EFFECT OF NITROGEN AND SULPHUR ON THE GROWTH AND YIELD OF BLACK CUMIN

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DHAKA-1207

JUNE, 2020

EFFECT OF NITROGEN AND SULPHUR ON THE GROWTH AND YIELD OF BLACK CUMIN

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REGISTRATION NO: 13-05262

A Thesis

Submitted to the Faculty of Agriculture, Dept. of Soil Science
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

IN

SOIL SCIENCE

SEMESTER: JANUARY- JUNE, 2020

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This is to certify that the thesis entitled, **“EFFECT OF NITROGEN AND SULPHUR ON THE GROWTH AND YIELD OF BLACK CUMIN”** 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 **SOIL SCIENCE,** embodies the result of a piece of bona fide research work carried out by **MINHAZ AKTAR** Registration No.**13-05262** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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Dedicated to

My Beloved Parents

ACKNOWLEDGEMENT

All praises are due to the Almighty "Allah" Who kindly enabled the author to complete the research work and the thesis leading to Master of Science in Soil Science, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

I would like to express my heartfelt respect, deepest sense of gratitude, profound appreciation and ever indebtedness to my supervisor, Professor **Dr. Alok Kumar Paul**, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for his sincere guidance, scholastic supervision, constructive criticism, extending generous help and constant inspiration throughout the course and in preparation of the manuscript of thesis.

I express my sincere respect to my Co-supervisor, **Prof. Dr. Md. Asaduzzaman Khan**, Department of Soil Science, Sher-e-Bangla Agricultural University, (SAU), Dhaka for his utmost co-operation, constructive suggestion to conduct the research work as well as preparation of the manuscript of thesis.

I feel to express my sincere appreciation and indebtedness to my esteemed teachers **Professor Dr. Asaduzzaman Khan**, Professor Mst. Afrose Jahan, Professor Dr. Mohammad. Mosharraf Hossain, Professor Dr. Mohammad. Issak, Professor Dr. Md. Saiful islam Bhuiyan, Professor Dr. Saikat Chowdhury, Dept. of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for their valuable teaching, direct and indirect advice, encouragement and cooperation during the whole study period.

I express my unfathomable tributes, sincere gratitude and heartfelt indebtedness from my core of heart to my parents, and also pleasant to my brother, whose blessing, inspiration, sacrifice, and moral support opened the gate and paved to way of my higher study.

I feel much pleasure to convey the profound thanks to my friends, well-wishers for their active encouragement and inspiration.

Place: Dhaka **Minhaz Aktar**

Dated: The June 2020

ABSTRACT

An experiment was conducted at the Farm of Sher-e-Bangla Agricultural University, Dhaka during rabi season (November to March) of 2018-19 to examine the effect of nitrogen and sulphur on growth & yield of black cumin (*Nigella sativa* L.). The experiment comprised of four levels of nitrogen viz. N_0 (0 kg N ha^{-1}), N_1 (30 kg N ha^{-1}), N_2 (60 kg N ha^{-1}) and N_3 (90 kg N ha^{-1}) and three levels of sulphur viz. S_0 (0 kg S ha^{-1}), S_1 (10 kg S ha^{-1}) and S_2 (20 kg S ha^{-1}). The experiment was set up in Randomized Complete Block Design (factorial) with three replications. There were 12 treatment combinations in all. Nitrogen and phosphorous levees singly as well as in combination had significant effect on most of the characters studied. The tallest plant was recorded at 90 kg N ha^{-1} followed by 60 kg N ha^{-1} at different growth stages. Application of 90 kg N ha^{-1} gave the maximum primary and secondary branches plant^{-1}, capsules plant^{-1}, seeds capsules^{-1}, 1000 seed weight and seed yield of 1446.00 kg ha^{-1}. The highest plant height, primary branches plant^{-1}, secondary branches plant^{-1}, capsules plant^{-1}, 1000 seed weight and seed yield of 1142.00.00 kg ha^{-1} was recorded at 20 kg S ha^{-1} closely followed by 10 kg S ha^{-1}. Application of 90 kg N ha^{-1} coupled with 20 kg S Nha^{-1} gave the maximum capsules plant^{-1} and seed yield of 1643.00 kg ha^{-1}which was similar to those parameters obtained from 90 kg N ha^{-1} × 10 kg S ha^{-1} and 60 kg N ha^{-1} × 20 kg S ha^{-1}. The highest concentration of N, K and S in post harvest soil was recorded in the treatment combination of 90 kg N ha^{-1} coupled with 20 kg S ha^{-1}.

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LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
HRC	=	Horticulture Research Centre
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agricultural Organization
N	=	Nitrogen
et al.	=	And others
TSP	=	Triple Super Phosphate
MOP	=	Muriate of Potash
RCBD	=	Randomized Complete Block Design
DAT	=	Days after Transplanting
ha^{-1}	=	Per hectare
g	=	gram (s)
kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
wt	=	Weight
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
NS	=	Not significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of Coefficient of Variance

INTRODUCTION

Black cumin (*Nigella sativa* L.) commonly known as 'Kalozira' belongs to family Ranunculaceae. It is cultivated for seed yield and oil production. It is widely cultivated throughout South Europe, Syria, Egypt, Saudi Arabia, Iran, Pakistan, India and Turkey (Riaz *et al.,* 1996). In India, it is commercially cultivated in Punjab, Himachal Pradesh, Madhya Pradesh, Jharkhand, Assam, West Bengal and Andhra Pradesh (Vijay and Malhotra, 2006). The whole seeds contain 30-35 % of oil which has several uses for pharmaceutical and food industries (Ustun *et al.,* 1990). The black cumin seed cake is a by-product obtained from the black cumin seeds which is used in the production of bio-oil (Sen and Kar, 2012). Black cumin is an annual flowering plant, native to Southwest Asia. It grows to 20 to 30 cm tall, with finely divided, linear (but not thread-like) leaves. The flowers are delicate, and usually coloured pale blue and white, with 5 to 10 petals. The fruit is a large and inflated capsule composed of 3 to 7 united follicles, each containing numerous seeds. The seed is used as a spice (Abadi *et al.,* 2015).

Black cumin's capsule (fruit) has five parts and its seeds are usually small (1-5 mg) in dark gray or black color. The ripe seed contains 7 % moisture, 4.34 % ash, 23 % protein, 0.39 % fat, 4.99 % starch and 5.44 % raw fiber (Zargari, 1990).

Medicinal plants are used to cure many ailments that are either non-curable or seldom cured through modern systems of medicine. Approximately 80% of the world population depends on medicinal plants for their health and healing (Aliyu, 2003). Societal motivations to use herbs are increasing due to concern about the side effects of synthetic drugs. Many botanicals and some dietary supplements are good sources of antioxidants and anti-inflammatory compounds (Balasubramanian and Palaniappan, 2001). Quality in medicinal plants is more important than other plant products. Environmental factors have an important role on plant growth. Some of these factors such as irrigation and manure can be controlled by human. Both of them are essential to increase yield and quality of plants (Singh and Goswami, 2000). Because the need of increasing the medicinal plant production all over the world, its production became an ultimate goal to meet the great increase of population to avoid chemical therapy side effects on human health through utilization of the medical herbs. However, the use of the most suitable and recommended agricultural practices in growing such crops could provide the producers with higher income, in comparison with many other traditional crops (Hassan *et al*., 2012).

Nitrogen is essential for plant growth which ultimately increases yield of the crop. It is reported that application of 30 -60 kg nitrogen per hectare is essential to achieve maximum performance of cumin (Champawat and Pathak, 1982; Ehteramian, 2002; Tuncturk *et al*., 2012).

The amount of available nitrogen during the season is often not enough for high yields and good quality. The nitrogen in the soil at planting is affected by many factors, for example previous crop, fertilisation history, precipitation since the last crop, soil humus content, soil texture and temperature. Much of the nitrogen left in the soil the previous year can be lost through leaching. Often the root system of the seedlings or transplants is too limited to reach nitrogen from lower soil layers. Nitrogen fertilizer is therefore added to the field. Chemical fertilizers can be either organic (like manure) or inorganic with different composition of ammonium, nitrate, urea, etc. Since broccoli requires large quantities of nitrogen to produce high yields and the timing of nitrogen uptake is crucial for optimum growth, inorganic fertilizers are often used. They are easier to apply and the grower knows exactly the amount of nitrogen applied and approximately when it is available to the crop.

Sulphur is essential for production of protein, fats and oils, promotes enzyme activity and helps in chlorophyll formation, improves root growth and grain filling resulting in vigorous plant growth and resistance to cold. Its deficiency causes interveinal chlorosis with a very distinct reddish color of the veins and petioles (Shanyn and Lucy, 13). Sulphur deficiency has been aggravated in soils due to continuous crop removal under intensive cropping system and use of sulphur free high analysis NPK fertilizers. Sulphur which has now emerged as the third most important plant nutrient for crop plays a multiple role in nutrition. It helps in chlorophyll formation and also a constituent of amino acids like cysteine, cysteine and methionine. Sulphur is also responsible for synthesis of certain vitamins (biotin and thiamine), proteins, fats and metabolism of carbohydrates (Tondon, 1991)

Sulphur (S) involves in various metabolic and enzymatic process including photosynthesis, respiration and legume-rhizobium symbiotic nitrogen fixation (Srinivasa Rao *et al*. 2001). Sulphur is one of the essential plant nutrients and its contribution in increasing the crop yields is well documented. Application of sulphur as gypsum increased plant height, dry matter production, leaf area index and straw yield of black cumin (Singh *et al.*, 1994). Sulphur application through gypsum significantly increased the growth and yield of black cumin. Pandey and Singh (2001) reported that highest grain and straw yield of black cumin was obtained by application of sulphur. The growth and yield potential of black cumin can be improved by optimum dose of sulphur through gypsum. Generally, a soil with less than 22 kg ha^{-1} of available sulphur is said to be deficient in sulphur. ‘S’ deficiency have been reported over 70 countries worldwide, of which India is one. Tamil Nadu is one of the agriculturally important states with very little documents on sulphur status. It has been found that 80% of the sample obtained from 15 benchmark clay soil in Cuddalore district were reported to be ‘S’ deficient. Sulphur assumes greater significance in increasing growth and yield of black cumin, as far as black cumin is concerned no work have been done earlier with regard sources and level of sulphur on growth and yield of rice fallow black cumin.

