EFFECT OF FOLIAR APPLICATION OF MICRONUTRIENTS ON GROWTH, YIELD AND OIL QUALITY OF SESAME (*sesamum indicum* L.)

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CERTIFICATE

*This is to certify that the thesis entitled "**EFFECT OF FOLIAR APPLICATION OF MICRONUTRIENTS ON GROWTH, YIELD AND OIL QUALITY OF SESAME (Sesamum Indicum L.)** " submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Agricultural chemistry**, embodies the result of a piece of bona fide research work carried out by **Md. Nazmul Islam Shekh**, Registration number: **12-04842** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2018
Place: Dhaka, Bangladesh

Dr. Rokeya Begum
Professor
Supervisor

DEDICATED

TO

MY BELOVED PARENTS

AND MYSELF

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June, 2018 ***The Author***
SAU, Dhaka

EFFECT OF FOLIAR APPLICATION OF MICRONUTRIENTS ON GROWTH, YIELD AND OIL QUALITY OF SESAME (*Sesamum indicum* L.)

ABSTRACT

A field experiment entitled "Effect of foliar application of micronutrients on growth, yield and oil quality of sesame (*Sesamum indicum* L.)" was conducted during Kharif-1 2017 at central farm of SAU, Dhaka and chemical analysis were done in the laboratory of BARI, Gazipur. Sesame (*Sesamum indicum*.L) is one of the most valuable oilseed crops whose seeds are used as traditional health food, with high quality oil, protein and natural antioxidants. The experiment was laid out in a Randomized Block Design with ten treatments and replicated thrice. The treatments were comprising of T_1: control (no micronutrients), T_2: B (100 ppm), T_3: Zn (100 ppm), T_4: Mo (50 ppm), T_5: Cu (100 ppm), T_6: Fe (100 ppm), T_7: Mn (100 ppm), T_8: Co (50 ppm), T_9: (combination of above micronutrients) and T_{10}: commercial mixture of micronutrients. Observations on plant height, number of branches, total dry matter, growth analysis parameters, chlorophyll content of leaf at various stages of crop, yield and yield attributes, oil content and N, P and K uptake by plant and plant parts were recorded. The results revealed that most of the putative morphological traits like plant height, number of branches, total dry matter of plant and plant parts increased with foliar application of different micronutrients but significantly the highest increase was found when micronutrients were applied in combination followed by individual application of Zn, B and Mo. Physiological growth parameters such as leaf area index, leaf area duration, relative growth ratio , net growth ratio , crop growth ratio and chlorophyll content of leaf increased significantly by foliar application of different micronutrients either in single or in combination. Seed yield in sesame increased significantly over control by foliar application of different micronutrients used in single or in their combination. In view of such beneficial effects of foliar application of micronutrients on sesame, it may be asserted that improvement in productivity of sesame can be achieved under a depleted soil condition through supplementary application of micronutrients viz. B, Zn, Mo, Cu, Fe, Mn, Co, either in single or their combination along with basal dose of N, P and K.

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CHAPTER I

INTRODUCTION

Sesame (*Sesamum indicum L.*) belongs to the family Pedaliaceae is one of the significant oil crops. It is grown for seed and oil both for human ingestion and has been grown for thousand of years and today its major production areas are the tropic and the subtropic of Asia, Africa, East and Central America. In Bangladesh, it is locally known as til and is the second vital edible oil crop (Mondal *et al.*, 1997). Sesame is one of the significant oilseed crops in Bangladeshi agriculture. Sesame seeds are rich source of food, nutrition, edible oil and bio-medicine. Sesame oil has superb nutritional, medicinal, cosmetic and cooking qualities for which it is known as 'the queen of oilseeds'. Due to the manifestation of potent antioxidants, sesame seeds are called as 'the seeds of immortality'. Sesame cake or meal attained as a byproduct of the oil milling industry is rich in protein, vitamin (Niacin) and minerals (Ca and P). The crop is grown for its seeds, which contain 50-60% oil, 8% protein, 5.8% water, 3.2% crude fiber, 18% carbohydrate, 5.7% ash and it is very opulent in minerals such as Ca, P and vitamin E (BBS, 2017). Also, sesame oil has a very high level of unsaturated fatty acids, which is presumed to have decreasing effect on plasma cholesterol, as well as on coronary heart disease. In 2016-2017, the crop covered an area of 8530 acres in Bangladesh with the production 2970 Metric tons (BBS, 2017).

Sesame is the second most important oil-producing crop in the country. From ancient times, sesame is being cultured in the Indian subcontinent and in China. The plants may attain a height of about one metre, usually with side branches. In Bangladesh it is grown in almost all districts but grows well in greater Khulna, Faridpur, Pabna, Barisal, Rajshahi, Jessore, Comilla, Dhaka, Rangpur, Sylhet, and Mymensingh districts (BBS, 2017).

Generally this crop is grown by the farmer with short dose of fertilizer under rainfed condition but application of nutrients at a right time is important in gaining good yields. Application of nutrients in split will fulfill the nutrient demands of plant at acute stages of the plant growth and development. Foliar fertilization is gaining more importance in recent years due to the accessibility of soluble fertilizers and is of great significance in rainfed areas under changing climatic environments. Many research

reports indicated the positive effect in increasing the crop yield and quality of oilseed crops. Application of nutrients through foliar spray helps in quick regain in drought condition and also prevents loss of nitrogen by different means. Micronutrients are the fundamentals which are essential for plant growth, but are required in quite smaller quantities than those of the primary nutrients, nitrogen, phosphorus and potassium. They play an crucial role in cell division and development of meristematic tissues, stimulate photosynthesis, respiration, energy and nucleotide transfer reactions and fasten the plant maturity (Marschner, 1998).

Although micronutrients are needed in relatively small quantities for optimum plant growth and production, their deficiencies induce a great disruption in different physiological and metabolic processes in the plant. The situation has been forced with the introduction of high yielding crop varieties and intensive cropping system (Harborne JB 1973). As the demands of nutrients for higher yields proliferation and plant requirements for major nutrients are only met micronutrient deficiencies are likely to become acute. In Dhaka soil , the deficiency of micronutrients like Zn, B, and Mo have been reported both by farmers, extension and research workers (Hatwar GP *et al 2003*). Low seed yield, due to deficiency of above micronutrients, have been well renowned due to several reasons such as flower and fruit drop, low harvest index and poor vegetative growth.

Phytochemical studies conducted on this plant revealed the presence of lignans, phenolics acids, flavonoids, saponins and alkaloids (Hassan and Umar 2004). The Proximate composition and mineral analysis of sesame seeds both whole and decupled at different part of the world has been determined (Hui 1996; Obiajunwa et al. 2005; Ugboi et al. 2008).

The role of different micronutrients has been well recognized in plant metabolism. Zinc (Zn), as micronutrients, is tangled in the biosynthesis of auxins, indole -3- acetic acid. It participates in the metabolism of plant as an activator of several enzymes. Boron (B) is involved in the carbohydrate transport within the plant which helps in translocation of sugar and DNA synthesis in meristems. Also it has been concerned in cellular differentiation and development, nitrogen metabolism, fertilization, active salt

absorption, hormone metabolism, water relations, fat metabolism, phosphorus metabolism and photosynthesis (Mortvedt *et al.*, 1999). Therefore, the steady amount of macro nutrients and Zn was found to increase stem height and nodes for capsule development in sesame. Major micronutrients like nitrogen, phosphorus and potassium along with micronutrients such as zinc and manganese are influencing the growth and yield of sesame (Babaeian *et al., 2011).*

Cobalt (Co) being a beneficial element is known to cause irreversible damage to a number of vital metabolic ingredients of plant cell and cell membrane. However it has been known for many years that cobalt is an essential element for humans, animals and prokaryotes, but the physiological function for this element in higher plants has not been identified. The cobalt-containing vitamin B_{12} does not occur in plants deficient with cobalt. Although normal cobalt concentrations in plants are found to be as low as 0.1-10 mg g^{-1} dry weights, its beneficial role as a trace element has been described by (Bakkaus *et al.*, 2005). Iron (Fe) plays important role in biological redox system, enzyme activation and transferring oxygen in nitrogen fixation. Copper (Cu) is vital for physiological redox processes, pollen viability and lignification's (Marschner, 1998). Thus trace elements are necessary for the normal metabolic functions of the plant, but at higher concentrations, these metals are toxic and may severely interfere with physiological and biochemical purposes.

Therefore, the present study aimed to provide information on the chemical composition, available nutrients and the physicochemical properties of the oil extracted from the seed of *S. indicum*. Keeping all the above fact into consideration, present enquiry has been undertaken to study the effect of micronutrients applied as foliar spray, on metabolism, growth and yield of sesame crop with the following objectives.

OBJECTIVES

1. Effect of micronutrient on growth and yield attributes of sesame.
2. Effect of micronutrient on the uptake of major nutrient by plant and oil content of seed.

CHAPTER II

REVIEW OF LITERATURE

Role of micronutrients in crop nutrition and eventually plant growth and development has been well recognized. In recent years their position on maximization of production and quality of oilseed crops has attracted the devotion of scientists all over the world. The micronutrients like iron, manganese, zinc, boron, copper, molybdenum and cobalt which are integral parts of several photosynthetic and respiratory enzymes have limiting role on absorption of crop plants and hence growth and development. Iron is essential for protein amalgamation and chloroplast development. Manganese is for cell division and expansion, zinc is essential for RNA and protein synthesis, at the same time boron is important for carbohydrate metabolism and translocation. Here attempts have been made to review the effect of micronutrients on growth, yield and quality of oilseed crop with due emphasis on sesame.

2.1 Growth and development

Boron

Sing and Sing (1996) conducted a pot culture experiment on tomato with dissimilar boron concentration 0.5, 1.0, 1.5 and 2.0 ppm and distilled water as control. They showed that boron plays an essential role in the development and growth of new cells in the plant meristem. Number of flowers and fruits increased significantly at all levels of B application and the element had positive effects on plant height, number of branches, leaves, flowers and fruit set resulting in improved number of fruits per plant and the total yield.

Nath and Biswas *et al.,* (2002) reported that foliar application of boron 100 ppm twice at monthly interval produced the maximum height of plant, increased the number of leaves per clump resulting in improved yield of spikes per plot. Foliar spray of micronutrients causes more somatic growth and increases the final plant height (Sepehr *et al.*,2002).

Boron is a most required micronutrient for all plant nutrition. It plays important roles in most of the crops e.g. cell wall strengthening, development, cell division, fruit and seed setting, sugar translocation, and hormonal development. Boron (B) is measured as

an element for plant growth and development. Sexual reproduction of plants is more affected to B deficiency, than vegetative growth (Ahmad *et al.*, 2009).

Bilen *et al.*, (2011) also reported that appropriate dose of boron increase plant height and higher level of boron lower urease enzyme action which was observed in 9 kg ha^{-1} boron at sowing time that reduces plant height.

Zinc

Rajput *et al.*, (2003) in *Tagetus minuta* observed that application of boron independently or in combination with zinc and sulphur increased the plant height and fresh weight of plant significantly over the control, Individual submission of boron increased the dry matter yield significantly by 69.8 per cent and 71.1 percent over the control.

Jauhari *et al.*, (2005) found that foliar spray of zinc sulphate at 0.2 percent recorded extreme plant height, spike length, number of florets per spike and corms yield per m^2. Corm yield per square meter was maximum with the application of zinc sulphate at 0.4 per cent. It was also perceived that higher concentration of zinc sulphate (beyond 4 percent) had negative effects on plant growth, flowering and corm yield, revealing that 0.4 per cent zinc sulphate is the ideal concentration in gladiolus for better performance.

Molybdenum

Gupta and Vyas (1994) observed that dry weight of soybean plant was increased due to application of zinc, iron, molybdenum. Iron, zinc and molybdenum are the metallic compounds of one or more enzymes which are involved in various physiological purposes and there by increased the leaf area index, crop growth rate; relative growth rate leading to the development and productivity of plant.

Copper

The favorable effect of Zn and Cu on fruit yield in brinjal plant could be attributed to their effect in maintaining and optimum balance of nutrients in the plant for better growth and developments (Dhakshinamoorthy and Krishanamoorthy, 1989).

Iron

Zinc foliar application increases tallness, branch number per plant and dry weight of stem of grass pea. Also zinc, magnesium and iron foliar application increases growth parameters, yield and plant parts significantly (Thalooth *et al.*, 2006).

Manganese

Micronutrient play an indispensable role in cell division and development of meristematic tissues, stimulate photosynthesis; respiration, energy and nucleotide transmission reactions and fasten the plant maturity (Marschner *et al.*, 1998).

Mixture of micronutrient

Micronutrients are involved in all metabolic and cellular functions. Plants differ in their need for micronutrients; boron (B), iron (Fe), zinc (Zn), copper (Cu), chloride (Cl), manganese (Mn), molybdenum (Mo) and nickel (Ni). These elements are active that kinds them essential as catalytically active cofactors of enzymes, others have enzyme activating functions, and yet others fulfill a organizational role in stabilizing proteins. Improvement in growth characters due to micronutrient application might basically be due to enhanced photosynthetic and other metabolic activities related to cell division and elongation as opined by Hatwar *et al.*, 2003.

