_1=60 kg Nha^{-1}

N_2=120 kg Nha^{-1}

Factor B: Micronutrient

M_0= without micronutrient

M_1= 50 ppm micronutrient

M_2=100 ppm micronutrient

M_3=150 ppm micronutrient

Appendix III. 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 IV. 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 V. 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	0.58NS	0.51NS	0.51NS
Error	22	0.78	0.69	0.69

* significant at 5% level of probability,
** significant at 1% level of probability,
NS- Non significant

Appendix VI. 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			
		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 VII. 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		
		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 VIII. 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			
		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