Availability of nitrogen is of prime importance for growing plants as it is a major and indispensable constituent of protein and nucleic acid molecules (Troug, 1973). An adequate supply of nitrogen is associated with vigorous vegetative growth and more efficient use of available inputs finally lead to higher productivity. Looking to the situation, there is an urgent need to augment supplies of customized fertilizers supplying secondary and micronutrients to sufficiently support, the integrated need of nutrient in black cumin production. Considering the above facts, the studies on effect of different levels of nitrogen and sulphur on growth, yield and quality of black cumin was undertaken with the following objectives:

1. To observe the role of N and S on the growth and yield of black cumin.

2. To find out the doses of N and S to maximize the growth and yield of black cumin.

3. To observe the interaction effect of nitrogen and sulphur on the growth and yield of black cumin.

CHAPTER - II

REVIEW OF LITERATURE

Black cumin is one of the most important medicinal plants all over the world including Bangladesh. The yield of black cumin depends on many factors such as are land topography, soil fertility, soil productivity, environment (light, temperature, moisture, humidity and rainfall), and cultural practices. Different types of chemical fertilizers play an important role on its growth, yield and quality. Nitrogen and Sulphur are the two major important macronutrients and micronutrient which are responsible for controlling growth and yield of black cumin. A number of research works have been done on different levels of nitrogen and Sulphur on the yield of black cumin in various parts of the world, which have been made in this regard in Bangladesh. The present study has been taken to investigate the effect of nitrogen and Sulphur on growth and yield of black cumin (*Nigella sativa* L.). In the chapter an attempt has been made to research findings related to the present study have been reviewed here.

2.1 Effect of nitrogen on growth & yield of black cumin

Hossain Talaei *et al.* (2018) conducted based on a randomized complete block design with two factors of chemical nitrogen (46% urea nitrogen) at Â two levels (Zero, 25 and 50 kg/ha^{-1}), biological nitrogen (Azotobacter) with trade name Nitroxin at 2 levels inoculated and non-inoculated in 2011. The results of analysis of variance showed that the effects of biological fertilizers (Azotobacter) Nitroxin of chemical (urea 46%) nitrogen in different treatments on plant height, umbel number per plant, grain number per umbel, biological yield, grain yield, harvest index (HI) and essential oil yield were significant at P> 0.01. The results showed that the greatest plant highest (28.18 cm), biological yield (201.187 g.m^2), grain yield (75.600 g.m^2) and essential oil yield (2.115 g.m^2) were obtained by a treatment of Nitroxin + chemical nitrogen (25 kg/ha^{-1}). In general, the results of the present study revealed that the application of biological fertilizers plays a remarkable role in improving yield quality and quantity in Cumin and can be viewed as a suitable replacement for chemical fertilizers.

Essential oil (EO) and fixed oil (FO) isolated from the seeds of *Nigella sativa* L. (*N. sativa*) used in various aspects of traditional medicine and different food products. The bilogical activities such as antimicrobial of N. sativa oils were reported by previous investigators. There are two major nitrogen (N) sources i.e Urea (UR) and ammonium sulfate (AS). The UR and AS contain 46 and 21% of N respectively. In addition, AS also contains about 24% of sulfur (S). Nutrition with more N content is preferred over low-N nutrition because of the lower cost of transport and application. The objective of this study was to evaluate effect of AS and UR on EO and FO composition of Black cumin. Experimental areas were divided into 3 main groups. The first group was subjected to no rate of N (control). The second group was subjected to different doses of N (50, 100 and 150 kg N ha^{-1}) as AS (20.5 % N). The third group was subjected to the same treatments of N but UR (46 % N) was added. The EO and FO were isolated from black cumin seeds of all treatments and analyzed by GC-MS. Data were statistically analyzed using 1-way analysis of variance (ANOVA-1). Significant rates were identified according to P values ($P < 0.05$ = significant, $P < 0.01$ = moderate significant and $P < 0.001$ = highly significant). The highest amounts of EO contents were recorded under at 100 kg N ha^{-1} rate (as UR) with the values of 0.4 -0.5%; 11.6 -14.5 g $(100\ plant)^{-1}$. Greatest amounts of main components were produced from 100 kg N ha^{-1} (as AS) with the values of 51.7% (p-cymene) and 15.9 (α-thujene). Treatment 50 kg N ha^{-1} (as UR) produced the highest contents of FO which recoded 31.8 and 33.6%; 699.6 and 739.2 g $(100\ plant)^{-1}$. Greatest amounts of major FA were obtained from the treatment of 150 kg N ha^{-1}(as AS) with the values of 22.9% (oleic) and 74.7% (linoleic). Different nitrogen sources caused significant changes ($P < 0.05$) in EO, FO, main compounds of EO and major FA (Khalid, 2018).

Aytac *et al*., (2017) carried out to determine the efficiency of nitrogen (N) doses (0, 30, 60, and 90 kg Nha^{-1}) under supplemental potassium (K) application (50 kg K_2O ha^{-1}) on black cumin in 2011 and 2012. The results showed that increased N levels resulted in increasing seed yield and N and K contents in seed, while oil content decreased. The seed yield and oil yield were peaked at the doses of 60kg N ha^{-1} and 50 kg K ha^{-1}. An increase in N doses caused a reduction in oil content regardless of K supply. Saturated fatty acids and oleic acid were slightly increased by K application, while minor changes in linoleic acid were detected. It was concluded that 60 kg N ha^{-1} with supplemental K application should be advised for enhancement in seed yield, oil yield, and N and K contents in seeds of black cumin without significant changes in fatty acid composition.

Ali *et al.* (2015) conducted an experiment at the research farm of Crop Physiology and Ecology Department, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh, during November 2013 to April 2014 to determine the growth and yield performance of four varieties of black cumin (Exotic variety , BARI kalozira-1, Faridpur local and Natore local) as influenced by three levels of fertilizers (40-20-30 Kg ha^{-1}, 80-30-45 Kg ha^{-1} and 120-40-60 Kg ha^{-1} N-P-K, respectively). First flower bud initiation day, capsule setting, and capsule ripening in 50% plant were not significantly influenced by N-P-K fertilizer levels. The secondary branch $plant^{-1}$, tertiary branch $plant^{-1}$, plant height at harvest, capsule length, capsule diameter and 1000 seed weight of black cumin were also not influenced significantly by the fertilizer levels. The dry matter weight $plant^{-1}$, primary branch $plant^{-1}$, fruit $plant^{-1}$, seed capsule-1and grain yield of black cumin genotypes were significantly influenced by different levels of N-P-K fertilizers. Natore local gave maximum dry matter production plant-1at 55 DAS with moderate N-P-K levels and at 70 DAS with higher N-P-K fertilizer levels (0.22 and 1.06 g, respectively), whereas Exotic black cumin genotype showed maxi mum dry matter $plant^{-1}$ at 85 and 100 DAS with higher N-P-K fertilizer levels (2.30 and 4.97 g, respectively). Exotic variety produced maximum grain yield (3.43 g $plant^{-1}$ and 2.30 t ha^{-1}) at higher level of N-P-K fertilizer, but BARI $kalozira^{-1}$ (2.95 g $plant^{-1}$and 1.95 t ha^{-1}), Faridpur local (2.80g $plant^{-1}$ and 1.90 t ha^{-1}) and Natore local (2.69 g $plant^{-1}$ and 1.80 t ha^{-1}) showed maximum yields at moderate N-P-K fertilizer levels. Among the test varieties of black cumin, the exotic variety showed better yield performance than the others.

Yimam *et al*. (2015) conducted an experiment at Duka, Konta district to determine the effect of Nitrogen (N) and Phosphorous (P) fertilizers on growth, yield and yield components of black cumin. Five levels of N (0, 15, 30, 45 and 60 kg ha^{-1} in the form of urea) and three levels of P (0, 20, 40 kg ha^{-1} in the form of TSP) arranged in RCB design with three replications. Results indicated that interaction of N and P highly significantly ($p<0.01$) influenced the different growth and yield parameters except for 1000 seed weight. The highest seed yield (1336.7 kg ha^{-1}was obtained from 60/40 kg N P ha^{-1}. Highest number of pods per plant (45.9) was obtained from 60 kg N ha^{-1} and 40 kg P ha^{-1}interactions. The tallest plants (72.5cm) were measured o plots fertilized at the rate of 60/40 kg N P haG1. The highest number of branches (46.1) was obtained from the interaction effect of 60/40 kg N P ha^{-1}. The highest numbers of seeds per pod (91.6) was achieved at treatment combination of 60/40 kg N P ha^{-1}followed by 88.4 seeds by the treatment combination of 60/20 kg N P ha^{-1}. The highest harvest index (20.8%) was obtained from the treatment that received 60/40 kg NP followed by 20.5%, which received 45/20 kg, N P ha^{-1} interactions and the lowest harvest index (15.1%) was recorded from the treatment that received 15and 0 kg NP interaction. The longest days to 50% flowering (86.7 days) were observed for the treatment that received 60/40 kg N P ha^{-1}. However, the shortest flowering days (75.5) days were for the control treatment. Partial budget analysis has shown that two treatment combinations of (NP ha^{-1}) were found to be economically viable with marginal rate of revenue beyond the minimum acceptable level (150%). The highest MRR (%) was obtained with the interaction effect of 45/40 kg NP ha^{-1} with marginal rate of revenue (1272.2%) for net benefit 15254.1 birr, followed by the interaction effect of15/20 kg NP ha^{-1} with marginal rate of revenue (485%) for net benefit 10325 birr over the control with a net benefit 8595.0 birr. Since the experiment was conducted at one place and only for one cropping season, it will not be appropriate to arrive at a strong recommendation. However, as a recommendation, growers can be advised to use a combination of 45/40 kg NP ha^{-1} followed by 15/20 Kg N P_2O_5 $ha^{-1}$for black cumin production in the area.