Ibrahim *et al.* (2007) in faba bean found that foliar application of both amino acids and micronutrients significantly increased plant height, number of branches, leaf area and number of pods per plants and subsequently the faba bean seed yield.

Micronutrient elements play a critical role in plants that lead to increase of leaf area index as well as thereby increased light absorption and increase the amount of dry matter gathering and economic yield (Rabi *et al.*, 2008).

Yadav *et al.* (2009) studied on "effect of micronutrients in combinations with organic manures on invention and net returns of sesame (*Sesamum indicum*)" in bundelkhand tract of Uttar Pradesh and found that the treatments applied with 100% of the recommended NPKS fertilizer along with micronutrients and organic manure recorded expressively higher growth and yield attributing characters, seed yield and net returns

over half of the recommended dose of fertilizer (20:10:10:15 kg NPKS/ha) coupled with micronutrients and organic manure.

Salwa *et al.* (2010) studied on "Amelioration productivity of sandy soil by using amino acids, sulphur and micronutrients for sesame production" found that there were significantly rise in the whole plant weight with increasing application of sulphur as soil application and micronutrients as foliar spray. Generally, a combined submission of amino acid with micronutrient Fe, Zn, Mn in the presence of elemental sulphur expressively increased the sesame yield; improved nutrition and increased seed quality.

2.2 Yield and yield attributes

Boron

Sakal *et al.* (1994) evaluated the direct and residual effect of varying levels of B (0, 8, 16, 32 and 64 kg Borax ha^{-1} and FYM (0.25 and 5.0 t ha^{-1}) alone and in combinations on crops in maize-lentil cropping system. Increasing levels of B up to16 kg borax ha^{-1} significantly increased and higher levels declined the yield of first crop. Application of 16 kg Borax ha^{-1} in conjunction with 5 t FYM ha^{-1} was an ideal combination which considerably enhanced the cumulative grain yield response as well as sustained the productivity.

Talashilkar and Chavan (1996) observed that pod production of groundnut was enhanced significantly with the addition of B by 44 percent. The maximum pod and haulm yields were recorded in the treatment receiving B through super phosphate along with application of FYM, N and P. Vyakaranahal *et al.* (2001) reported that significant affect on 100-achene weight. This may be due to the B role in translocation of photo conforms from vegetative to reproductive parts of sunflower.

Zahoor *et al.* (2011) reported that application of boron at propagating time, increase the biological yield. It might be due to positive correlation present between boron and other micronutrients and enzymatic activity, thus stem diameter, head diameter and plant height increased and ultimately organic yield of sunflower was also increased.

Zinc

Singaravel *et al.* (2002) described that the combined application of Zn and Mn in soil produced the highest number of capsules per plant by 59% and number of seeds per capsules by 57% over control. They also reported that application of Zn alone as foliar

and soil increased the yield from 592 to 611 kg ha^{-1}. Zn and Mn increased growth and yield components as well as an increased availability and better uptake of these nutrients.

Kobraee *et al.* (2011) reported that Zinc foliar application enhanced soybean yield by influencing the number of seeds per plant and seed weight. Grain yield increased significantly with each increment of zinc (Pable and Patil, 2011).

Molybdenum

Micronutrients in soybean are useful to improve productivity as well as seed quality parameters. Among the micro nutrients Mn, Zn, B, and Mo are important for increasing the productivity of soybean crop (Devarajan and Palaniappan, 1995).

Liu *et al.* (2003) studied the effects of Mo and B, alone or in mixture, on seed quality of soybean cultivars Zhechum 3, Zhechun 2, and 3811grown in pot. Application of Mo and/or B increased the content of protein, in dispensable amino acids, total amino-acids (excluding proline), N, P, K and decrease the content of Ca and oil.

Manganese

Moussavi-Nik *et al.* (1997) reported that application of iron, zinc and manganese have a significant and positive effect on wheat biomass production and yield components. Micronutrient applications significantly increased yield components, viz. number of capsules per plant and number of seeds per capsule. The combined application of Zn and Mn in soil produced the highest number of capsules per plant and number of seeds per capsules. The valuable influence of micronutrients might be due to the activation of various enzymes and the efficient utilization of applied nutrients resulting in increased yield components (Tiwari *et al.*, 2000; Shanker *et al.*, 1999).

Foliar application of micronutrients particularly Zn as well as Mn in small amounts had significant positive effect on 1000 seed weight, plant height, biological yield, grain yield, harvest index and oil content of sunflower (Babaeian *et al.*, 2011).

Shehu (2014) studied on Manganese and Zinc nutrition of Sesame (*Sesamum indicum*) in Mubi, Northern Guinea Savannah Zone of Nigeria. And found that there were no significant (P=0.05) 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.

Mixture of micronutrients

Yilmaz *et al.* (1997) reported that the use of micronutrients be able to increase the 1000 seed weight. Micronutrients increases photosynthesis rate and improves leaf area duration thus seed yield will be increased (Cakmak, 1999).

Zeidan *et al.* (2006) found that foliar spray of micronutrients considerably superior the number of pods per plant, 1000 seed weight and seed yield. The increase of 1000 seed weight due to micronutrients application might be due to their positive effects on assimilates translocation, activation of photosynthetic enzymes, chlorophyll development as well as improvement of plant growth (Mohavahhedi *et al.*,2009).

Kohnaward *et al.* (2012) studied on "Effect of foliar application of micronutrients on yield and yield components of safflower under conservative and ecological cropping systems" and found that significant effect of cropping system an foliar application on the number of seeds per head and number of heads per plant, and however significant interaction effect on 1000 seed weight, seed yield and biological yield. The highest 1000 seed weight (36.37 g), seed yield (4115.6 kg/ha) and biological yield (8175 kg/ha) were obtained from plants treated by zinc at high input cropping system. In all foliar sprays, there was a descending trend from along with reducing inputs, so the minimum 1000 seed weight (20.76 g), seed yield (1540.3 kg/ha) and biological yield (3112.5 kg/ha) were gained from ecological system. In conclusion, use of micronutrients, foliar application caused to improve the yield of safflower; especially in medium and low input systems.

2.3 Chlorophyll content

Schlegel *et al.* (1987) revealed that Photosynthetic pigments such as chlorophyll 'a', chlorophyll 'b' and total chlorophyll contents of *Sesamum indicum* reduced with

increasing Co level in the soil. The increased chlorophyll content at lesser level of Co was obviously due to better growth.

Hemantaranjan *et al.* (2000) lead a field experiment on soybean. Plant height, root length, chlorophyll-b content, total dry matter production, seed yield of soybean were higher at 50 than 100 ppm B. However, chlorophyll-a content was higher at 100 ppm B. The collective application of S and Fe considerably increased shoot height, root length, number of leaves per plant, leaf area per plant, total dry matter production as well as seed oil content, with 80 + 20 mg per kg soil giving the best results.

Iron plays essential roles in the metabolism of chlorophylls. Exterior application of Fe increased photosynthesis, net assimilation relative growth in seawater stressed rice (Sultana *et al.*, 2001).

Combined application of B and Zn is active to increase in chlorophyll content, nitrogen content in dry matter and seed, phosphorus content in dry matter and seed, potassium content in dry matter and seed, and oil and protein content in seeds of sunflower (Gitte *et al.*, 2005). Zinc may be required for chlorophyll production, pollen function and fertilization (Pandey *et al.*, 2006). Xiong *et al.* (2006) reported that higher application of Cu adversely affects plant growth characterized by fewer leaves, lesser chlorophyll content and shorter roots.

Iron plays an important role in the amalgamation of chlorophyll and plant growth regulators. Iron improves photosynthesis and assimilates transportation to sinks and finally enlarged seed yield (Alvarez - Fernandez *et al.*, 2006).

Iron is an essential micro element for plant development; it plays an important role in the formation of chlorophyll A and chlorophyll B, carbohydrate production, cell respiration and chemical reduction of nitrate (Mousa and *zedan* 2010).

Iron plays an important role in the stimulation of chlorophyll and in the synthesis of many heme proteins such as different cytochrome, which participate in different functions in the plant metabolism (Al -Bamarny *et al.*, 2010).

2.4. N, P, K uptake

Ramamoorthy and Sudrasan (1992) found that B application considerably increased the protein contents due to highest uptake of nitrogen by seed and N might have been incorporated in the protein molecule.

Huang *et al.* (2000) revealed that Zn deficiencies increases P content of plant shoot. They found Zn to play definite role in the regulative mechanism of the genes encoding phosphate transporter proteins in the plasma membranes of sugar beet and barley. Thus, measured uptake of P is lost under low or deficient levels of Zn leading to high concentration of P in plants.

Thiruppathi *et al.* (2001) announced that there are two ways to add Zn foliar spray and fertilization. In these ways the absorption of nitrogen (N), phosphorus (P), potassium (K), harvest index, yield components and seed yield in sesame increased.

Singaravel *et al.* (2002) recorded significant increase in K uptake from additions of Mn and Zn to NPK on Vertisols. Combined application of Zn and Mn in soil recorded the highest NPK uptake in seed and shoot. The soil or foliar application of Fe, Cu and B significantly increased N and P uptake from soil and increased their content in flax plants (El-Nagdy *et al.*, 2010).

Potarzycki and Grzebisz (2009) reported that zinc exerts a great stimulus on basic plant life processes, such as (i) nitrogen metabolism– uptake of nitrogen and protein quality; (ii) photosynthesis– chlorophyll synthesis, carbon anhydrase activity.

Narimani *et al.* (2010) indicated that foliar application of Zn, Mg, Mn and Fe significantly increased growth parameters; yield of durum wheat and foliar application of microelements improved effectiveness of macronutrients.

Application of boron at sowing time, increase the seed yield of sunflower. This might be due to applying of boron through soil, which improves the facility of crop to absorb micronutrient, leading to favorable in direct effect on uptake of nitrogen, phosphorous, potassium and yield of crop increased (Silva *et al.*, 2011).

Devi *et al.* (2012) studied the effect of sulphur, boron fertilization on yield, quality and nutrient uptake by soybean under upland condition and found useful for obtaining maximum yield attributes.

Shehu *et al.* (2014) studied on Effects of Manganese and Zinc Fertilizers on Shoot content and Uptake of N, P and K in Sesame (*Sesamum indicum* L.) on Lithosols and found that stem height, number of branches, leaves, and capsules were not significantly influenced by Mn and Zn. Seed yield was depressed at 1 kg Mn ha^{-1}, 1 kg Mn $^{+1}$ kg Zn ha^{-1} and 0.5 kg Mn $^{+}$ 0.5 Zn ha^{-1} by 17.57 and 41% respectively. Number of seed $capsule^{-1}$ was depressed by 9% at 1 kg Mn ha^{-1}. Combined Mn and Zn had dry matter yield disadvantage by 16 and 18% at 0.5 and 1 kg ha^{-1} of Mn and Zn rates, respectively. Shoot N, P, K, Mn, and Zn contents of sesame, N and P uptake were not significantly influenced.

2.5. Oil content

In China, on a clayey soil with 0.7 mg B kg^{-1}, application of B fertilizer to *Brassica napus* L. improved plant height, pod-bearing branches and pod number per plant, seed number per pod, seed yield and oil content (Hu *et al.*, 1994). Renukadevi and Savithri *et al.* (2003) reported that enhanced uptake of B in the seed had a significant effect on oil contents in sunflower. Zinc also plays an important role in the production of biomass, grain yield, quality and extent of oil (Kaya and Higgs, 2002; Cakmak, 2008).

Dehnavi *et al.*(2008) studied the possessions of foliar application of zinc and manganese on oil content and fatty acid profiles in some safflower cultivars under drought conditions, also found that the zinc and manganese foliar applications significantly increased palmitic and oleic acids, whereas these foliar applications declined linoleic acid percent.

2.6. Biochemical composition

The protein content of the 13 Moroccan cultivars grown in different areas varied from 26.77 to 27.93%, with an average of 27.4%. The protein content depends on the climatic conditions and the stage of development of the plant. Sesame seeds protein contains high amounts of aspartic acid, glutamic acid and arginine (Prakash and Nandi 1975) presenting a great reservoir of amino acids. Also sesame seeds are rated among the

highest organic sources containing cysteine (Rangarajan and Ambilly 2012). Also, sesame seeds are an important source of dietary fiber. The Moroccan cultivars contain high amounts of dietary fiber, ranging from 17.55 to 20.84% of dry matter, with an average of 19.2%. The amount of insoluble dietary fibers varied from 12.46 to 15.78%, while that of soluble dietary fibers varied from 4.50 to 5.87%. Average of the latter was 5.21%, which is higher than that of cereals and its derivatives, such as corn, wheat bran, oat bran and rice bran, having a fiber content ranging from 0.4 to 4.1% (Abdul-Hamid and Luan 2000).