Kaheni *et al.* (2013) conducted an experiment in a randomized complete block design with two factors and three levels of nitrogen (0, 30 and 60 kg N ha^{-1}) and four planting dates (11 November, 1 December, 23 December and 2 January) with three replications in Agricultural and Natural Resources Research Center of South Khorasan, located in 20 km Kerman-Birjand road. Different levels of nitrogen fertilizer had a significant effect on the number of umbels per plant, 1000 seed weight and dry matter yield, but were not significantly affected on the number of seeds per umbel, plant height, and number of branches, forage and grain yield. In final results, due to reduce the risk of untimely cold winter in this region, we were recommend to achieve maximum performance in cumin, application of 60 kg nitrogen and late planting dates (as 23 December and 2 January).

Girma and Taddesse (2013) conducted an experiment to find out effect of nitrogen and phosphorus rates on yield and yield components of Ethiopian cumin. The treatment consisted of four levels of nitrogen (0, 50, 100 and 150 kg ha^{-1}) and four levels of phosphorus (0, 25, 50 and 75 kg ha^{-1} in form of P_2O_5). Main and interaction effects of fertilizer significantly improved plant height, number of secondary and tertiary branches $plant^{-1}$, number of umbels $plant^{-1}$, dry matter yield, seed yield, essential oil content and essential oil yield. Number of seeds $umbel^{-1}$ was influenced only by the main effect of fertilizer while number of primary branches and 1000- seed weight were remained unaffected. Combined effect of 100 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1} gave maximum significant total dry matter yield (3307 kg ha^{-1}), seed yield (1072 kg ha^{-1}) and essential oil yield (39.0 liter ha^{-1}).

Tuncturk *et al*. (2012) carried out an experiment to determine the effects of different nitrogen doses (0, 20, 40, 60 and 80 kg ha^{-1}) on the yield and some yield components of black cumin (*Nigella sativa* L.) in Van ecological conditions in 2006 and 2007. In the study, plant height (cm), number of branch $plant^{-1}$, number of capsule $plant^{-1}$, number of seeds $capsule^{-1}$, thousand-seed weight (g) and seed yield (kg ha^{-1}) were determined. In conclusion, the effects of nitrogen doses on the yield and some yield components were statistically significant except for 1000 seed weight and number of seeds capsule^{-1}. Plant height, number of branch plant^{-1}, number of capsule plant^{-1} and seed yield were increased by increasing nitrogen doses. According to the results, the highest values were obtained in seed yield (575 kg ha^{-1}), the number of capsule (7.5 capsule plant^{-1}) and the number of branch (4.51 branch plant^{-1}) from 60 kg N ha^{-1} application.

Rana *et al.* (2012) conducted an experiment during rabi season of 2010-11 to find out the effect of nitrogen and phosphorus on growth, yield and quality of black cumin. Among the varieties, AN-1 recorded maximum value for number of capsules per plant (30.30), number of seeds per capsules (60.33), test weight (1.46 g), seed yield (4.88 q/ha), straw yield (12.48 q/ha), harvest index (27.89 %) and biological yield (17.36 q/ha) as compared to local cultivar of nigella. Maximum plant height at harvest (45.95 cm), number of branches per plant at harvest (17.30), fresh weight per plant at 60 DAS (13.08 g) and dry weight of shoot per plant at 60 DAS (3.21 g) were recorded with the application of fertilizer 60:120 kg ha^{-1} N, P followed by 45: 90 kg ha^{-1} N, P and lowest in control at all the growth stages. Therefore, the application of 60 kg ha^{-1} N and 120 kg ha^{-1} P fertilizer with the variety AN-1 gave the maximum growth, yield and quality of nigella with the highest net return per hectare.

Hammo (2008) conducted during the season 2005-2006 in singar-Mosul city to investigate the effects of high level (280 N, 260 P_2O_5) kg ha^{-1} and very high level (320 N, 300 P_2O_5) kg ha^{-1}fertilizer, pinch and without pinch, and plant seed rate sowing (0.6, 0.8, 1.0, 1.2) g/10m^2 cultivated within 3, 4, 5, 6 rows respectively in (10) m^2 plot area on growth and yield of *Nigella sativa* L. The experiment was laid out in a Randomized Complete Block Design (factorial) with three replications. The result indicated that very high level of nitrogen and phosphorus caused a significant increase in plant length, stem diameter, fresh weight, plant seed yield and total seeds yield kg/ha, were as branch number and fruit number cannot be affected significantly by previous factor. Pinching causes a significantly increased in branch number and fruit number while plant high decreased significantly. Increased seed rate sowing from 0.6

to 1.2 g/10m^2 caused a significant increasing in branch number, fresh weight and plant seed yield while stem diameter and fruit number didn't effected significantly by this factor except total seeds yield kg/ha which increased significantly when seed rate sowing are increased to 1.2 g/10 m^2 and they reach 651.85, 843.56, 1076.51, 1232.67 kg/ha for the four seed rate consecutively.

Shah (2007) reported the effect of basal nitrogen (0, 176, 264, 352 or 442 mg N pot^{-1}) applied with or without 10^{-5} M kinetin (KIN) spray on *Nigella sativa* L. Although, N alone was found to significantly enhance all parameters, (viz, nutrient (NPK) accumulation, number of capsules, seed yield plant^{-1}, oil and essential oil yields plant^{-1} except oil and essential oil contents.

Ahmad *et al.* (2004) reported that the split dose of nitrogen might increase black cumin yield.

Nataraja *et al.* (2003) conducted an experiment to study the influence of nitrogen, phosphorus and potassium on growth and seed yield of black cumin at Sanjivini Vatika, University of Agricultural Sciences, Bangalore during 2000-2001. The experiment consisted of twenty seven treatment combinations with three levels each of nitrogen (0, 50 and 100 kg ha^{-1}), phosphorus (0, 20 and 40 kg ha^{-1}) and potassium (0. 30 and 60 kg ha^{-1}), and was laid out in factorial randomized block design with three replications. The results revealed significant differences in growth and yield parameters among the treatments. Application of nitrogen at 100 kg ha^{-l} recorded the maximum values for plant spread (427.75 cm2) and number of seeds (57.52) per pod. Significant differences were also observed with the interaction of NPK at 50:40:30 kg ha^{-1} producing pods of good size (3.84 cm2), higher test weight of 1000 seeds (2.38 g) and seed yield (17.45 q ha^{-1}).

Singh and Singh (1999) indicated that the moderate doses of nitrogen and phosphorus fertilizer increase the seed yield of black cumin.

2.2. Effect of Sulphur on the growth and yield of black cumin

Bepari *et al*. (2018) conducted during rabi season 2017-18 at the Horticulture Research Farm, College of Horticulture, Mandsaur (M.P.) to study the response of sulphur and zinc on growth, yield and quality of black cumin. The experiment was laid out in factorial RBD with three replications including four levels of sulphur (0, 15, 30 and 45 kg S/ha) and four levels of zinc (0, 2, 4 and 6 kg Zn/ha). Results showed that sulphur application at 45 kg/ha significantly increased leaf area index, leaf area duration, specific leaf area, crop growth rate, relative growth rate, seeds umbel^{-1}, biological yield, seed yield (16.93 q/ha), seed index (g), chlorophyll content (SPAD) essential oil and dry matter content in seed (%) over control and 15 kg S/ha. Therefore, the application of 45 kg S/ha and 6 kg Zn/ha gave maximum growth, yield and quality of black cumin.

Soils polluted with toxic elements are one of the major environmental problems in human societies. Sulfur (S), an essential element for the growth and development plants, plays an important role in reducing the toxicity of toxic elements as arsenic. In this study, the role of Sulfur different regimes (0, 50, 100 and 150 mg per kg) in reducing arsenic (As) toxicity in black cumin (Nigella sativa L) was investigated. The obtained results indicated that Sulfur application increased the activities of antioxidant enzymes and photosynthetic pigments, but it's decreased the arsenic induced oxidative stress. Reduction of shoot and root biomass occurred in presence of sulfur different regimes and As various concentrations. S supplement under high As concentration increased protein content of shoot. Different S regimes resulted in enhanced both shoot and root As accumulation. Meanwhile, different treatments of sulfur allowed high translocation of As quantities from root to shoot. It is well illustrated that phytoextraction is one of the best methods for toxic metals phytoremediation. Thus from present study it is evident that the phytoremediation ability of plants for accumulates toxic metals may be enhanced through exogenous sulfur application (Ghalehni and Poozesh, 2018).

Yousuf *et al.* (2014) conducted an experiment at the Spices Research Centre, Shibgonj, Bogra, Bangladesh during the rabi seasons of 2008-2009 and 2009-2010 to determine the requirement of N, P, K, and S of black cumin(BARI kalozira 1) for achieving satisfactory seed yield of this crop. Different levels of nitrogen (0, 40, 70, and 100 kg/ha), phosphorus (0, 25, 50, and 70 $kgha^{-1}$), potassium (0, 30, 60, and 90 $kgha^{-1}$), and sulphur (0, 10, 20, and 30 $kgha^{-1}$) were distributed in the plot. There was positive impact of application of those nutrients on the yield and yield contributing characters of up to a moderate level of N_{70} P_{50} k_{30} S_{20} $kgha^{-1}$. The highest seed yield (2.06 t/ha in 2008-2009 and 2.09 t/ha in 2009-2010) was obtained with this moderate application of N, P, K, and S (70, 50, 30, and 20$kgha^{-1}$, respectively) and yield was declined with higher doses of these elements. The fertilizer treatment N_{70} P_{50} k_{30} S_{20} $kgha^{-1}$was observed to be the best suitable dose for black cumin cultivation on Grey Terrace Soil of Amnura Soil Series under AEZ-25(Level Barind Tract) of Bangladesh.