Polyphenols, which are secondary metabolites distributed in the plant, are considered to be very important antioxidants, due to their ability to give a hydrogen atom or an electron to form an intermediate stable radical, and consequently avoid the oxidation of different biological molecules. The polyphenol content of Moroccan sesame seeds ranged from 3.75 to 3.92 mg/g. The content of flavonoids, which are also lesser metabolites, with an important role in the plant defense system, and which function as hydroxyl radical sensors and peroxides, ranged from 0.13 to 0.14 mg/g and no significant differences were detected between the cultivars. Actually, the content of primary and secondary metabolites is strongly influenced by plant stress when exposed to severe scarcity conditions (Vishwanath et al., 2011)

Sesame is also considered as a rich source of minerals such as calcium, magnesium (which plays an important role for the support of the respiratory system), iron, potassium and selenium which is detected in sesame at doses useful to health (Ensminger and Ensminger 1986)

Calcium, phosphorus and potassium are the most rich minerals in seeds of the different cultivars. Magnesium, which is an essential mineral for enzyme activity, is also found in significant amount in sesame seeds. Like calcium, magnesium plays a role in regulating acid-alkaline balance in the body, a significant role in photosynthesis. Also, the potassium is an essential nutrient and has an key role in the synthesis of amino acids and proteins (Fallon and Znig 2001)

CHAPTER III

MATERIALS AND METHODS

A field experiment entitled "Effect of foliar application micronutrients on growth, yield and oil quality of sesame (*sesamum indicum* L.) " was conducted at central farm (SAU), Dhaka during kharif-1 season 2016-2017 and chemical analysis done in the laboratory of BARI , Gazipur in order to assess the effect of foliar application of certain micronutrients on the growth and yield of sesame. The materials used and the methods of different experimental techniques employed during the course of investigation are mentioned in the foregoing pages.

3.1 Location of the experimental site

The research work was carried out at the research field of Sher-e- Bangla Agricultural University Dhaka during the kharif-1 period from March to June 2017. The experimental field was located at 90° 33' E longitude and 23° 71' N latitude at a height of 9 m above the sea level. The land belongs to the Agro-ecological zone "Madhupur Tract' (AEZ-28) of Nodda soil series.

3.1.1 Soil

The soil of the experimental site was well drained and medium high. The soil was clay loam in texture and having soil pH varied from 5.41-5.63. Organic matter content was very low (0.83%). The physical composition such as sand silt and clay content were 40%, 40% and 20%, respectively. The physical and chemical properties of soil of experimental field have been presented in Table 1 and Table 2 respectively.

Table 1. Physical composition of the soil

Physical composition	Percentage composition (Air dry basis)	Methods adopted.
Sand coarse sand	51.3	Bouyoucos hydrometer method
Fine sand	30.2	
Silt	8.1	
Clay	10.3	
Texture class	Sandy loam	

Source: BARC, SRDI

Table 2. Chemical composition of the soil

Chemical composition	Amount present (oven dry basis)	Amount present (oven dry basis)
pH	5.4	Digital PH meter with 1:2.5, soil: water
Organic carbon %	0.43	Walkley and black method
Available N (kg/ha)	204.5	Alkaline Potassium permanganate (KMO4) distillation method
Available P (kg/ha)	20.0	Brays – I method
Available K (kg/ha)	110.7	Flame photometer method

Source: BARC, SRDI

3.1.2 Climate

Sher-e-Bangla Agricultural University, Dhaka comes under the 28th agro-climatic region of the country where organic matter content and fertility level is high i.e. characterized by high temperature and heavy rainfall during kharif-1 season. The average annual rainfall of Dhaka is 1854 mm. which is about 80% rainfall occurs from May to September and the rest is received within October to May. The average maximum temperature ranges from 27°-35°C during May to June while the minimum temperature varies from 15-18°C during December to January. The relative humidity varies between 50% in summer and 90% in rainy season. The details of the weather condition during the period of investigation from March to June 2017 have been presented in the Table 3.

Table 3. Meteorological data of Dhaka from March to June 2017

Year	Month	Monthly mean temp. in °C		Monthly mean Relative humidity		Total rainfall in mm	Sunshine hours
		Max.	Min.	Morning	Afternoon		
2017	March	32	20	83	63	65	7
2017	April	34	24	85	64	155	6
2017	May	33	25	87	65	340	5
2017	June	34	27	89	66	335	3

Source: Bangladesh meteorological department (http://www.bmd.gov.bd/)

3.1.3 Experimental details

Preparation of experimental plot

The experimental field was ploughed thoroughly earlier in the season and FYM was applied @ 5t/ha and was incorporated thoroughly in to the soil. Recommended dose of N P and K 30:20:20 kg/ha was applied to the experimental plots before sowing and mixed thoroughly. Fifty percentage of N and all P and K were applied as basal dose and rest of N was applied as top dressing after first weeding and before flowering. Then the plots were laid out as per the plan.

REPLICATION-1	REPLICATION-2	REPLICATION-3
T_1	T_5	T_4
T_2	T_8	T_1
T_3	T_{10}	T_3
T_4	T_2	T_9
T_5	T_3	T_6
T_6	T_1	T_8
T_7	T_6	T_5
T_8	T_9	T_2
T_9	T_4	T_7
T_{10}	T_7	T_{10}

Figure 1. Experimental Plot Layout

3.1.4 Design of experiment

The experiment was carried out in randomized block design with 12 treatments and replicated thrice.

Table 4. Experimental Design.

Design	RCBD
No. of Replication	Three
Plot size (Gross)	4.0m x 2.5m
Date of Sowing	20.03.2018
Spacing	30 cm. x 15 cm
Seed Rate	7 Kg/ha

3.1.5 Collection of seeds

The variety of sesame used for the present study was BARI Til-3. The seeds of this variety were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur. Before sowing, the seeds were tested for germination in the laboratory and the percentage of germination was found to be over 90%. The important characteristics of this variety is mentioned below

3.1.6 Description of variety

BARI Til-3

Plants are of average 100-110 cm in medium height. Leaves are darker green and rough. Days to maturity medium (85 days). Stem is branched and contains 3-5 branches. The number of capsule per plant is 60-65 and seeds per capsule is 50-55. Maximum yield is 1200-1400 kg/ha. Seeds contain 42-50% oil and 25% protein. 1000 seed weight is 3.0 g.

3.1.7 Details of treatments

Ten treatments were involved in the experiment. These were

T_1: Controlled (RDF N P K 30:20:20 kg/ha)

T_2: T_1 + foliar spray of Boron @ 100ppm ($Na_2B_4O_7.10H_2O$)

T_3: T_1 + foliar spray of Zinc @ 100ppm as ($ZnSO_4$)

T_4: T_1 + foliar spray of Mo @ 50ppm as ($NH_4Mo_7O_{24}.\ 4H_2O$)

T_5: T_1 + foliar spray of Cu @ 100ppm as ($CuSO_4\ .5H_2O$)

T_6: T_1 + foliar spray of Fe @ 100ppm as ($FeSO_4.7H_2O$)

T_7: T_1 + foliar spray of Mn @ 100ppm as ($MnSO_4\ .H_2O$)

T_8: T_1 + foliar spray of Co @ 50ppm as ($Co(NO_3)_2$)

T_9: T_1 + Mixture of all above micronutrient

T_{10}: T_1 + foliar spray of Commercial micronutrient mixture (5 mL/2L H_2O)

3.2 Intercultural operation

3.2.1 Thinning

To maintain optimum plant population in the experimental field, thinning was done after 15 days of seedling emergence to keep plant to plant distance 15 cm in each line.

3.2.2 Weeding

Weeding was done with thinning to keep the plots weed free through hand weeding. Generally, 3 weeding were adequate for this purpose and the second dose of nitrogen was top dressed after the last weeding.

3.2.3 Irrigation

Irrigation was given as when needed. From sowing till harvest six number of irrigations were applied to the crop.

3.2.4 Foliar application

Solutions of different concentrations of micronutrients as per treatments were prepared in deionized water and were sprayed twice at 45 and 60 DAS.

Table 5. Calendar of field operation

Date	Field operation
11.03.2017	Collection of soil sample
13.03.2017	Ploughing
17.03.2017	Application of FYM and Fertilizer
19.03.2017	Layout and leveling
20.03.2017	Sowing
21.03.2017	Irrigation
03.04.2017	2nd Irrigation
08. 04.2017	Thinning
09. 04.2017	Hoeing and weeding
10. 04.2017	Top dressing
11. 04.2017	Earthing Up
13. 04.2017	3rd irrigation
23. 04.2017	4th irrigation
05.05.2017	1st Foliar application
10.05.2017	Sampling of plant
13.05.2017	5th irrigation
20.05.2017	2nd Foliar application
27.05.2017	Sample collection
23.06.2017	6th irrigation
25.06.2017	Harvesting

3.3 Pre harvest observations

3.3.1 Sampling techniques

Plants were sampled from a unit area of 0.30 m^2 5 no. of plants at random from each plot leaving sufficient border rows around it. The plant parts were separated and sun dried. Then dried in a hot air oven at 80^0 C for 72 hrs. till constant weight. The dry weight of different plant parts were recorded**.**

3.3.2 Growth observations

The following observations were recorded at 45, 60 and 90 DAS.

3.3.2.1 Plant height

Height of the main shoot was measured from the base of the main shoot up to the tip of the top most leaf, averaged out and expressed in cm.

3.3.2.2 Number of branches per plant

Primary branches developing from the main shoot were considered as the criteria of observation.

3.3.2.3 Leaf area

Systronics leaf area meter model 211 was used for measuring leaf area. For this all the leaflets from each of the sample plants were detached and their area (one side) was recorded to compute leaf area per plant and expressed (cm^2/plant).

3.4 Physiological growth parameters

3.4.1 Leaf Area Index (LAI)

LAI is expressed as the ratio of the leaf area (A) (only one side) to the ground area (P) occupied by the crop.

$$\mathbf{LAI = A / P}$$

3.4.2 Leaf Area Duration (LAD)

LAD is defined as the leaf area index integrated over time

$$LAD = \frac{A_1 + A_2}{2} \times (t_2 - t_1)$$

Where, A_1 = Leaf area index at the start of test period

A_2 = Leaf area index at the end of test period

$t_2 – t_1$ = Period in days between initial and final observation

3.4.3 Leaf area ratio (LAR)

LAR is defined as the ratio between leaf area (A) and total plant dry weight (W). It reflects the leafiness of a plant.

$$\mathbf{LAR = A_L / W}$$

3.4.4 Specific leaf weight (SLW)

SLW is the ratio between leaf dry weight (W_L) and leaf area (A)

$$\mathbf{SLW = W_L / A}$$

3.4.5 Specific Leaf Area (SLA)

SLA is the ratio between leaf area (A) and leaf dry weight (W_L).

$$\mathbf{SLA = A / W_L}$$

3.4.6 Relative Growth Rate (RGR)

Relative Growth Rate (RGR) is defined as the total plant dry weight increase in a time interval in relation to the initial weight or Dry matter increment per unit biomass per unit time or milligrams of dry weight increase per gram of dry weight increased per gram of original weight per unit time and expressed as unit dry weight / unit dry weight / unit time (mg/ g/day).

$$\text{RGR} = \frac{lnW_{2-}lnW_1}{T_{2-}T_1}$$

Where, $\mathbf{W_1}$ = whole plant dry weight at t_1

$\mathbf{W_2}$ = whole plant dry weight at t_2

$\mathbf{T_2 – T_1}$= time interval in days

3.4.7 Net Assimilation Rate (NAR)

NAR is defined as dry matter increment per unit leaf area per unit time and expressed as mg/cm^2/day.

$$\text{NAR} = \frac{(\mathbf{W - W1})}{(\mathbf{t_2 - t\,1})} \times \frac{(\boldsymbol{lnL_{2-}lnL_1})}{(\boldsymbol{L_{2-}L_1})}$$

Where, W_1 = dry weight of whole plant at time t_1

W_2 = dry weight of whole plant at time t_2

L_1 = leaf area at t_1

L_2= leaf area at t_2

$t_1 - t_2$ = time interval in days between initial and final observations

3.4.8 Crop Growth Rate (CGR)

The CGR explains the dry matter accumulated per unit land area per unit time ($g/m^2/day$).

$$CGR = \frac{(W_2 - W_1)}{\rho\ (t_2 - t_1)}$$

Where, $\mathbf{W_1}$ = whole plant dry weight at time t_1

$\mathbf{W_2}$ = whole plant dry weight at time t_2

$\mathbf{t_2 - t_1}$ = time interval in days

$\boldsymbol{\rho}$ = ground area on which W_1 and W_2 were recorded.

CGR of a species are usually closely related to interception of solar radiation.