Meena *et al.* (2017) was aimed to examine the effect of two varieties, four levels of sulphur (0, 20, 40 and 60 kg S/ha) and four levels of zinc (0, 2.5, 5.0 and 7.5 kg Zn/ha) making 32 treatment combination under split plot design with three replications. Results showed that significantly increased umbels/plant, umbellets/umbel, seeds/umbel, seed (1409 kg/ha), stover and biological yields, and net returns (Rs 39396/ha) were obtained with black cumin variety RCr-436 as compared to variety RCr-435. The variety RCr-436 recorded 13.1 and 24.2% higher seed yield and net returns as compared to RCr-435. Sulphur application at
40 kg/ha significantly increased umbels/plant, umbellets/umbel, seeds/umbel and test weight, seed (1406 kg/ha), stover and biological yields, and net returns (39175/ha) over control and 20 kg S/ha. The sulphur at 40 kg/ha register 20.8 and 7.5 % higher seed yield, 39.0 and 12.7% more net return over control and 20 kg/ha, respectively. Significantly increased umbels/plant, umbellets/umbel, seeds/umbel and test weight, seed (1436 kg/ha), stover and biological yields, and net returns (Rs. 39309/ha) were obtained with 5.0 kg Zn/ha over control and 2.5 kg Zn/ha. Zinc application @ 5.0 kg/ha recorded significantly more seed yield by 30.3 and 10.5 % and net returns by 35.2 and 10.4 %, respectively.

Patel *et al.* (2013) conducted an experiment on loamy sand soil of Agronomy Instructional Farm, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during *rabi* season of 2009-10 to investigate effect of varying levels of nitrogen and sulphur on growth and yield of black cumin (*Nigella Sativa* L.). Sixteen treatment combinations consisting of four levels each of nitrogen (20, 40, 60 and 80 kg Nha^{-1}) and sulphur (0, 10, 20 and 30 kg S ha^{-1}) replicated four times. Among the levels of nitrogen @ 80 kg ha^{-1} showed its producing highest seed yield (1203 kg ha^{-1}) and straw yield (1596 kg ha^{-1}). The highest performance is attributed to significant improvement in growth and yields parameters *viz.*, plant height, number of branches plant^{-1}, number of umbels plant^{-1}, number of umbellate umbel^{-1}, number of seeds umbellate^{-1}, Test weight (g) and seed weight plant^{-1} (g). Similarly application of nitrogen @ 80 kg ha^{-1} recorded highest quality parameters (protein content, volatile oil content and total oil yield) and uptake of nitrogen and sulphur . Among the levels of sulphur @ 30 kg ha^{-1} recorded significantly higher seed yield (1184 kg ha^{-1}) and straw yield (1577 kg ha^{-1}). Sulphur application @ 30 kg ha^{-1} significant improvement in growth and yield parameters *viz.*, number of branches plant^{-1}, number of umbels plant^{-1}, test weight (g) and seed weight plant^{-1} (g). Application of sulphur @ 30 kg ha^{-1} also showed positive effect on protein, volatile oil content and total oil yield as well as uptake of nitrogen and sulphur.

Lal *et al*. (2014) conducted an experiment during the Rabiseason of 2012-13 at NRCSS, Ajmer, Rajasthan, to study growth and yield of black cumin as influenced by varying levels of sulphur and zinc. Treatments comprising of three sulphur levels (soil application of 20, 30 and 40 kg sulphur ha^{-1}) and three zinc levels (foliar application of 0.4, 0.5 and 0.6 % zinc) were studied in factorial randomized block design with four replications. Reduction in days to germination initiation and enhanced days of flowering were observed due to higher dosage of sulphur. Plant height was not significantly influenced with varying sulphur levels except at 60 days after sowing. Higher number of primary (8.03) and secondary branches plant^{-1} (25.08), number of umbellates umbel^{-1} (5.61) and seed yield (1990.69 kg ha^{-1}) was obtained with soil application of 40 kg sulphur hectare^{-1}. Varying levels of foliar application of zinc did not significantly influence plant height except at 60 DAS. The highest number of primary branches plant^{-1} (7.66), number of umblets umbel^{-1} (5.61) and seed yield (2027 kg ha^{-1}) were obtained with foliar application of 0.6% zinc. Basal application of sulphur @ 40 kg ha^{-1} along with foliar application of 0.6 percent zinc is better for realizing higher yield of black cumin.

Meena *et al.* (2014) study aims to examine the effect of Plant growth regulators and sulphur on productivity of black cumin. The experiment consisting of four PGRs (1000ppm Triacontanol, 1.0ppm Brassinolide, 500ppm Thiourea and water spray) and four levels of sulphur (0, 20, 40 and 60kg/ha) making 16 treatment combinations under randomized block design (RBD) with three replications.. Application of sulphur up to 40 kg/ha significantly increased all above mentioned growth, yield attributes and yield of black cumin over control and 20 kg S/ha. In terms of net returns and B:C ratio, the treatment 500ppm thiourea and 40kg S/ha fetched significantly higher net returns and B:C ratio over rest of the treatment. It was concluded that independent application of 500 ppm thiourea as foliar spray twice at 45 and 80 days after sowing and soil applied sulphur at 40kg/ha is recommended as these treatments fetched significantly higher economic net returns from black cumin.

Chapter III

MATERIALS AND METHODS

The experiment was carried out during rabi season (November to March) of 2018-19 to examine the effect of nitrogen and Sulphur on growth & yield of black cumin (*Nigella sativa* L.).

3.1 Experimental site

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

3.2 Climatic condition

The experimental area under the sub-tropical climate that is characterized by less rainfall associated with moderately low temperature during rabi season, October to March.

3.3 Soil condition

The soil of experimental area situated to the Modhupur Tract under the AEZ - 28 and Tejgoan soil series. The soil was sandy loam in texture having pH 6.27 - 6.49. The physical and chemical characteristics of the soil have been presented in Appendix II.

3.4 Methods

3.4.1 Treatments

Factor A: 4 levels of N (kg/ha)

N_0 = 0 kg N/ha

N_1 = 30 kg N/ha

N_2 = 60 kg N/ha

N_3= 90 kg N/ha

Factor B: 3 level of S (kg/ha)

S_0= 0 kg S/ha

S_1= 10 kg S/ha

S_2 =20 kg S/ha

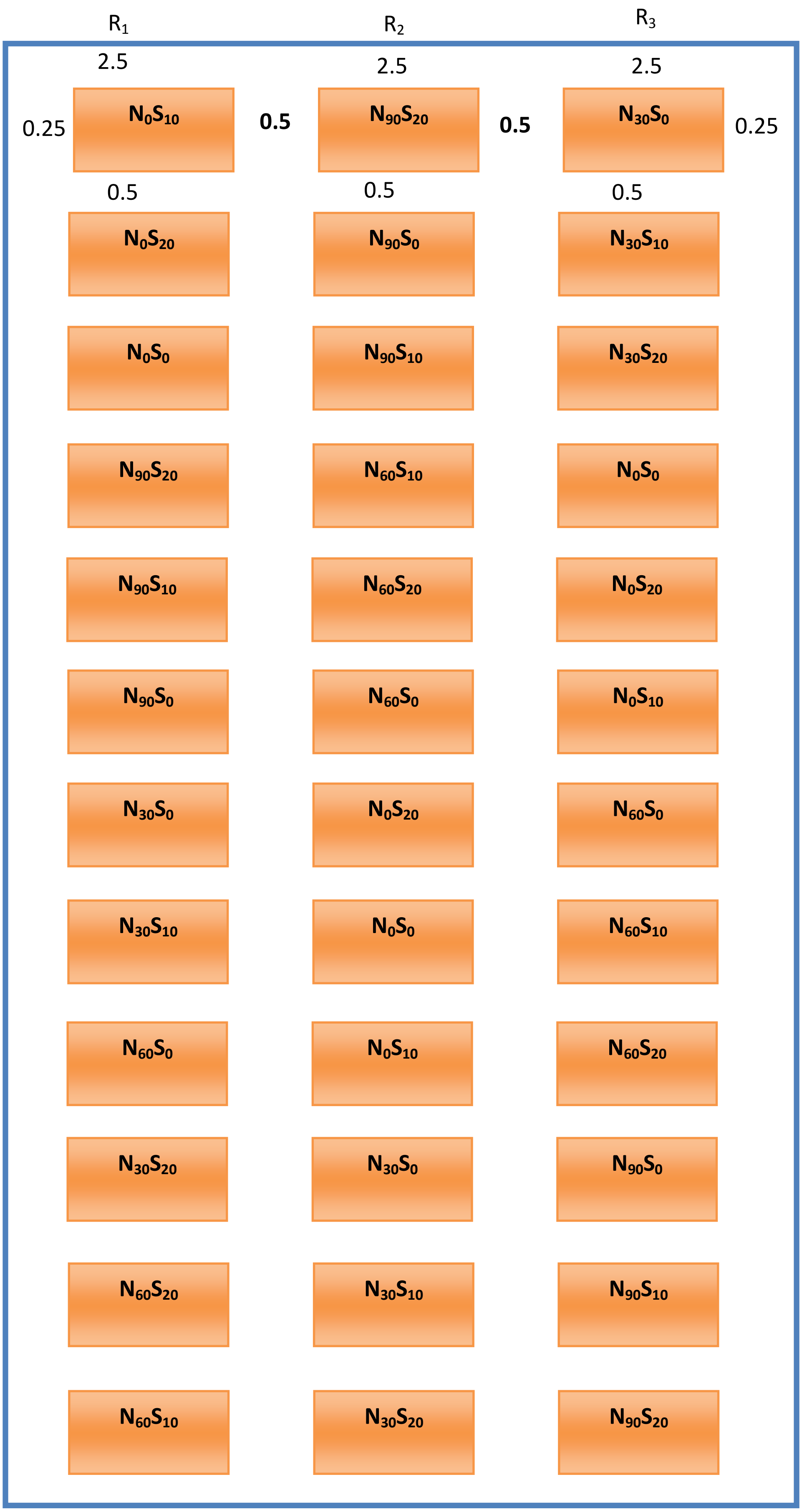
3.4.2 Treatment combination

There were 12 treatment combinations of different N and S doses used in the experiment which are as follows:

1. N_0S_0	7. N_2S_0
2. N_0S_1	8. N_2S_1
3. N_0S_2	9. N_2S_2
4. N_1S_0	10. N_3S_0
5. N_1S_1	11. N_3S_1
6. N_1S_2	12. N_3S_2

3.4.3 Design and layout

The experiment consisted of 12 treatment combinations and was laid out in Randomized Complete Block Design (RCBD) with 3 replications. The total plot number was 12 x 3 = 36. The unit plot size was 2.5 m x 1.5 m (3.75 m^2). The distance between block to block was 1 m and distance between plot to plot was 0.5 m.



24m×9m

RCBD

2 Factor

F_1=4 } total no of treatment 12
F_2=3

3 Replication

3.4.4 Land preparation

The land was ploughed well with power tiller for four times. Ploughed soil was then brought into desirable fine tilth and leveled by laddering. The weeds were cleaned properly. The final ploughing and land preparation were done on 17 November, 2018. According to the lay out of the experiment the entire experimental area was divided into three blocks and subdivided into plot for the sowing of black cumin seed. In addition, irrigation and drainage channels were prepared around the plot.

3.4.5 Fertilization application

In this experiment fertilizers were used under as follows:

Fertilizers	**Rate of application per ha.**
Urea	As per treatment
TSP	18 kg
MP	45 kg
Sulphur	As per treatment

The source of N, P ,K and S were urea, triple super phosphate, muriate of potash and gyosum. Half of urea and total amount of all other fertilizers of each plot were applied and incorporated into soil during final land preparation. Rest of the urea was top dressed after 30 days of sowing (DAS)

3.4.6 Sowing of seed

Sowing was done on 19 November, 2018 in rows 10 cm apart. Seeds were sown continuously in rows at the rate of 6 kg/ha. After sowing; the seeds were covered with fine tilth soil and slightly pressed by hand. In this experiment black cumin variety of BARI Kalozira-1 was used in the experiment as a planting material. BARI Kalozira-1 was developed by Bangladesh Agricultural Research Institute (BARI) in 2009. The seed was collected from the Regional Spice Research Centre, BARI, Joydebpur, Gazipur.

3.4.7 Thinning and weeding

The optimum plant population, 60 plants/ m^2 was maintained by thinning excess number of plants from the row at 15 days after sowing (DAS). The plant to plant and row to row distance was maintained as 9 cm and 24 cm, respectively. One weeding with trowel was done on 25 DAS.

3.4.8 Irrigation

Eight irrigations were given as plants required. First irrigation was given immediately after top dressing and other irrigation were applied as 14, 21, 28, 35, 42, 49, 56 DAS with watering can. After irrigation when the plots were in zoe condition, spading was done uniformly and carefully to conserve the soil moisture.

3.4.9 Crop protection

The field was investigated time to time to detect visual differences among the treatments and any kind of infestation by weeds, insects and diseases so that considerable losses by pest could be minimized. Diazinon 60 Ec was spayed twice at 15 days interval @ 2 ml L^{-1} of water to control aphid. Some plots started to die after rotting in the basal portion of the plant. For controlling this disease, Dithane M-45 was sprayed thrice at 10 days interval @ 2 g L^{-1} water.

3.4.10 Harvesting and threshing

Previous randomly selected ten plants, those were considered for data recording was collected from each plot to analyze the yield and yield contributing characters. The rest of the crops were harvested when 80% of the pod in terminal matures. After collecting sample plants, harvesting was started on March 16 and completed on March 30, 2019. The harvested crops were tied into bundles and carried to the threshing floor. The crop bundles were sun dried by spreading those on the threshing floor. The seeds were separated from the plants by beating the bundles with bamboo sticks.

3.4.11 Drying and weighing

The seeds thus collected were dried in the sun for couple of days. Dried seeds of each plot were weighed and subsequently converted into yield kg/ha.

3.5 Data collection

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

1. Plant height (cm)
2. Number of primary branches per plant
3. Number of secondary branches per plant
4. Number of capsule per plant
5. 1000 seed weight (g)
6. Seed yield per plot (g)
7. Seed yield (kg/ha)

3.5.1 Plant height (cm)

Plant height was measured at harvest. The height of the plant was determined by measuring scale considering the distance from the soil surface to the tip of the randomly ten selected plants and mean value was calculated for each treatment.

3.5.2 Number of primary branches per plant

The number of primary branches per plant was counted at harvest of black cumin plants. Mean value of data were calculated and recorded.

3.5.3 Number of secondary branches per plant

The number of secondary branches per plant was counted at harvest of black cumin plants.

3.5.4 Number of Capsules per plant

The number of capsules from ten plants were counted and calculated as per plant basis.

3.5.5 1000 seed weight (g)

A composite sample was taken from the yield of ten plants. The 1000-seeds of each plot were counted and weighed with a digital electric balance. The 1000-seed weight was recorded in gram.

3.5.6 Seed weight per plot (g)

The separated seeds of plot were collected, cleaned, dried and weighed properly. The seed weight per plot was then recorded in gram.

3.5.7 Yield (t/ha)

After threshing, cleaning and drying, total seed from harvested area were recorded and was converted to tones per hectare

3.6 Post harvest soil sampling

After harvest of crop soil samples were collected from each plot at a depth of 0 to 15 cm. Soil sample of each plot were air-dried, crushed and passed through a two mm (10 meshes) sieve. The soil samples were kept in plastic container to determine the physical and chemical properties of soil.

3.7 Soil analysis

Soil samples were analyzed for both physical and chemical characteristics viz. organic matter, pH, total N and available P, K, and S contents. The soil samples were analyzed by the following standard methods as follows:

3.7.1 Textural class

Mechanical analysis of soil were done by hydrometer method (Bouyoucos, 1926) and the textural class was determined by plotting the values of % sand, % silt and % clay to the Marshall’s textural triangular co-ordinate following the USDA system.

3.7.2 Soil pH

Soil pH was measured with the help of a glass electrode pH meter, the soil water ratio being maintained at 1: 2.5 (Jackson, 1962).

3.7.3 Organic matter

Organic carbon in soil sample was determined by wet oxidation method of Walkley and Black (1935). The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_2O_7$ solution with 1N $FeSO_{4.}$ To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results were expressed in percentage (Page *et al.*, 1982).

3.7.4 Total nitrogen

Total N content of soil were determined followed by the Micro Kjeldahl method. One gram of oven dry ground soil sample was taken into micro kjeldahl flask to which 1.1 gm catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 7 ml H_2SO_4 were added. The flasks were swirled and heated 160 ^{0}C and added 2 ml H_2O_2 and then heating at 360 ^{0}C was continued until the digest was clear and colorless. After cooling, the content was taken into 50 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination (Page *et al.*, 1982).

Then 20 ml digest solution was transferred into the distillation flask, Then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Add sufficient amount of 10N-NaOH solutions in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water.

Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink.

The amount of N was calculated using the following formula:

$$\% N = (T-B) \times N \times 0.014 \times 100 / S$$

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight in gram

3.7.5 Available phosphorus

Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen *et al.*, 1954). Phosphorus in the extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated the standard P curve (Page *et al.*, 1982).

3.7.6 Exchangeable potassium

Exchangeable K was determined by 1N NH_4OAc (pH 7) extraction methods and by using flame photometer and calibrated with a standard curve (Page *et al*. 1982).

3.7.7 Available Sulphur

Available S content was determined by extracting the soil with $CaCl_2$ (0.15%) solution as described by (Page *et al*. 1982). The extractable S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths.

3.8 Data analysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program MSTAT-C and the mean differences were adjusted by Least Significance Difference (LSD) test (Gomez & Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The results on effectiveness of various treatments of nitrogen and phosphorous including untreated control for achieving quality and higher yield of black cumin have been described and discussed below in details under the following head:

4.1. Plant height

4.1.1. Effect of nitrogen

Plant height was significantly influenced by different levels of nitrogen (Fig.1). Application of 90 kg N ha^{-1} produced the tallest plant (45.66 cm), which was statistically dissimilar with other treatment. The control treatment gave the lowest plant height (43.18 cm). It is clear that all N levels maintained a lead over control with regard to plant height. It is also observed that nitrogen doses increased with increasing of plant height. This corroborates the results of Tuncturk *et al*. (2012).

4.1.2 Effect of sulphur

Application of sulphur fertilizer significantly increased plant height (Fig. 2). The tallest plant (45.13 cm) was recorded from 20 kg S ha^{-1}, which was statistically similar with S_1 treatment. The shortest plant (42.76 cm) was recorded from control treatment. It is observed that plant height increased with the increased sulphur levels.