3.5 Chemical constituent

3.5.1 Estimation of chlorophyll content

Chlorophyll a, b and total chlorophyll content in the leaves were firm by using the method stated by Arnon (1949). The second leaf from the top was sampled for the purpose. The collected leaf samples were nearly kept in moist polythene bags to keep them turgid. Exactly 100 mg of fresh leaf was taken from the middle portion of the leaf and were cut into minor pieces. The leaf discs were then put in 80 % v/v acetone solution. The vial is covered by aluminium foil kept in dark for 24 hours. Then the content was filtered by Whatman No.1 filter paper and the filtrate was used to record the absorbance (OD) at 645 nm and 663 nm. The respective chlorophyll content was calculated using the following formula and expressed as mg g^{-1} FW leaf.

$$\text{Chlorophyll-a} = (12.7 \times OD663 - 2.69 \times OD645) \times \frac{V}{1000 \times Wf}$$

$$\text{Chlorophyll-b} = (22.9 \times OD645 - 4.68 \times OD663) \times \frac{V}{1000 \times Wf}$$

$$\text{Total Chlorophyll} = (20.2 \times OD645 - 8.02 \times OD663) \times \frac{V}{1000 \times Wf}$$

Where, OD645 = OD value at 645 nm

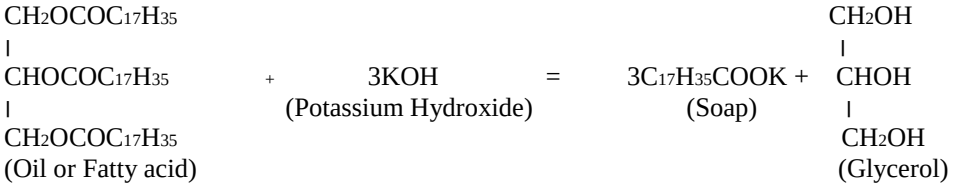
OD663 = OD value at 663 nm

V= Total volume of extract (ml)

Wf = Fresh weight of leaf (g)

3.5.2. Saponification value

Saponification value is the number of milligrams of KOH required to entirely saponify 1 g of oil. The method is based upon the principle that fat, on conduct with excess of alcoholic KOH is used up. The excess of KOH left unused may then be found by titrating it against a standard acid.(Mortvedt JJ *et al.* 1999)



Reagents

1. Hydrochloric acid 0.5N

2. Alcoholic solution of Potassium hydroxide. 28 g potassium hydroxide are taken and dissolved it in very little water. Make up to one liter by adding rectified spirit (C_2H_5OH) of specific gravity 0.81.

Procedure

1. Weight accurately 2 g of fat in 250 mL conical flask. Add 25 mL of 0.5 N alcoholic potash solutions and fit the flask with a cork and a long air condenser.

2. Reflux the contents of the flask for about 30 minutes by heating on boiling water bath so that the contents just simmer. Cool the flask and add 1 ml of 1% solution of phenolphthalein and titrate the excess of the alkali against standard N/2 acid (a).

At the same time and under similar conditions carry out a blank expt. (b) without fat (25 mL of the same alcoholic KOH heated in a similar way is titrated, against .05 N acid). 1 mL of 0.5 N HCL was equivalent to 0.02805g of KOH.

Calculation

$$\text{Saponification value} = \frac{(b-a)\text{x } 0.02805 \text{ x } 1000}{\text{Wt.of substance in g}}$$

3.5.3 Acid value

Acid value of oil is determined by titration of a known weight of it against N/.4 sodium hydroxide using phenolphthalein as the indicator.

$$C_{17}\ H_{33}COOH + NaOH = C_{17}\ H_{33}COONa + H_2O$$

Reagents

1. Phenolphthalein: 1 percent solution in alcohol neutralized with 0.1 N NaOH.
2. Denatured alcohol (Neutral): Mix 10 volumes of ethyl alcohol with 1 volume of methyl alcohol and neutralize with N/40 NaOH using phenolphthalein as indicator.
3. N/4 Sodium hydroxide and N/10 Sodium hydroxide.

Procedure

Weigh 5-7 g of oil in 250 mL conical flask and add 50 mL denatured alcohol (neutral) and shake well. Now add 2 mL of phenolphthalein as indicator and titrate against N/4 NaOH with vigorous shaking after each addition till a permanent light pink color is produced which persists for at least 1 minute (a).

$$\text{Acid value} = \frac{\text{a x } 0.00561}{\text{Wt.of oil}}\ x\ 1000$$

3.5.4 Estimation of fatty acid composition

Seed sample of sesame were received from ORC, BARI, Joydebpur, Gazipur. Fatty acid composition was determined by Gas-liquid chromatographic method.

Reagent

1. Ethylate reagent (Petroleum ether / 0.02M sodium hydroxide in ethanol (2/3)
2. A Salt solution (80 g NaCl and 3g Sodium hydrogen Sulphate in 1 litre water)

Procedure

1. About 12 mg of oil or equivalent amount of oil seeds was taken (seed was crushed in an oil paper and then transferred into a test tube).

2. The sample was extracted and transesterified at the same time with 5 mL ethylated reagent and shaked.
3. The samples were kept for overnight at room temperature.
4. 10 ml salt solution was added and shaked. As soon as the two layers were separated, the benzene phase was transferred to small test tubes.
5. A Philips PU 4500 chromatograph instrument was used with flame ionization detector (FID).
6. A glass column (1.5m x 4mm) was packed with BDS. With this column the injection post, column and detector temperature was set at 220$_o$ C, 185$_o$ C and 240$_o$ C, respectively.
7. Nitrogen flow (used as career gas) rate was 22 ml/min, the injection volume was 2µl.
8. Peak areas were measured with an electronic digital integrator (Shinadzu C-R6A chromatopac).

3.5.5 Estimation of total protein content by Microkjeldhal method

The protein content of food stuff is obtained by estimating the nitrogen content of the material and multiplying the nitrogen value by 6.25 (according to the fact that nitrogen constitutes on average 16% of a protein molecule). This is referred to as crude protein content, since the non-protein nitrogen (NPN) present in the material is not taken in consideration. The estimation of nitrogen is done by Kjeldhal method which depends upon the fact that organic nitrogen when digested with sulphuric acid in the presence of catalyst selenium oxide, mercury or copper sulfate is converted into ammonium sulphate. Ammonia liberated by making the solution alkaline is distilled into a known volume of a standard acid which is then back titrated.
The nitrogen present in the sample is converted to ammonium sulphate by digestion at (380 oC) with sulphate acid in presence of a catalyst, potassium sulphate and mercuric oxide. Ammonia liberated by distilling the digest with sodium hydroxide solution is absorbed by boric acid and is titrated for quantitative estimation.

Equipments

1. Balance
2. Microkjeldhal (Mkj) digestion set
3. Mkj distillation set.

Reagents

1. Digestion mixture: 100 g of potassium sulphate (K_2SO4) was thoroughly mixed with 20 g of copper sulfate ($CuSO_4.5H_2O$) and 2.5 g selenium dioxide (SeO_2) was added with it.
2. 60% Sodium hydroxide solution: 600 g sodium hydroxide and 50 g sodium thiosulphate were dissolved in distilled water, cooled and made the volume up to 1 liter.
3. Boric acid: 40 g of boric acid was dissolved in water and made up to 1 liter.
4. Double indicator: 200 mg each methyl red and bromocresol green was dissolved separately in 100 ml of 70% ethanol. One part of methyl red and five parts of bromocresol green were mixed before use.
5. Hydrochloric acid (0.02 N HCl): 8.5 ml concentrated hydrochloric acid was added to 5 liter of distilled water. Standardized to 0.02 N acids by titrating it against standard sodium carbonate (0.02 N) solution.

Procedure

A known quantity of the finely mustard ground sample (100 mg) weighted out in an Mkj digestion flask. About 2 g digestion mixture was added with it 2 ml of concentrated sulphuric acid was dispensed into the flask. Then it was digested for about 2 hrs in Mkj digestion set and was cooled the clear digest. The digest was dissolved in minimum amount of distilled water and carefully transferred to an Mkj distillation set. 10 ml of sodium hydroxide solution was added and distilled it. The distillate was collected for 5 min into 5 ml boric acid containing 2 drops of mixed indicator in a 50 ml conical flask, till the color of solution was changed. The distillate was titrated against a standard hydrochloric acid and noted the titer value (TV).

Calculation

$$N\ \% = \frac{(14.007)\ x\ (\text{normality of the acid},0.02)\ x\ (TV)}{\text{Weight of sample (mg)}}\ x100$$

Where 14.007 is the equivalent weight of nitrogen. Nitrogen % is converted into protein by multiplying with a factor 6.25 for cereals and pulses.

Viscosity measurements

A rheometer as described by Nzikou *et al.* (2007) was used to measure the different oil viscosities. By this procedure, a concentric cylinder system is submerged in the oil and the force necessary to overcome the resistance of the viscosity to the rotation is measured. The viscosity value, in mPa.s, is automatically calculated on the basis of the speed and the geometry of the probe. Temperature (20°C) was controlled with awater bath connected to the rheometer. The experiment was carried out by putting 3 mL of sample in a concentric cylinder system using 100 sG1 as shear rate.

3.6. Estimation of Chemical content

3.6.1. Estimation of seed nitrogen content of different plant parts

Nitrogen content of different plant parts at harvest were estimated by following the procedure of AOAC (1970). 200mg of dry and powdered plant samples were taken in 100ml digestion tube. About 200mg of digestion mixture (K_2SO_4:$CUSO_4$= 5:1) and 4ml of concentrated sulphuric acid (H_2SO_4) were added. These tubes were kept as such for about 1hr and transferred the digestion tubes into digestion unit, then heated slowly till frothing occurred. To check the frothing, two crystals of sodium thiosulphate were added to each digestion tube. Thereafter, digestion was continued until the contents of the tubes became completely cleared blue syrupy liquid without any bubbling. The tubes were cooled and 10 mL of distilled water was added to it and mixed thoroughly. The digestion tubes were cooled by running tap water over the outside surface of tube and transferred the content to 50 mL volumetric flask. The digestion tubes were ringed with about 5 mL distilled water twice and transferred to the same volumetric flask and volume was made up to 50 mL and kept it for sample analysis. 10ml of diluted sample extract was transferred in to a microkjeldahl distillation unit. Then followed by 10 ml of 40% NaOH and distillation was continued for 10 minutes. During distillation liberated ammonia was absorbed by 10ml of saturated boric acid present in a 150 mL uncial flask containing 2 drops of mixed indicator. After completion of distillation, the distillate was titrated against 0.05 N HCL.

Calculation

$$\textbf{\% of nitrogen in the sample} = \frac{(\textbf{sample titer} - \textbf{blank titer}) \times \textbf{N of HCL} \times 14 \times 100 \times 5}{\textbf{Sample wt.(g)} \times 1000}$$

3.6.2 Estimation of phosphorus and potassium contents of plant sample

Digestion of plant sample for determination of phosphorus and potassium

1g powdered plant sample was taken in 100mL conical flask separately. To each flask 10ml of ternary acid mixture (HNO_3+ H_2SO_4+ $HClO_4$ = 5:1:2) was added and pre-digested slowly for 15 minutes on a hotplate. Gradually heat was increased and digestion was continued till content became clear and white fumes encircle inside the flask. Then content was cooled and 30 ml distilled water was added. The contents were transferred to 50mL volumetric flask and volume was made up to 50mL with distilled water and the aliquot was filtered through whatmann no. 1 filter paper. The filtrate was kept for the estimation of phosphorus and potassium present in plant sample.

3.6.3 Estimation of phosphorus present in plant sample

Phosphorus present in plant sample was estimated by adopting the procedure of Jackson 1973.

Sample analysis

Standards of 0, 2, 4, 6, 8, 10 and 12mL of 25ppm phosphorus solution and 2mL of digested sample extracts were taken in 25mL volumetric flask separately. 5mL of 2N HNO_3 solution was added to each flask. Then required amount of distilled water was added to each flask to make the final volume 15 mL. thereafter 2.5 mL molybdate vanadate solution was added. Final volume was made up to 25 mL with distilled water and flasks were shaken well thoroughly. Absorbance was measured by a spectrophotometer at 420 nm after 20 mins of shaking. The phosphorus content of plant sample was calculated in percentage by using the standard curve.

3.6.4 Estimation of potassium present in plant sample

1mL of digested sample extract was taken in a 25 mL volumetric flask and the volume was adjusted to 25 mL with distilled water. Similarly 1,2,3,4,5 ppm standard solution were prepared by diluting 1,2,3,4,5 ml of 100 ppm of K solution (i.e 0.1907g of KCL per litre) in 100mL volumetric flask with water. The readings for standards and samples were taken in a digital flame photometer. As per the standard curve, the ppm of potassium present in the extracted solution was calculated. Then the percentage of potassium presents in plant and seed samples were estimated.

3.6.5 Estimation of oil content

The oil percentage in seed sample was determined by soxhlet apparatus. 2g of crushed seed was taken in a thimble put in a soxhlet extraction apparatus connected with a pre weight extraction flask containing 250mL petroleum ether. Then the flask was heated for 1hr the solvent petroleum ether circulated through the condenser of soxhlet apparatus over the entire reflushing period. Then the receiving flask was detached and again attached with another condenser to recollect the pure petroleum ether in another flask. The remained petroleum ether with oil in the previous flask was heated to make the oil free from petroleum ether. Then the weight of the extraction flask with oil was taken and the % of oil content was determined.

Calculation

$$\text{Oil content (\%)} = \frac{\mathbf{W_0}}{\mathbf{W_s}} \text{ x } \mathbf{100}$$

W_0 = weight of oil extracted in grams

W_s= weight of seed in grams

3.6.5 Oil content in seed Post harvest studies

3.6.6 Capsules per plant

Matured capsule from ten sample plants were detached, counted and averaged per plant.