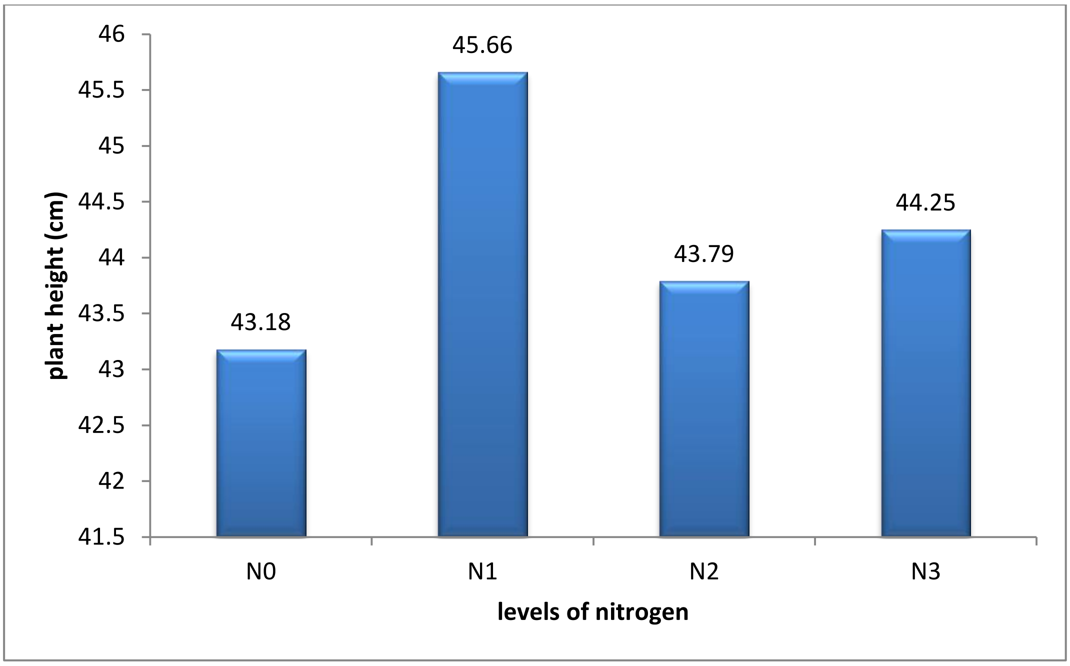


Fig. 1. Effect of nitrogen on plant height of black cumin

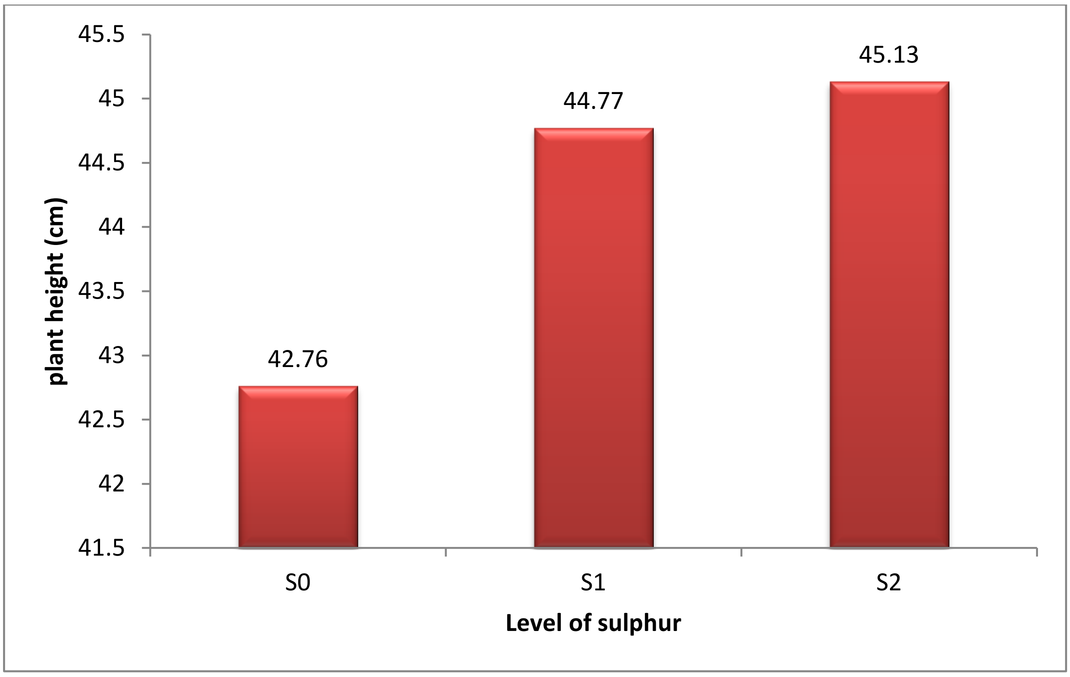


Fig. 2. Effect of sulphur on plant height of black cumin

4.1.3 Combined effect of nitrogen and sulphur

The combination of nitrogen and sulphur levels had significant effect on plant height of black cumin (Table 1). However, application of 90 kg N ha^{-1}coupled with 20 kg S ha^{-1} (N_3S_2) gave the tallest plant(49.40 cm). The Control treatment (N_0S_0) gave the lowest plant height (40.85 cm).

4.2 Number of primary branches plant^{-1}

4.2.1 Effect of nitrogen

Number of primary branches plant^{-1} was significantly influenced by different rates of nitrogen application under the present study (Fig.3). The highest number of primary branches plant^{-1} was recorded from 90 kg N ha^{-1} (N_3) (4.67), which were statistically similar with N_1 and N_2 treatments. The lowest number of primary branches plant^{-1} was observed from control treatment (N_0) (3.75). Number of primary branches plant^{-1} increased with the increased nitrogen doses. These findings were in consonance with those of Tuncturk *et al*. (2012).

4.2.2 Effect of sulphur

Application of sulphur fertilizer significantly influenced number of primary branches plant^{-1} (Fig.4). The maximum number of primarybranches plant^{-1}was recorded 20 kg Sha^{-1}(4.78). The minimum number of primary branches plant^{-1} was recorded from control treatment (3.83).

Table 1.Interaction effect of nitrogen and sulphur on plant height, number of primary branch and number of secondary branch per plant of black cumin

Treatment	Plant height (cm)	Number of primary branch	Number of secondary branch
N_0S_0	40.85 b	3.33 c	1.67 d
N_0S_1	44.97 ab	3.67 bc	3.33 bcd
N_0S_2	43.73 ab	4.33 abc	2.67 cd
N_1S_0	44.04 ab	4.00 abc	2.67 cd
N_1S_1	40.96 b	4.33 abc	4.67 abc
N_1S_2	41.71 ab	5.00 a	4.67 abc
N_2S_0	43.54 ab	3.67 bc	3.67 bcd
N_2S_1	45.87 ab	4.67 ab	4.00 bc
N_2S_2	46.88 ab	4.67 ab	4.33 bc
N_3S_0	45.29 ab	4.33 abc	5.33 ab
N_3S_1	43.41 ab	4.67 ab	5.33 ab
N_3S_2	49.40 a	5.00 a	6.67 a
$LSD_{(0.05)}$	7.23	1.12	1.88
CV (%)	9.65	5.35	7.21

Means with uncommon letters in a column are significantly different at 5% level of significance by DMRT.

N_0 = 0 kg N/ha

N_1 = 30 kg N/ha

N_2 = 60 kg N/ha

N_3= 90 kg N/ha

S_0= 0 kg S/ha

S_1= 10 kg S/ha

S_2 =20 kg S/ha

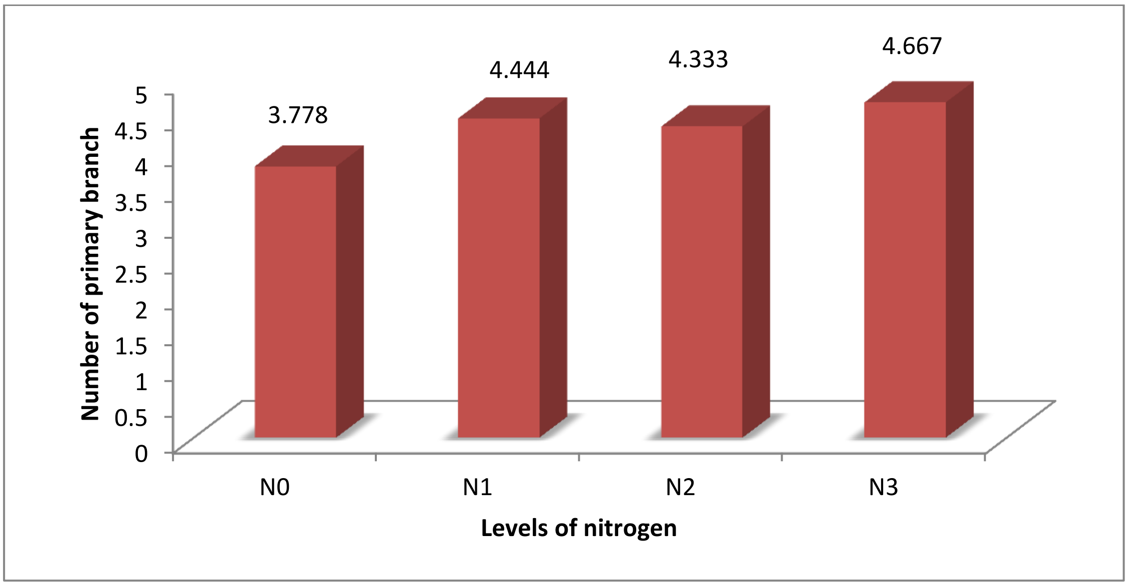


Fig. 3. Effect of nitrogen on number of primary branch per plant of black cumin

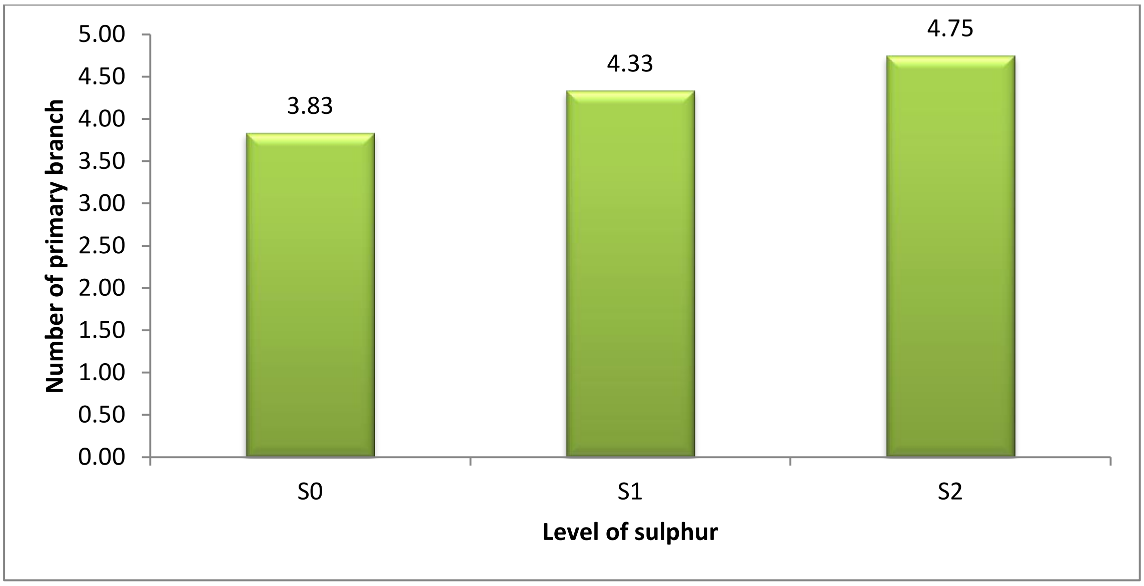


Fig. 4. Effect of sulphur on number of primary branch per plant of black cumin

4.2.3 Interaction effect of Nitrogen and Sulphur

The combination of nitrogen and sulphur levels had significant effect on number of primary branches plant^{-1} of black cumin (Table 1). However, the highest number of branches plant^{-1}(5.0) was observed at 90 kg N ha^{-1} along with 20 kg S ha^{-1} (N_3S_2) and (N_1S_2). The lowest number of primary branches plant^{-1}(3.33) was obtained from N_0S_0 and treatment.