3.6.7 Shelling percent

The weight of seed obtained from 100 gm dry pods from each treatments replication wise was recorded to calculate shelling %.

3.6.8 Thousand seed weight

One thousand seeds were selected randomly replication wise from each treatment and the weight was taken.

3.6.9 Seed yield

Seeds were collected from 10 samples and weight recorded to compute seed yield per plant. Plants were cut from base at maturity from each plot and sundried. Seeds were collected after threshing and seed yield per plant and per hectare was calculated.

3.7 Harvest index

$$\textbf{HI} = \frac{\textbf{Seed yield}}{\textbf{Total dry matter of plant}} \times 100$$

3.8. Statistical analysis

Analysis of variance

The data collected from the experiment on various aspects of growth, yield and yield attributing characters of groundnut were arranged in appropriate tables according to the treatments and were subjected to statistical analysis appropriate to the design (Panse and Sukhatme, 1985). Values represented are the means and standard deviations for three replicates. Statistical analysis was carried out by Excel Version 8.0 software. Significance was defined at $P < 0.05$. The treatment variations were tested for significance of F test. The standard error of mean {SE (m)} and critical difference (CD) at 5% were calculated as

$$\text{SE (m)} = \sqrt{(\text{EMS} \div r)}$$

Where EMS = error mean sum of square

R = number of replication

$$\text{CD (0.05)} = \text{SE (m)} \times \sqrt{2} \times \text{t (0.05) at error d.f.}$$

CHAPTER IV

RESULTS AND DISCUSSION

Field experiment was conducted at central farm at SAU, Dhaka, during Kharif-1 2017 with 10 treatments replicated thrice in a Randomized Block Design to study the "Effect of foliar application of micronutrients on growth, yield and oil quality of sesame (*Sesamum indicum* L.)". The morphological, physiological and biochemical observations taken at various growth stages during the course of investigation were recorded, statistically analyzed and presented in this chapter with appropriate tables and figures.

4.1 Morphological Growth Parameters

4.1.1 Plant height and branches per plant

Plant height and branches per plant recorded at 45, 60 and 90 DAS (table 6) revealed that height and number of branches increased with age of the plant up to 90 DAS. Irrespective of treatments maximum rate of elongation and formation of branches occurred during 45 to 60 DAS as compared to 60 to 90 DAS.

Plant height varied among the treatments at all the 3 stages of crop growth. Foliar application of micronutrients significantly increased the plant height which varied a minimum height of 61, 91.3 and 95.2 cm in control (T_1) to a maximum of 76.9, 108.8 and 109.1 cm in (T_9) at 45, 60 and 90 DAS respectively. Foliar application of all micronutrients combination (T_9) registered the highest plant height followed by foliar application of Zn (T_3), B (T_2), and Mo (T_4) among the treatments at all the growth stages. Application of micronutrients as foliar spray significantly increased number of branches per plant as recorded at different growth stages (table 6). Minimum number of branches per plant was recorded in control (T_1) and the maximum number of branches per plant was recorded in combined application of micronutrients (T_9). Foliar spray of all the micronutrients alone or in combination as well as their commercial mixture significantly increased number of branches over control except the application of Cu (T_5). Significantly the highest number of branches (T_8) per plant was recorded in plants sprayed with the treatments combined micronutrients (T_9) followed by Zn (T_3), B (T_2) and Mo (T_5).

Table 6. Effects of different micronutrients on plant height (cm) and number of branches per plant at different growth stages

Treatments	Plant height (cm)			No. of branches /plant		
	45DAS	**60DAS**	**90DAS**	**45DAS**	**60DAS**	**90DAS**
T1	61.0	91.3	95.2	2.0	3.3	4.0
T2	70.6	104.5	106.3	4.6	6.6	7.3
T3	73.5	104.9	107.1	5.3	6.0	7.3
T4	69.3	101.4	106.0	4.0	5.3	6.6
T5	62.9	95.5	96.7	2.6	4.0	6.0
T6	66.4	96.7	98.5	3.3	5.3	6.0
T7	68.1	100.1	100.5	4.0	4.6	6.6
T8	67.0	98.8	99.0	3.3	4.6	6.0
T9	76.9	108.8	109.2	6.0	8.0	8.0
T10	66.2	101.4	102.6	4.0	5.3	7.3
SE(m)±	**0.586**	**0.749**	**1.499**	**0.225**	**0.307**	**0.372**
LSD(0.5)	**1.94**	**2.82**	**4.85**	**0.87**	**0.99**	**1.36**

LSD(0.5): Least Significance Difference ., **SE(m)±:**Standard Error

4.1.2 Dry matter accumulation and its partitioning

Dry matter accumulation and its partitioning into different plant parts were recorded at 45, 60, and 90 DAS were presented in table 7. Data revealed that there was concomitant increase in total dry matter (TDM) accumulation till 90 DAS alternatively it's partitioning to different parts like leaf, stem and pod increased up to 60 DAS alternatively at 90 DAS partitioning of TDM was less to the leaf compared to stem and pod.

Foliar application of all the micronutrients and their combination significantly increased leaf dry matter (LDM), stem dry matter (SDM), pod dry matter (PDM) and total dry matter (TDM) of plants recorded at 45, 60 and 90 DAS over control except foliar application of Cu (T_5), Fe (T_6) which found at par with control with respect to total dry matter (TDM) and its partitioning to different plant parts at various growth stages. Significantly the highest accumulation of dry matter in leaf , stem, pod as well as in whole plant recorded at all the growth stages in plant applied with foliar spray of treatments T_9 followed by foliar application of T_3 and T_2. The pattern of partitioning of TDM at 45 and 60 DAS are same i.e. stem > leaf > pod whereas pattern of partitioning of TDM was in a sequence of pod > stem > leaf at 90 DAS.

4.2 PHYSIOLOGICAL TRAITS

4.2.1 LAI, SLA, SLW and LAR

Growth parameters like LAI, SLA, SLW and LAR determined at 45 and 60 DAS were presented in table 8. Data indicated that higher value of LAI and SLW were found at 60 DAS where as higher value of SLA and LAR were noticed at 45 DAS in all the treatments.

Leaf area index (LAI) increased significantly due to foliar application of micronutrients which was ranged 0.91 (T_1) to 1.35 (T_9) at 45 DAS and 1.08 (T_1) to 2.24 (T_9) at 60 DAS. In both the stages (45 and 60 DAS) significantly the highest LAI was recorded in plants sprayed with T_9 followed by application of T_3, T_2, T_4 and T_{10}.

Table 7. Effect of different micronutrients on Dry matter accumulation (g/plant) and its partitioning

Treatments	45 DAS				60 DAS				90DAS			
	LDM	**SDM**	**PDM**	**TDM**	**LDM**	**SDM**	**PDM**	**TDM**	**LDM**	**SDM**	**PDM**	**TDM**
T1	0.95	0.90	0.08	1.95	1.93	3.08	2.80	7.81	1.71	4.31	4.42	10.44
T2	1.51	1.68	0.32	3.52	3.27	5.50	5.50	14.27	2.95	7.01	10.27	20.23
T3	1.59	1.69	0.25	3.54	3.90	5.56	5.30	14.76	3.73	7.63	10.14	21.50
T4	1.49	1.64	0.22	3.37	3.12	4.57	4.40	12.09	2.83	5.88	8.21	16.92
T5	1.09	1.11	0.10	2.30	2.11	3.97	3.30	9.38	1.96	4.37	5.90	12.23
T6	1.27	1.23	0.11	2.62	2.67	4.13	3.50	10.30	1.77	4.79	6.59	13.15
T7	1.33	1.50	0.19	3.03	2.83	4.31	3.60	10.74	2.56	5.50	7.63	15.69
T8	1.32	1.48	0.12	2.93	2.80	4.29	3.50	10.59	2.64	5.18	7.14	14.96
T9	1.92	1.72	0.36	4.01	4.26	7.16	6.90	18.32	4.09	8.40	13.40	25.89
T10	1.49	1.55	0.20	3.24	2.88	4.34	4.30	11.52	2.77	5.85	7.59	16.21
SE(m)±	**0.014**	**0.003**	**0.015**	**0.183**	**0.171**	**0.268**	**0.303**	**0.690**	**0.158**	**0.341**	**0.479**	**0.979**
LSD(0.5)	**0.04**	**0.008**	**0.04**	**0.54**	**0.50**	**0.79**	**0.90**	**2.05**	**0.47**	**1.01**	**1.42**	**2.90**

LSD(0.5): Least Significance Difference ., **SE(m)+:**Standard Error

Table 8. Effect of different micronutrients on LAI, SLA, SLW, LAR at different growth stages

Treatments	LAI		SLA(cm^2/g)		SLW(mg/cm^2)		LAR(cm^2/g)	
	45 DAS	**60 DAS**	**45DAS**	**60 DAS**	**45DAS**	**60 DAS**	**45DAS**	**60 DAS**
T1	0.91	1.08	428.8	252.8	2.33	3.95	210.4	62.4
T2	1.08	1.77	324.2	244.4	3.08	4.09	139.0	56.0
T3	1.13	2.10	319.0	243.2	3.13	4.11	143.7	64.2
T4	1.09	1.65	329.2	239.1	3.03	4.18	146.4	61.7
T5	0.98	1.33	405.0	284.3	2.46	3.51	191.6	63.9
T6	1.00	1.38	353.6	233.6	2.82	4.28	171.7	60.5
T7	1.06	1.63	360.1	259.7	2.77	3.84	158.3	68.4
T8	0.98	1.32	335.3	213.0	2.98	4.69	151.7	56.3
T9	1.35	2.24	317.3	237.4	3.15	4.21	151.9	55.2
T10	1.07	1.64	321.9	257.0	3.10	3.89	148.2	64.2
SE(m)±	**0.052**	**0.053**	**0.641**	**0.606**	**0.082**	**0.001**	**0.475**	**3.382**
LSD(0.5)	**0.15**	**0.15**	**1.90**	**1.79**	**0.24**	**0.002**	**1.41**	**NS**

LSD(0.5): Least Significance Difference ., **SE(m)+:**Standard Error

Specific leaf area (SLA) was recorded at 45 and 60 DAS differed significantly among the treatments. At 45 DAS the highest SLA 428.8 cm^2/g was recorded in T_1 and lowest 317.3 cm^2/g in T_9 where as at 60 DAS the SLA was highest 284.3 cm^2/g in T_5 and the lowest 213 cm^2/g recorded in T_8. Though significant difference in SLA was observed among the treatments in both the stages but no definite trend in influence of micronutrient spray on SLA was observed at both stages.

Specific leaf weight (SLW) recorded at 45 and 60 DAS differed significantly among the treatments. Foliar application of most of the micronutrients alone or in combination significantly increased SLW over control. At 45 DAS the maximum SLW 3.15 mg/cm^2 recorded in plants applied with foliar spray of T_9 followed by T_3, T_{10} and T_2 where as at 60 DAS, the highest SLW 4.69 mg/cm^2 was recorded in Co T_8 followed by T_6 and T_9. The lowest value of SLW was recorded in T_1 at 45 DAS and in T_5 at 60 DAS.

Leaf area ratio (LAR) recorded at 45 and 60 DAS varied among the treatments. The highest LAR 210.4 and the lowest 139 cm^2/g were recorded in T_1 and T_2 respectively at 45 DAS. Whereas highest LAR 68.4 and lowest 55.2 cm^2/g were recorded in foliar spray of T_7 and T_9 respectively at 60 DAS. Though LAR differed among the treatments recorded at both the stages, but no definite influence of micronutrient spray on LAR was observed.

4.2.2 RGR, NAR, CGR and LAD

RGR, NAR, CGR and LAD determined between 45 and 60 DAS were depicted in table 9. Relative growth rate (RGR) increased with foliar spray of most of the micronutrients over control but significant increase was recorded (101.3 mg/g/day) in sprayed T_9 followed by T_3. Net assimilation rate (NAR) significantly influenced by foliar application of micronutrients. The significant increase in NAR over control was observed in case of foliar spray of all the micronutrients except T_7 which was at par with control. The highest NAR 1.2 mg/cm^2/day was recorded in T_9 followed by T_2 and T_3.

Table 9. Effect of different micronutrients on RGR, NAR, CGR and LAD at different growth period

Treatments	RGR(mg/gm/day)	NAR(mg/cm^2/day)	CGR(g/m^2/day)	LAD
	45-60 DAS	**45-60 DAS**	**45-60 DAS**	**45-60 DAS**
T1	92.5	0.87	8.7	14.97
T2	93.2	1.13	15.9	21.49
T3	95.0	1.05	16.6	24.31
T4	85.2	0.95	12.9	20.66
T5	93.5	0.91	10.5	17.37
T6	91.2	0.96	11.4	17.90
T7	84.4	0.85	11.4	20.24
T8	85.5	0.98	11.3	17.36
T9	101.3	1.20	21.1	27.01
T10	84.4	0.91	12.2	20.36
SE(m)±	**0.763**	**0.001**	**0.760**	**0.596**
LSD(0.5)	**2.26**	**0.002**	**2.58**	**1.77**

LSD(0.5): Least Significance Difference **., SE(m)+:**Standard Error

Crop growth rate (CGR) was significantly increased by application of different micronutrients as foliar spray. Among the treatments the maximum CGR 21.1 g/m^2/day was registered in plants applied with T_9 followed by T_3, T_2 and T_4. The lowest CGR was recorded in T_1 where no micronutrient was applied.

Leaf area duration (LAD) was influenced significantly by foliar application of micronutrients. Among the treatments the highest LAD 27.01 was registered in T_9 followed by application of Zn (24.31), B (21.49), and Mo (20.66). The lowest LAD was recorded in control plant without T_1.

4.2.3 Chlorophyll index and total chlorophyll content

Chlorophyll index and total chlorophyll content of leaf were recorded at 45 and 60 DAS presented in table 10. The data revealed that, the chlorophyll index and total chlorophyll content of leaf were more at 60 than 45 DAS.

The chlorophyll index differed significantly between control and micronutrient applied plants. The index varied with the lowest value of 8.16 (T_1) to highest value of 13.39 (T_9) at 45 DAS and lowest value of 8.99 (T_1) to highest value of 17.74 (T_9) at 60 DAS among the treatments. Foliar application of all the micronutrients alone or in combination as well as their commercial mixture significantly increased the chlorophyll index over control except application of T_5, which was at par with control. Among the treatments, the highest chlorophyll index was recorded in T_9 followed by T_3, T_2, and T_4 at both of the growth stages.

Like chlorophyll index similar trend was also observed for total chlorophyll content of leaf at both 45 and 60 DAS, which varied with the lowest value of 1.27 and 1.61 mg/g fresh wt. in T_1 and highest value of 1.67 and 1.93mg/g fresh wt. in T_9 at 45 and 60 DAS respectively. Almost all the treatments of micronutrients showed significantly greater chlorophyll content over control except application of T_5 which was found at par with control. Among the treatments, T_9 showed the maximum chlorophyll content followed by T_3, T_2 and T_4 at 45 and 60 DAS.

Table 10. Effect of different micronutrients on chlorophyll index and total chlorophyll content at different growth stages

Treatments	chlorophyll index		total chlorophyll content(mg/g fresh weight)	
	45 DAS	**60 DAS**	**45 DAS**	**60 DAS**
T_1	8.16	8.99	1.27	1.61
T_2	12.91	16.6	1.57	1.90
T3	13.19	17.2	1.65	1.91
T_4	11.94	14.58	1.56	1.86
T_5	9.54	10.11	1.35	1.69
T_6	10.83	13.11	1.48	1.79
T_7	11.15	13.33	1.49	1.85
T_8	10.22	12.06	1.47	1.76
T_9	13.39	17.74	1.67	1.93
T_{10}	11.16	14.21	1.53	1.85
SE(m)±	**0.653**	**0.548**	**0.047**	**0.003**
LSD(0.5)	**1.93**	**1.62**	**0.14**	**0.009**

LSD(0.5):Least Significance Difference ., SE(m)+:Standard Error

4.3 Uptake of N, P, K in Plant

4.3.1 N Content and Uptake

Nitrogen (N) content in different plant parts and its uptake were estimated at harvest and presented in table 11. N content (%) in various plant parts varied among the treatments and ranged a maximum of 1.4 to a minimum of 0.52 % in leaf, 0.17 to 0.10 % in stem and 1.96 to 1.08 % in seed. Among the treatments the highest N content was recorded in T_9 and lowest in T_1. Irrespective of treatments N content in different plant parts were found in the order of seed N content >leaf>stem. Significant increase in N content was observed in all the plant parts with foliar application of micronutrients over control except in seed where application of T_5 and T_7 were with control. Among the treatments foliar application of T_9 registered significantly the highest N content in leaf, stem and seed followed by T_2, T_{10} , T_3 and Mo (T_4) in that order.

Nitrogen uptake by plant and plant parts differed among the treatments and varied from 8.97, 4.52, 32.67,46.1 mg in T_1 to 57.26, 14.7, 125.6 and 197.5 mg in T_9 by leaf, stem, seed and whole plant respectively. The result indicated that partitioning of N uptake by plant was in the order of uptake in seed > leaf > stem. The lowest uptake of N was recorded in T_1 while all the foliar application of micronutrients increased N uptake significantly. Among all the treatments T_9 registered the highest N uptake followed by T_3, T_2, T_{10} in leaf, T_3, T_2, T_4 in stem T_2, T_{10}, T_3 in seed and T_2, T_3 and T_{10} in whole plant respectively.

4.3.2 P content and uptake

The Phosphorus (P) content and uptake by plant parts and whole plant at harvest were presented in table 12. Irrespective of treatments, P content in different plant parts were found in the order of seed P content > leaf > stem. P content (%) in various plant parts varied among the treatments and ranging from 0.37 to 0.48 % in leaf, 0.23 to 0.34 % in stem and 0.49 to 0.57% in seed. The data revealed that there was significant increase in P content of

Table 11. Effect of different micronutrients on Nitrogen content and uptake

Treatments	Nit	Nitrogen content (%)		Nitrogen uptake(mg/plant)			
	Leaf	Stem	Seed	Leaf	Stem	Seed	Total
T_1	0.52	0.10	1.08	8.97	4.52	32.67	46.1
T_2	1.22	0.15	1.36	36.13	10.51	80.20	126.8
T3	0.98	0.14	1.36	36.55	10.68	74.14	121.3
T_4	0.87	0.14	1.36	24.76	8.23	69.51	102.5
T_5	1.01	0.15	1.22	19.89	6.55	48.32	74.7
T_6	1.15	0.16	1.36	20.44	7.66	55.16	83.2
T_7	0.94	0.15	1.19	24.19	8.25	52.70	85.1
T_8	1.05	0.14	1.29	27.72	7.25	53.41	88.3
T_9	1.4	0.17	1.96	57.26	14.7	125.62	197.5
T_{10}	1.05	0.14	1.68	29.08	8.19	77.73	115.0
SE(m)±	**0.059**	**0.008**	**0.072**	**1.741**	**0.496**	**3.884**	**6.102**
LSD(0.5)	**0.17**	**0.02**	**0.21**	**5.17**	**1.47**	**11.53**	**18.12**

LSD(0.5): Least Significance Difference ., **SE(m)+:**Standard Error

stem over control by foliar application of all micronutrients except T_8 and T_9. Whereas, P content in leaf and seed were found in significant among the treatments.

Phosphorus (P) uptake by plant parts and whole plant showed variation among the treatments at harvest. The P uptake varied from 7.52 to 16.98 mg in leaf, 10.33 to 29.82 mg in stem, 15.82 to 32.86 mg in seed, and 33.67 to 69.23 mg in whole plant. The result indicated that P uptake by plant partitioned in order of P uptake by seed > stem > leaf. Foliar application of all the micronutrients and its combination significantly increased P uptake in leaf over control except T_5 and T_6. Among the treatments, the highest uptake of P in leaf was recorded by application of Zn (16.98mg) followed by T_9 (15.31mg), T_2 (14.21mg), T4 (13.11mg). Foliar application of all the micronutrients significantly increased P uptake in stem over control. Significantly the highest P uptake was recorded 29.82mg in T_2 followed by T_3, T_4, T_9 and T_{10} which were at par among themselves. P uptake by seed and whole plant showed a similar trend in response to foliar application of micronutrients. Maximum P uptake by seed (32.86 mg) and (69.23 mg) per plant in T_9 which followed closely by T_2, T_3 and T_4.

4.3.3 K content and uptake

The Potassium (K) content (%) and uptake by different plant parts and whole plant were presented in table 13. The data revealed that the K content varied from 1.06 to 1.31% in leaf, 1.75 to 1.97% in stem and 0.25 to 0.34% in seed, which indicated that K content in stem > leaf > seed. Among the treatments the highest K leaf content 1.31% was recorded in T_8 and the lowest in T_7. However no significant change in leaf K content was observed among the treatments. Significant increase in K content of stem was recorded due to foliar application of T_2, T_6, T_5 and T_9 over control but the rest of the treatments found non-significant as compared to control. K content in seed didn't differed significantly over control however the highest K content was recorded in T_{10} followed by T_9 and the least was recorded in T_3.

The uptake of Potassium(K) by plant parts and whole plant table 13 revealed that it varied from a minimum of 19.23mg (T_1) to maximum of 53.17 mg (T_9) in leaf, 75.4mg (T_1) to 157.5 mg (T_9) in stem, 9.03mg(T_1) to 21.63mg (T_9) in seed and 103.6mg (T_1) to 232.3 mg (T_9) in whole plant. This indicated that the partitioning of K uptake among the plant parts in the sequence of K uptake in stem > leaf > seed. All the foliar

application of micronutrients enhanced K uptake in different plant parts as well as per plant as compared to control. Foliar application of all the treatments T9 registered the highest K uptake followed by T_3, T_2 and T_{10} in leaf, T_2, T_3, T_4 in stem, T_{10}, T_4 and T_2 in seed and T_3, T_2 and T_4 in whole plant. However foliar application of T_5 and T_6 didn't register any significant change in K uptake per plant as well as in leaf.

Table 12. Effect of different micronutrients on Phosphorous content and uptake

Treatments	Phosphorous content (%)			Phosphorous uptake(mg/plant)			
	Leaf	**Stem**	**Seed**	**Leaf**	**Stem**	**Seed**	**Total**
T1	0.44	0.23	0.52	7.52	10.33	15.82	33.67
T2	0.48	0.34	0.51	14.21	29.82	30.44	68.31
T3	0.45	0.29	0.52	16.98	22.13	28.74	67.86
T4	0.46	0.36	0.56	13.11	21.10	28.82	63.04
T5	0.46	0.33	0.53	8.99	14.26	21.05	44.31
T6	0.46	0.28	0.55	8.25	13.69	22.14	44.10
T7	0.37	0.36	0.56	9.51	20.34	24.82	54.68
T8	0.37	0.24	0.57	9.79	12.93	23.66	46.39
T9	0.37	0.25	0.51	15.31	21.05	32.86	69.23
T10	0.45	0.34	0.49	12.66	19.76	22.80	55.23
SE(m)±	**0.024**	**0.018**	**0.025**	**0.672**	**1.061**	**1.478**	**3.098**
LSD(0.5)	**NS**	**0.05**	**NS**	**1.99**	**3.15**	**4.39**	**9.20**

LSD(0.5): Least Significance Difference **., SE(m)+:**Standard Error

Table 13. Effect of different micronutrients on Potassium content and uptake

Treatments	Potassium content (%)			Potassium uptake (mg/plant)			
	Leaf	**Stem**	**Seed**	**Leaf**	**Stem**	**Seed**	**Total**
T_1	1.12	1.75	0.30	19.23	75.4	9.03	103.6
T_2	1.28	1.97	0.25	37.98	138.4	14.68	191.1
T3	1.26	1.75	0.25	47.09	133.5	13.57	194.2
T_4	1.18	1.81	0.30	33.60	106.5	15.59	155.7
T_5	1.25	1.87	0.26	24.50	81.9	10.25	116.7
T_6	1.21	1.97	0.29	21.46	94.6	11.72	127.8
T_7	1.06	1.83	0.28	27.20	101.0	12.40	140.7
T_8	1.31	1.76	0.30	34.65	91.2	12.37	138.3
T_9	1.30	1.87	0.33	53.17	157.5	21.63	232.3
T_{10}	1.25	1.77	0.34	34.62	103.8	15.73	154.2
SE(m)±	**0.082**	**0.040**	**0.017**	**1.921**	**6.199**	**0.789**	**9.081**
LSD(0.5)	**NS**	**0.11**	**NS**	**5.70**	**18.17**	**2.34**	**26.98**

LSD(0.5): Least Significance Difference ., **SE(m)+:**Standard Error

4.4 Yield, Yield Attributes and Oil Content

Yield, yield attributes and oil content were depicted in table 14. Number of capsules per plant differed significantly among the treatments. It varied from a minimum of 25.1 to maximum 35.8 capsules per plant among the treatments. Foliar application of all the micronutrients significantly increased the number of capsules per plant over control except T_5 and T_6 whereas highest number of capsules was found in T_9 followed by T_2, T_3 and T_4.

Shelling percent varied among the treatments. The highest shelling percent (52.16%) was recorded in T_9 and the lowest (31.85%) in T_1 among the treatments. Foliar application of all the micronutrients showed significant increase in shelling percent over control except T_4 and T_5.