4.3 Number of secondary branches plant^{-1}

4.3.1 Effect of nitrogen

Number of secondary branches plant^{-1} was significantly influenced by different levels of nitrogen (Fig.5). The highest number of secondary branches plant^{-1} (5.78) was recorded from 90 kg N ha^{-1} (N_3) which was dissimilar with other treatments. The lowest number of secondary branches plant^{-1} (2.56) was observed from control treatment (N_0). Number of secondary branches plant^{-1} increased with the increase of nitrogen doses. These findings were in agreement with those of Tuncturk *et al*. (2012).

4.3.2 Effect of sulphur

Application of sulphur fertilizer insignificantly influenced number of secondary branches plant^{-1} (Fig. 6). The maximum number of secondary branches plant^{-1} (4.58) was recorded from the application of 20 kg S ha^{-1}. The minimum number of branches plant^{-1}(3.33) was recorded from control treatment.

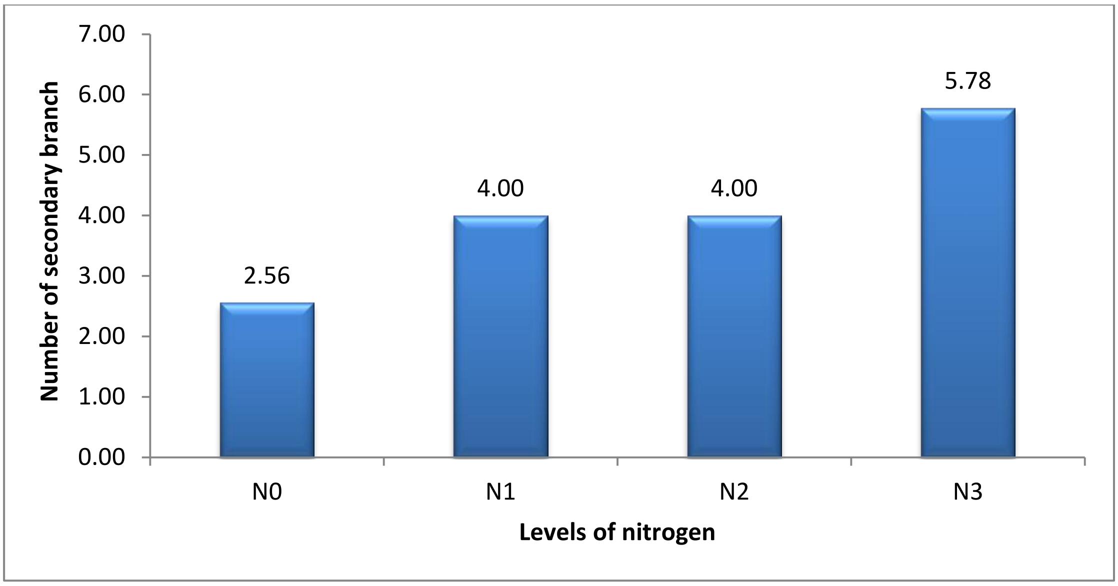


Fig. 5. Effect of nitrogen on number of secondary branch per plant of black cumin

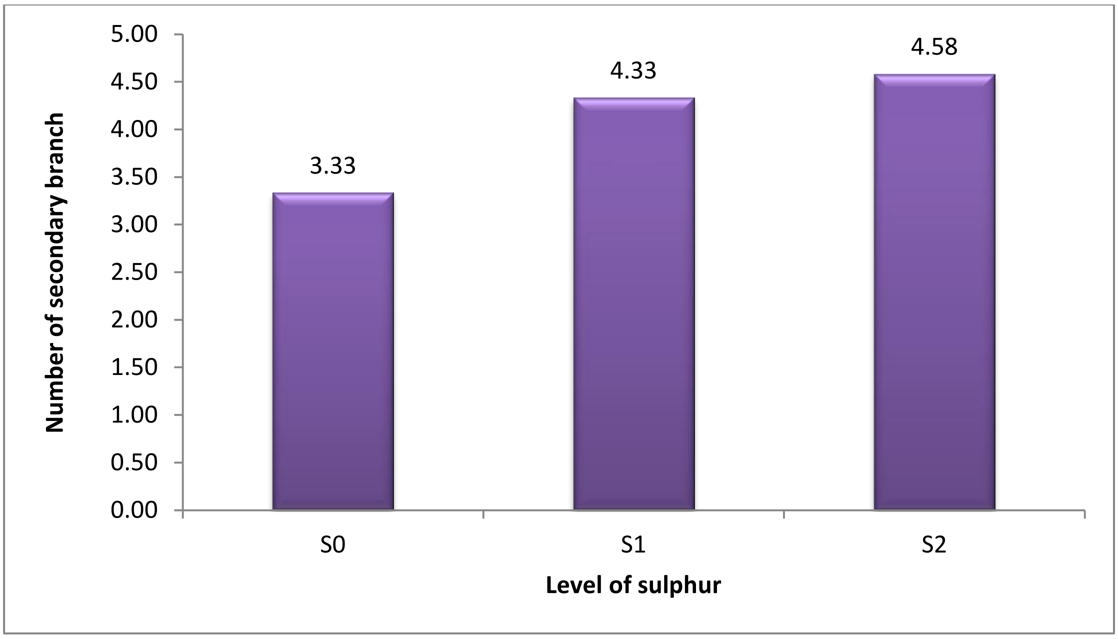


Fig. 6. Effect of sulphur on number of secondary branch per plant of black cumin

4.3.3 Interaction effect of nitrogen and sulphur

The combination of nitrogen and sulphur levels had significant effect on number of secondary branches plant^{-1} of black cumin (Table 1). However, the highest number of secondary branches plant^{-1} (6.67) was observed at 90 kg N ha^{-1}along with 20 kg S ha^{-1} (N_3S_2). The lowest number of secondary branches plant^{-1} was recorded from N_0S_0 treatment (1.67).

4.4 Number of Capsules plant^{-1}

4.4.1 Effect of nitrogen

The number of capsules plant^{-1} was significantly affected by different levels of nitrogenous fertilizers (Table 2).Number of capsules plant^{-1} increased with the increase level of nitrogen. The highest number of capsules plant^{-1} was recorded at 90 kg N ha^{-1}(10.89) which was statistically identical with N_2 treatment. The lowest number of capsules plant^{-1} was recorded from no nitrogen application (control) (6.89). Number of capsules plant^{-1} increased with the increase in nitrogen doses. These findings are in agreement with those of Tuncturk *et al*. (2012).

4.4.2 Effect of sulphur

Insignificant variations were clearly evident in case of number of capsules plant^{-1} with different sulphur levels (Table3). The highest number of capsules plant^{-1} (9.67) resulted from 20 kg Sha^{-1}and the lowest (7.58) was obtained from control treatment. Increase in sulphur level increased number of capsules plant^{-1}.

Table 2. Effect of nitrogen on yield and yield contributing character of black cumin

Treatment	Number of capsules per plant		Thousand seed weight (g)	Seed yield per plot (g)		Seed yield (kg/ha)	
N_0	6.89	c	1.66	275.57	b	734.84	d
N_1	8.22	b	1.70	302.00	b	805.33	c
N_2	9.22	ab	1.76	356.93	ab	951.82	b
N_3	10.89	a	1.83	395.37	a	1054.32	a
$LSD_{(0.05)}$	2.125		NS	65.06		22.8	
CV (%)	5.90		9.95	5.34		8.33	

Table 3. Effect of sulphur on yield and yield contributing character of black cumin

Treatment	Number of capsules per plant	Thousand seed weight (g)	Seed yield per plot (g)		Seed yield (kg/ha)	
S_0	7.58	1.70	303.83	b	810.20	b
S_1	9.17	1.73	320.73	b	855.27	b
S_2	9.67	1.78	372.85	a	994.27	a
$LSD_{(0.05)}$	NS	NS	41.31		46.74	
CV (%)	5.90	9.95	5.34		8.33	

4.4.3 Interaction effect of nitrogen and sulphur

The combination of nitrogen and sulphur levels had significant effect on number of number of capsules per plant of black cumin. The combination of 90 kg N ha^{-1} and 20 kg S ha^{-1}(N_3S_2) gave the highest number of capsules $plant^{-1}$ (11.67). The lowest number of capsules $plant^{-1}$ (5) was obtained from the control combination (N_0S_0) (Table 4).

4.5 1000 seed weight

4.5.1 Effect of nitrogen

Different levels of N fertilizer had no significant effect on 1000 seed weight of black cumin (Table 2). Application of nitrogen at different levels increased the 1000-seed weight up to 90 kg ha^{-1} which produced maximum seed weight (1.83 g) where control treatment gave the lowest seed weight (1.66 g).

4.5.2 Effect of sulphur

It reveals that sulphur levels had no significant effect on 1000-seed weight (Table.3).The application of sulphur increased 1000-seed weight. Application of 20 kg S ha^{-1} gave the highest 1000-seed weight (1.78g) where as control treatment gave the lowest (1.70g) 1000-seed weight. Seed yield increased with the increased sulphur doses. There was no significance difference observed among 10 and 20 kg S ha^{-1} in respect of 1000 seed weight.