Number of seeds per capsule varied among the treatments and ranged a minimum of 45.8 to a maximum of 55.6. Foliar application of all the micronutrients alone or in combination as well as their commercial mixture significantly increased the number of seeds per capsule over control except application of T_5. Among all the treatments the highest seeds per capsule was obtained in T_9 followed by T_2, T_3 and T_4. Variation in seed size was noticed among the treatments. The highest thousand seed weight (3.22g) and the lowest (2.62g) were recorded in T_9 and T_1 respectively. However no significant difference was observed among the rest treatments with respect to thousand seed weight

Table 14. Effect of different micronutrients on seed yield and its components

Treatments	No. of capsule/plant	Shelling (%)	No. of seeds/capsule	1000 seed weight(g)	Seed yield /plant(g)	Yield kg/ha.	HI (%)	Oil (%)
T1	25.1	31.85	45.8	2.62	3.01	662.6	28.84	43.2
T2	35.2	42.80	52	3.21	5.87	1292.6	29.03	48.6
T3	33	46.43	51.6	3.19	5.43	1195.0	25.26	49.3
T4	31.9	37.97	50.2	3.18	5.09	1120.3	30.09	47.4
T5	26.2	33.13	47.8	3.15	3.94	867.8	32.25	44.6
T6	26.4	38.67	48.6	3.15	4.04	889.1	30.73	45.1
T7	28.0	42.00	49.9	3.17	4.42	974.4	28.21	45.3
T8	26.7	42.22	49.2	3.14	4.12	907.4	27.57	44.9
T9	35.8	52.16	55.6	3.22	6.40	1410.0	24.75	50.2
T10	29.1	39.03	50	3.18	4.62	1017.9	28.54	46.5
SE(m)±	**0.533**	**2.254**	**0.876**	**0.182**	**0.274**	**60.377**	**1.576**	**0.837**
LSD(0.5)	**1.58**	**6.69**	**2.60**	**NS**	**0.81**	**179.36**	**NS**	**2.48**

LSD(0.5): Least Significance Difference ., **SE(m)+:**Standard Error

Seed yield per plant varied among the treatments. Foliar application of micronutrients significantly increased seed yield per plant over control. The highest seed yield (6.40g/plant) was recorded in T_9 followed by T_2 (5.87g), T_3 (5.43g), T_4 (5.09g) per plant. Seed yield per hectare showed similar trend as it was found in seed yield per plant. The highest seed yield 1410 kg per hectare was obtained by combined micronutrients (T_9) which registered 112% higher yield followed by 95% for B (T_2), 80% for Zn (T_3) and 69% for Mo (T_4) over control (T_1).

Harvest index varied in the range between 32.25 and 24.75 but no significant variation was found among the treatments. Variation in oil content was observed among the treatments. Foliar application of T_9 registered the highest oil content followed by Zn , B, Mo and commercial mixture which were significantly higher over control. However no significant difference in oil content was observed in rest of the treatments.

4.5 CHEMICAL COMPOSITION

The proximate analysis data of the leaves, seeds, roots and the whole plant are presented in Table 15. The moisture content of root (6.60%) was significantly different to other parts of the plant while that of the whole plant (4.22%) showed the least content. Both the leaves (5.04%) and the seeds (5.60%) compared well with each other.

Table 15. Proximate composition (%) of various parts of *Sesamum indicum*.

Nutrients	Leaves	Seed	Root	Whole parts
Moisture	5.04 ± 3.37 b	5.60 ± 3.74 b	6.60 ± 4.39 a	4.22 ± 2.81 c
Crude fiber	9.72 ± 6.48 b	6.60 ± 4.39 ac	12.80 ± 8.53 a	8.80 ± 5.87 b
Carbohydrates	56.37 ± 37.59 c	62.23±41.49 ab	67.90 ± 45.26 a	58.86 ± 38.94 b
Crude protein	19.25 ± 12.83 b	16.63 ± 11.09 c	7.88 ± 5.25 d	21.44 ± 14.29 a
Ash	9.62 ± 6.41 a	8.94 ± 0.96 a	4.82 ± 3.22 c	6.68 ± 4.45 b
Fats and Oil	3.88 ± 2.59 b	38.54 ± 25.69 a	2.66 ± 1.77 c	4.54 ± 3.03 b
Dry matter wt.	94.96 ± 63.31 a	94.40 ± 62.93 a	93.40 ± 64.94 a	95.78 ± 68.85 a
Food energy value	337.4±224.93bc	337.40±224.93 bc	327.06 ± 218.1 c	362.06 ± 241.37 a

Test values carrying different letters within a column are significantly different (P > 0.05) using the F- test. Data are expressed as mean ± SD (n = 3).

Table 16. Mineral compositions (%) of various parts of *Sesamum indicum*.

Minerals	Leaves	Seed	Root	Whole parts
Sodium	0.48 ± 0.32 a	0.23 ± 0.23 a	0.33 ± 0.22 a	0.33 ± 0.22 a
phosphorus	0.49 ± 0.38 b	0.55 ± 0.37 a	0.20 ± 0.14 c	0.20 ± 0.14 c
Calcium	1.41 ± 0.94 b	0.90 ± 0.60 c	1.71 ± 1.14 ab	1.71 ± 1.14 ab
Potassium	0.90 ± 0.64 b	1.20 ± 0.80 a	1.03 ± 0.69 a	1.03 ± 0.69 a
Magnesium	0.49 ± 0.38 b	0.24 ± 0.16 c	0.61 ± 0.40 a	0.61 ± 0.40 a

Test values carrying different letters within a column are significantly different (P > 0.05) using the F-test. Data are expressed as mean ± SD (n = 3).

The difference in the concentration of the various elements within the different parts may be attributed to preferential absorbability of the plant for the corresponding elements. In addition, the observed results may be linked to the minerals composition of the soil in which the plant grows and climatology conditions. In leaves, seed, root and whole parts sodium concentration is good. Other mineral composition is at various results. Calcium present in root (1.71%) and whole parts (1.71%).

The present investigation under taken in field condition to study the response of different micronutrients, viz. B, Zn, Mo, Cu, Fe, Mn, Co and their combination as well as commercial mixture as foliar application in Sesame crop. The data relating to various characters studied during course of investigation and interpreted in the preceding chapter were discussed in this chapter under the following heads.

4.6 Morphological growth

Plant height and number of branches which are considered important morphological traits of plant growth were significantly influenced by foliar application of different micronutrients applied either individually or in combination presented in table-4. Among all the treatments the height was maximum 77,108 and 109 cm at 45 ,60 and 90 DAS in case of T_9 followed by T_3, T_2, T_4. *Sesamum* plant applied with all the

micronutrients and their combination produced more number of branches as compared to control but significantly a highest number of branches (8/plant) were found in T_9 followed by T_3, T_2 and T_4.

Foliar spray of micronutrients improve metabolic function of plant causing more vegetative growth which manifested increase in height and more number of branches as reported by Ibrahim *et al.,* (2007) in bean and Yadav *et al.,* (2009) in *Sesamum* supported the present finding.

4.6.1 Dry matter accumulation

Dry matter accumulation and its partitioning into different plant parts were influenced by foliar application of micronutrients table 7. A gradual increase in TDM accumulation was observed up to 90 DAS but the pattern of its partitioning to different plant parts differed at various growth stages. Similar pattern of partitioning of TDM was found at 45 and 60 DAS, which was in the sequence of stem dry matter >leaf>pod, whereas at 90 DAS the TDM partitioning was in the order of pod dry matter>stem> leaf.

Among all the treatments the highest TDM in plant and its plant part like leaf, stem and pod were found in T_9 followed by T_3, T_2 and T_4. Similar increase in dry matter of plant and its plant parts due to foliar application of micronutrients have been reported in *Sesamum* by Salwa *et al.* (2010) and Yadav *et al.* (2009) which was corroborated the present result.

4.6.2 Physiological growth parameters

Growth analysis has the advantage of giving integrated measurement of net photosynthetic activity over wide range of condition that reveal in the field. Potential productivity is controlled by the efficient use of solar energy and photosynthetic rate per unit area. Leaf is the ultimate source for increasing biomass production and their translocation through transport network to the sink for such reasons desirable canopy structure must be established. This can be achieved by developing higher leaf area and rapid leaf area development as leaf is the ultimate source. Various physiological parameters related to canopy structure would always be useful which not only through light on crop productivity, but also their manipulation enhances potential productivity. In this regard the role of micronutrients in crop physiology is undisputable to harness the possibility of such manipulation for achieving higher productivity in different oil seed crops, *Sesamum* in particular.

The present findings in table 6 revealed that there was significant variation among the treatments with respect to LAI, SLA, SLW, LAR determined at 45 and 60 DAS of *Sesamum* plant. In all the treatments, higher value of LAI and SLW found at 60 DAS whereas, SLA and LAR were more at 45 DAS. High value of SLA and lower value of SLW at 45 DAS as compared to 60 DAS in all the treatments indicated a high rate of leaf expansion occurred at 45 DAS beyond that period thickness of leaf was more than its expansion.

Foliar application of different micronutrients and their combination showed higher value of LAI over control both at 45 and 60 DAS. Among the treatments, the highest LAI was found in plants with T_9 followed by T_3, T_2, T_4 and T_{10}. Similarly the highest SLW (3.15 mg/cm^2) was recorded for T_9 at 45 DAS followed by T_3, T_{10} and T_2 but at 60 DAS the highest SLW (4.69 mg/cm^2) was found with application of T_8 followed by T_6 and T_9. Maximum value of SLA and LAR were found in control plant T_1 as compared to plants applied with micronutrients. This might be due to low accumulation of dry matter in leaf in control plants as compared to other treatments. Micronutrients play critical role in plant that lead to increase of LAI and there by increased light absorption and increase the amount of dry matter accumulation and economic yield (Rabi *et al.* 2008) supported the present findings with respect to influence of micronutrients on LAI.

Foliar application of individual micronutrients and their combination as well as commercial mixture significantly influenced RGR, NAR, CGR and LAD (table 7). Among all the treatments, foliar spray of combined micronutrients (T_9) registered the highest RGR 101.3 (mg/g/day) followed by T_3. The highest NAR 1.2 (mg/cm^2/day) was found in T_9 followed by T_2 and T_3. Similarly, among all the treatments the CGR was highest 21.1 (g/m^2/day) for T_9 followed by T_3, T_2. The highest LAD (27.01) was also found in combined application of T_9 followed by T_3, T_2 and T_4 estimated during 45 to 60 DAS.

In plant micronutrients are involved in various physiological function and there by increased LAI, CGR, RGR, NAR leading to the development and productivity of plant in soybean (Gupta and Vyas 1994) and LAD by (Cakmak 1999) were in agreement with the result of present investigation which recorded significant increase in all the

above physiological growth parameters by foliar spray of individual micronutrients like Zn, B, Mo and their combination over control.

4.6.3 Chlorophyll index and total chlorophyll content

Chlorophyll index measured by speedometer and total chlorophyll content of leaves showed significant variation among the treatments at both 45 and 60 DAS (table 8). Foliar application of individual micronutrients, their combination and commercial mixture significantly influenced chlorophyll index as well as total chlorophyll in leaves of *Sesamum* plant over control. Among the treatments, the highest chlorophyll index was found 13.39 and 17.74 at 45 and 60 DAS respectively in plants applied with T_9 followed by T_3, T_2, T_4, T_{10}, T_7 and T_6. Similarly total chlorophyll was highest 1.67 and 1.93 mg/g fresh weight at 45 and 60 DAS respectively in T_9 followed by T_3, T_2, T_4, T_{10}, T_7 and T_6.

Fe plays essential role in the chlorophyll synthesis (Sultana *et al.*, 2001), Zn may be required for chlorophyll production (Pandey *et al.*, 2006). Combined application of B and Zn is effective to increase chlorophyll content, N, P and K content in dry matter and seed and oil protein content in seeds of sunflower (Gitte *et al.*, 2005) were in agreement with the present findings.

4.7 Nutrient uptake by plant and plant parts

In order to know the effect of micronutrients application on major nutrient status in sesame plant N, P and K content and their uptake by plant and plant parts were estimated at harvest.

4.7.1 N content and uptake

Nitrogen concentration varied 0.52 to 1.4 in leaf, 0.1 to 0.17 in stem and 0.08 to 1.96 in seed among the treatments table 9. It indicated that irrespective of treatments, concentration of N in different plant parts was found in the sequence of N content of seed > leaf > stem. Significant increase in N content was observed in all the plant parts due to foliar application of micronutrients table 9. Among the treatments T_9 registered the highest concentration of N in leaf, stem and seed followed by application of T_2, T_{10}, T_3 and T_4. Similarly N uptake by plant and plant parts significantly influenced by foliar application of micronutrients. Among all the treatments, highest uptake of N by plant

and plant parts was found in T_9 followed by T_3 and T_2. The result indicated that partitioning of N uptake by plant was in the order of N uptake by seed > leaf > stem.

4.7.2 P content and uptake

Phosphorus concentration varied in the range from 0.37 to 0.48 % in leaf 0.23 to 0.34% in stem and 0.49 to 0.57 % in seed among the treatments (table-10), which indicated that concentration of P was maximum in seed and minimum in stem. However no much difference in P concentration of different plant parts was found among the treatments. Uptake of P by plant and plant parts significantly influenced by application of micronutrients over control. Unlike P content partitioning of P uptake of plant in to its plant part was found maximum uptake by seed and minimum by leaf. Among the treatments maximum uptake of P in leaf (16.98 mg) was found due to Zn application, in stem (29.82 mg) due to B but maximum P uptake (32.86 mg) in seed and 69.23 mg/ plant was found due to combined application of T_9 followed closely by T_2, T_3 and T_4. The uptake of P by plant and plant parts was the least in T_1.

4.7.3 K content and uptake

Irrespective of the treatments Potassium (K) concentration was maximum in stem and minimum in seed. Foliar application of micronutrients did not show much difference in K content of different plant parts over control except in stem table 11, where significant increase in K content was found due to foliar spray of T_2, T_6, T_5, T_9 over control. In contrast K uptake by plant and plant parts significantly influenced by application of micronutrients. The highest uptake of K in plant and plant parts was recorded in T_9 followed by T_3 and T_2 and the least uptake was recorded in T_1. Similar results have been found by (Gitte et al 2005) who reported that combined application of B and Zn increase N, P and K content in dry matter in seed. Increased absorption of N, P and K in sesame due to foliar application of Zn (Tirupati *et al.,* 2001). Increase uptake of N, P and K in seed and stem due to combined application of Zn and Mn to sesame crop (Singervel *et al.*, 2002).

4.8 Yield and yield attributes

Yield of sesame is associated with various yields attributing characters such as number of seeds per capsule, capsules per plant, shelling %, seed weight. The product of these components determines the seed yield per plant, per hectare which very often influence by different factors. In this experiment the effect of different micronutrients spray on yield and yield attributes have been studied table 12.

Number of seeds per capsule and number of capsule per plant were influenced significantly by foliar application of different micronutrients to sesame plant. Among all the treatments, T_9 was the best which produced maximum number of capsule per plant and seeds per capsule followed by T_2, T_3 and T_4. Whereas T_5 and T_6 for number of capsule per plant and T_5 for seeds per capsule did not show any significant change over control.

Shelling percentage increased significantly over control by foliar application of all the micronutrients except T_4 and T_5. The highest shelling % (52.16%) was found due to combined application of T_9 followed by T_3, T_2 and T_8.
Seed size measured in terms of 1000 seed weight found maximum (3.22 g) in T_9 and minimum (2.62 g) in T_1. Significant difference in seed size was only observed between T_1 and T_9 but the rest of the treatments did not show any significant difference as compared to control.

Seed yield per plant as well as per hectare showed similar trend among the treatments. Both were increased significantly by the foliar application of micronutrients over control. Whereas highest seed yield 6.4 g per plant and 1410 kg/ha were found due to combine application of T_9 followed by T_2, T_3, T_4. Which registered an increase in the seed yield to the tune of 112%, 95%, 80% and 69% respectively over control but harvest index (HI) did not show any significant difference among the treatments.

Foliar application of micronutrients increased oil content in seed of *Sesamum*. Among the treatments, the highest oil content (50.2%) was found in plant applied with T_9 followed by T_3, T_2, T_4 and T_{10} which were found significantly higher than control. But the rest of the treatments did not increase oil content significantly over control. Increase in seed yield and seed quality of *Sesamum* due to combined application of

micronutrients was reported by (Salwa et al 2010). Micronutrients application significantly increased yield and yield components viz. number of capsules per plant and number of seeds per capsule. The beneficial influence of micronutrients might be due to the activation of various enzymes and the efficient utilization of applied nutrients resulting in increased yield components (Tiwari et al 2000, Shankar *et al.* 1999) are in accordance with the present findings.

Various parts of sesame and mineral composition

The good distribution of nutrients in the leaves may explain the usage of this plant as a forage feed given to the domestic animals. The roots had the highest content of crude fibre (12.80 ± 8.53%) and carbohydrate (67.90 ± 45.26%). Crude protein was highest (21.44 ± 14.29%) in whole plant followed by the leaves (19.25 ± 12.83%) but lowest in the roots (7.88 ± 5.25%). The high concentrations of proteins suggest that the whole plant of S. indicum can contribute to the daily protein need of 21.44 g for adults near 23.6 g recommended by the National Research Council (1975). These values corroborate with the protein content (21.44) found in non-Nigerian benniseed within the range of 18.00 to 23.18% as reported by Dashak and Fali (1993).The seeds have the maximum oil contents (38.54%),lowest in roots (2.66%). The observed results support the usefulness of sesame seeds as a good source of edible oils which can be used in cooking as well as soap manufacturing industry. The data revealed high food energy value in the seed (662.3%) which may be due to high lipids content. There was no significant different in dry matter weight (93.40-95.78%) of various plant parts investigated in this study. The proximate analysis of the ash contents was significantly high in the leaves (9.62 ± 6.41%), followed by the seed (8.94 ± 5.96%), whole plants (6.68 ± 4.45%) while that of the roots (4.82 ± 3.22%) was very low. The values of ash and crude fibre content are important in terms of the suitability of food vegetable and digestibility (Bowmen and Russell 2001). The values of crude fibre contents of this plant as recommended by National Research Council (1975) may contribute to the daily needs of fibre. Recently, the interest in dietary fibre has been stimulated due to its ability to prevent chronic diseases such as cardiovascular disease, cancer and diabetes mellitus (Bowmen and Russell, 2001) to bowel irritation and possibly colon cancer.

The difference in the concentration of the various elements within the different parts may be attributed to preferential absorbability of the plant for the corresponding elements. In addition, the observed results may be linked to the minerals composition of the soil in which the plant grows and climatology conditions. The functional roles of these elements are well documented but must be taken appropriately to meet the daily requirement. Data obtained on elemental concentrations of various parts of *S. indicum* may be useful in deciding the dosage or quantity for consumption as well as herbal remedies of this plant.

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted during Kharif-1 2017 at central farm SAU, Dhaka and chemical analysis were done in the laboratory of BARI, Gazipur to study the " Effect of foliar application of micronutrients on growth, yield and oil quality of sesame (*Sesamum indicum* L.) ". The experiment was laid out in a Randomized Block Design with ten treatments and replicated thrice. The treatments were T_1: control (no spray of micronutrients), T_2: B (100 ppm), T_3: Zn (100 ppm), T_4: Mo (50 ppm), T_5: Cu (100 ppm), T_6: Fe (100 ppm), T_7: Mn (100 ppm), T_8: Co (50 ppm), T_9: (combination of above micronutrients) and T_{10}: commercial mixture of micronutrients. Micronutrient treatments were applied to the crop at 45 and 60 DAS. Notes were recorded on growth characters, chlorophyll content, yield and yield attributes, N, P and K uptake and oil content of sesame seed during the course of investigation. After statistical analysis of the data, the salient findings are summarized as follows.

Plant height of *sesamum* significantly improved by foliar application of different micronutrients as recorded at 45, 60 and 90 DAS. Among the treatments plant height was maximum due to foliar application of joined micronutrients (T_9) at all the growth stages followed by Zn (T_3), B (T_2), and Mo (T_4). Number of branches per plant increased pointedly over control by foliar treatment of micronutrients except Cu (T_5). Among the treatments the highest number of branches produced in plant due to application of combined micronutrients (T_9) followed by Zn (T_3), B (T_2) and Mo (T_4). Significant increase in dry matter accumulation in plant and plant parts due to micronutrient application was found over control at 45, 60 and 90 DAS. Meaningfully the highest accumulation of dry matter in leaf, stem, pod and whole plant at all the three stages was recorded due to application of combined micronutrients T_9 followed by application of Zn and B. LAI increased significantly due to foliar application of micronutrients. At both the stages of 45 and 60 DAS the highest LAI was found in T_9 followed by T_3, T_2 and T_4 over control.

SLA was recorded at 45 and 60 DAS differed significantly among the treatments. At 45 DAS the highest SLA was in T_1 and lowest in T_9. However at 60 DAS the SLA was highest in T_5 and the lowest was in T_8. No definite trend was observed midst the treatments at both the growth stages. SLW recorded at 45 and 60 DAS differed significantly among the treatments. Foliar application of most of the micronutrients alone or in amalgamation significantly increased SLW over control. At 45 DAS maximum SLW was found in combined micronutrients followed by Zn, commercial mixture and B. whereas, at 60 DAS the highest SLW was recorded in Co followed by Fe and combined micronutrients. LAR recorded at 45 and 60 DAS varied among the treatments. The highest and lowest LAR were recorded in T_1 and T_2 respectively at 45 DAS, whereas highest and lowest LAR were recorded in T_7 and T_9 at 60 DAS. No definite influence of micronutrient spray on LAR was observed.

RGR increased with foliar spray of micronutrients over control but major increase was noted in combined application of micronutrients (T_9) followed by Zn (T_3). NAR significantly increased by foliar application of all the micronutrients over control excluding Mn (T_7). The highest NAR was recorded in combined micronutrients (T_9) followed by B (T_2) and Zn (T_3). CGR was significantly increased by all the micronutrient treatments over control except Cu (T_5). Among all the treatments the determined CGR was found in T_9 followed by T_3, T_2 and T_4. LAD was increased significantly by foliar application of micronutrients over control. Among all the treatments, the highest LAD was registered in T_9 followed by application of Zn, B and Mo. Chlorophyll index as well as total chlorophyll content of leaf were more at 60 DAS than 45 DAS. Chlorophyll index and total chlorophyll content significantly improved by all the treatments of micronutrients over control except Cu (T_5). Among the conducts the highest value was found in T_9 followed by T_3, T_2 and T_4. Influence of micronutrients on chlorophyll content exposed similar trend at both 45 and 60 DAS.

Nitrogen content and uptake of plant and plant parts significantly prejudiced by foliar application of micronutrients. N content and uptake in different plant parts were found in the order of seed > leaf > stem. Among the treatments the highest N content was recorded in T_9 followed by T_2, T_{10}, T_3 and T_4. Among the treatments T_9 registered the highest N uptake followed by T_3, T_2 and T_{10} in leaf, T_3, T_2 and T_4 in stem, T_2, T_{10} and T_3 in seed and T_2, T_3 and T_{10} in whole plant respectively. Irrespective of treatments, P content in dissimilar plant parts were found in the order of seed > leaf >stem. The micronutrients effect on P content was found significant only in stem and non-significant in leaf and seed. The significant increase was found in P content in stem over control by foliar submission of all the micronutrients except T_8 and T_9. Foliar application of all the micronutrients and its combination significantly increased P uptake in leaf over control except Cu and Fe. The highest uptake of P in leaf was found in Zn followed by T_9, T_2 and T_4. The highest P uptake of stem was found in T_2 followed by T_3, T_4 and T_9 and in both the seed and total plant the P uptake was highest in T_9 followed by T_2, T_3 and T_4.

Potassium content varied among the plant parts by foliar submission of micronutrients. K content in plant parts was found in the order of stem > leaf > seed. Application of K in leaf and seed did not diverged significantly among the treatments whereas micronutrient treatments significantly inclined K content in stem. The highest K content was found in T_2 followed by T_6, T_5 and T_9 in stem. K uptake enlarged significantly by foliar application of micronutrient. Partitioning of K uptake into plant parts was in the order of stem > leaf > seed. All the foliar application of micronutrients heightened K uptake in different plant parts and per plant as compared to control. Foliar application of all the micronutrients in mixture (T_9) registered the highest K uptake followed by T_3, T_2 and T_4 in leaf, T_2, T_3 and T_4 in stem, T_{10}, T_4 and T_2 in seed and T_3, T_2 and T_4 in whole plant. However foliar application of Cu (T_5) and Fe (T_6) did not register any momentous change in K uptake per plant as well as in leaf. All the micronutrients significantly increased number of capsule per plant over control except Cu and Fe. Among all the treatments highest number of capsules produced per plant due to application of combined micronutrients followed by T_2, T_3 and T_4.

Shelling % significantly influenced by foliar submission of micronutrients except T_4 and T_5. Among the treatments the highest shelling % was recorded in T_9 and the lowest was in T_1. Number of seeds per capsule pointedly increased over control by all the micronutrient treatments except Cu (T_5). The highest number of seeds per capsule was obtained in T_9 followed by T_2, T_3 and T_4. Thousand seed weight did not differ significantly among the treatments but highest 1000 seed weight was found in T_9 and lowest in T_1. Seed yield per plant as well as yield per hectare significantly increased by foliar application of micronutrients. Among the treatments foliar application of mutual micronutrients gave highest yield per plant and per hectare and recorded a gain in yield by 112% followed by application of B (95%), Zn (80%) and Mo (69%) over control. Foliar application of micronutrients in combination (T_9) registered the maximum oil content followed by Zn (T_3), B (T_2), Mo (T_4) and commercial mixture (T_{10}), which were significantly higher over control. But the rest of the treatments found insignificant compared to control.

In the present study, it was apparent that foliar application of different micronutrients each alone or their combination heightened most of the morpho-physiological traits and bio chemical attributes seed yield and yield features over control. Application of micronutrients in combination (T_9) excelled over rest of the treatments in respect of seed yield and oil content. Further application of specific micronutrients viz. B, Zn and Mo also performed well for growing seed yield and oil content in sesamum next to combined micronutrient treatment. Keeping in view of the above beneficial effect of micronutrient application, from the present effort, it was concluded that foliar spray of individual micronutrients viz. B, Zn, Mo, Fe, Mn, Cu and Co or their combination can be used as supplementary application laterally with the basal dose of N, P and K in order to improve the productivity of oil seed crop in general and *sesamum* in particular.

CHAPTER VI

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Appendix






Plate 1. Some photographs shows the experimental works.