Table 4. Interaction effect of nitrogen and sulphur on yield and yield contributing character of black cumin

Treatment	Number of capsules per plant		Thousand seed weight (g)		Seed yield per plot (g)		Seed yield (kg/ha)	
N_0S_0	5.00	e	1.60	c	246.70	e	657.87	g
N_0S_1	8.00	cd	1.63	bc	257.70	de	687.20	fg
N_0S_2	7.67	d	1.73	abc	322.30	c	859.47	d
N_1S_0	7.00	de	1.67	abc	268.00	de	714.67	f
N_1S_1	8.67	bcd	1.67	abc	280.30	d	747.47	e
N_1S_2	9.00	bcd	1.77	abc	357.70	b	953.87	c
N_2S_0	8.00	cd	1.73	abc	327.30	c	872.80	d
N_2S_1	9.33	abcd	1.77	abc	367.20	b	979.20	bc
N_2S_2	10.33	abc	1.77	abc	376.30	b	1003.47	b
N_3S_0	10.33	abc	1.80	abc	373.30	b	995.47	b
N_3S_1	10.67	ab	1.83	ab	377.70	b	1007.20	b
N_3S_2	11.67	a	1.87	a	435.11	a	1160.29	a
$LSD_{(0.05)}$	2.19		0.19		26.09		32.88	
CV (%)	5.90		9.95		5.34		8.33	

N_0 = 0 kg N/ha

N_1 = 30 kg N/ha

N_2 = 60 kg N/ha

N_3= 90 kg N/ha

S_0= 0 kg S/ha

S_1= 10 kg S/ha

S_2 =20 kg S/ha

4.5.3 Interaction effect of nitrogen and sulphur

The treatment combination of nitrogen and sulphur had significant effect on 1000-seed weight under the present study (Table 4). However, the combination of 90 kg N ha^{-1} with 20 kg S ha^{-1} (N_3S_2) supported plant to produce maximum 1000-seed weight (1.87 g) where the lowest one (1.60 g) was obtained from control treatment (N_0S_0).

4.6 Seed yield per plot

4.6.1 Effect of nitrogen

In the present study, significant variation was found in seed yield per plot (3.75 m^2) at different nitrogen levels (Table 2). Application of nitrogen at 90 kg ha^{-1} (N_3) produced the highest seed yield (395.37 g plot^{-1}) which was statistically similar with 60 kg N ha^{-1}and the control treatment gave the lowest seed yield 275.57 g plot^{-1}), which was statistically similar with 30 kg N ha^{-1} treatment. Seed yield plot^{-1}increased with the increase of nitrogen doses. These findings are in agreement with Tuncturk *et al*. (2012).

4.6.2 Effect of sulphur

Significant variation in seed yield per plot (3.75 m^2) was observed among the application of different sulphur levels represented in Table 3. Application of sulphur@20 kg ha^{-1} gave the highest seed yield (372.85 g plot^{-1}). Seed yield increased with the increasing application of sulphur fertilizer. The lowest seed yield (303.83 g plot^{-1}) was obtained from control treatment, which was statistically similar with S_1.

4.6.3 Interaction effect of nitrogen and sulphur

Nitrogen and sulphur fertilizer in combination put significant effect on perplot (3.75 m^2) seed yield and it was significantly superior (435.11 g plot^{-1}) at 90 kg N ha^{-1} with 20 kg S ha^{-1} (N_3S_2). There was no significant difference among N_3S_1, N_3S_0, N_2S_2, N_2S_1, and N_1S_1 in respect of seed yield plot^{-1}. But control treatment (N_0S_0) gave the lowest seed yield (246.70 g plot^{-1}) (Table 4).

4.7 Seed yield

4.7.1 Effect of nitrogen

Significant variation was found in seed yield per hectare at different nitrogen levels (Table 2). Nitrogen at 90 kg ha^{-1} (N_3) produced the highest seed yield (1054.32 kg ha^{-1}) and control treatment gave the lowest seed yield (734.84kg ha^{-1}). Application of 60 kg N ha^{-1} gave the second highest seed yield per hectare.

4.7.2 Effect of sulphur

Significant variation was observed in seed yield per hectare among the application of different sulphur levels (Table 3). Application of 20 kgS ha^{-1} gave the highest seed yield (994.27). The lowest seed yield was obtained from control treatment (810.20 kg ha^{-1}), which was statistically similar with 10 kg S ha^{-1} (S_1 treatment) .

4.7.3 Interaction effect of nitrogen and sulphur

Nitrogen and sulphur in combination influenced per hectare seed yield (Table 4). Application of 90 kg N ha^{-1} coupled with 20 kg S ha^{-1} (N_3S_2) gave the maximum seed yield (1160.29 kg ha^{-1}) which was dissimilar with other treatment. But the treatment combination (N_0P_0) gave the lowest seed yield (657.87 kg ha^{-1}).

4.8 Nitrogen concentration in post harvest soil of black cumin field

4.8.1 Effect of nitrogen

The effect of different doses of nitrogen fertilizer showed a statistically insignificant variation in the N concentration in post harvest soil (Table 5) of black cumin field. The total N content of the post harvest soil varied from 0.019 % to 0.026 %. Among the different doses of nitrogen fertilizer, N_3 (90 kgha^{-1}) treatment showed the highest N concentration (0.026 %) in soil. The lowest value was 0.019 % under control treatment and N_0.

4.8.2 Effect of sulphur

The effect of different doses of Sulphur fertilizer did not show a statistically significant variation in the N concentration in post harvest soil (Table 6) of black cumin field. The total N content of the post harvest soil varied from 0.019% to 0.025 %. The highest total N content (0.025 %) was observed in S_2 (20 kgha^{-1}) treatment. The lowest value of N (0.019 %) was observed under control (S_0) treatment.

Table 5. Effect of nitrogen fertilizer on the total nitrogen, available phosphorus, exchangeable potassium and available sulphur concentrations in post harvest soil in black cumin field

Treatment	Total N (%)	Available P (ppm)		Exchangeable K (meq/100g soil)	Available S (ppm)
N_0	0.019	10.91	b	0.18	17.67
N_1	0.024	17.26	a	0.20	19.22
N_2	0.020	19.83	a	0.22	20.83
N_3	0.026	18.60	a	0.25	23.50
$LSD_{(0.05)}$	NS	2.74		NS	NS
CV (%)	6.050	8.96		7.21	5.29

Table 6. Effect of Sulphur fertilizer on the total nitrogen, available phosphorus, exchangeable potassium and available sulphur concentrations in post harvest soil in black cumin field

Treatment	Total N (%)	Available P (ppm)	Exchangeable K (meq/100g soil)	Available S (ppm)
S_0	0.019	13.45 b	0.20	18.55
S_1	0.023	17.92 a	0.22	19.97
S_2	0.025	18.57 a	0.22	22.40
$LSD_{(0.05)}$	NS	3.26	NS	NS
CV (%)	6.05	7.21	8.96	5.29

4.8.3 Interaction effect of nitrogen and sulphur

Effect of combined application of different doses of nitrogen and Sulphur fertilizer on the N concentration was not observed significant in post harvest soil of black cumin field (Table 7). The highest concentration of N in post harvest soil (0.028 %) was recorded in the treatment combination of N_3S_2. On the other hand, the lowest N concentration (0.012%) in post harvest soil was found in N_0S_0.

4.9 Available phosphorus conce. in post harvest soil of black cumin field

4.9.1 Effect of nitrogen

The effect of different doses of nitrogen fertilizer showed a statistically significant variation in the available P concentration in post harvest soil (Table 5) of black cumin field. The available P content of the post harvest soil varied from 10.92 to 19.84 ppm. Among the different doses of nitrogen fertilizer, N_2 (60 kgha^{-1}) treatment showed the highest available P concentration (19.84 ppm) in soil which were statistically identical with N_3 and N_1 treatment. The lowest value was 10.92 ppm under control treatment and N_0.

4.9.2 Effect of sulphur

The effect of different doses of sulphur fertilizer showed a statistically significant variation in the available P concentration in post harvest soil (Table 6) of black cumin field. The total P content of the post harvest soil varied from 13.45 to 18.57 ppm. The highest available P content (18.57 ppm) was observed in S_2 treatment, which showed statistically similar result with S_1. The lowest value of P (13.45 ppm) was observed under control (S_0) treatment.

Table 7. Combined effect of nitrogen and sulphur fertilizer on the total nitrogen, available phosphorus, exchangeable potassium and available sulphur concentrations in post harvest soil in black cumin field

Treatment	Total N (%)	Available P (ppm)		Exchangeable K (meq/100g soil)		Available S (ppm)
N_0S_0	0.012	9.48	g	0.17	b	14.50
N_0S_1	0.022	10.89	fg	0.18	ab	17.98
N_0S_2	0.023	12.36	f	0.21	ab	20.54
N_1S_0	0.021	13.02	ef	0.21	ab	17.99
N_1S_1	0.024	18.77	c	0.22	ab	19.10
N_1S_2	0.027	19.98	bc	0.18	ab	20.57
N_2S_0	0.019	15.02	de	0.19	ab	19.11
N_2S_1	0.020	21.68	ab	0.23	ab	20.90
N_2S_2	0.023	22.77	a	0.24	ab	22.48
N_3S_0	0.025	16.30	d	0.25	ab	22.58
N_3S_1	0.026	20.36	bc	0.24	ab	21.90
N_3S_2	0.028	19.14	c	0.26	a	26.02
$LSD_{(0.05)}$	NS	2.03		0.08		NS
CV (%)	6.05	7.21		8.96		5.29

4.9.3 Interaction effect of nitrogen and sulphur

Significant effect of combined application of different doses of nitrogen and Sulphur fertilizer on the available P concentration was observed in post harvest soil of black cumin field (Table 7). The highest concentration of available P in post harvest soil (22.77 ppm) was recorded in the treatment combination of N_2S_2. On the other hand, the lowest available P concentration (9.48 ppm) in post harvest soil was found in N_0S_0.

4.10 Exchangeable potassium concentration in post harvest soil of black cumin field

4.10.1 Effect of nitrogen

The effect of different doses of nitrogen fertilizer showed a statistically insignificant variation in the exchangeable K concentration in post harvest soil (Table 5) of black cumin field. The exchangeable K content of the post harvest soil varied from 0.18 to 0.25 meq/100g soil. Among the different doses of nitrogen fertilizer, N_3 (90 kg ha^{-1}) treatment showed the highest exchangeable K concentration (0.25meq/100g soil) in soil. The lowest exchangeable K value was 18 meq/100g soil under control treatment and N_0.

4.10.2 Effect of sulphur

The effect of different doses of Sulphur fertilizer showed a statistically insignificant variation in the exchangeable K concentration in post harvest soil (Table 6) of black cumin field. The exchangeable K content of the post harvest soil varied from 0.20 to 0.22meq/100g soil. The highest exchangeable K content (0.22) was observed in S_2 and S_1 treatment. The lowest value of exchangeable K (0.20 meq/100g soil) was observed under control (S_0) treatment.

4.10.3 Interaction effect of nitrogen and sulphur

Significant effect of combined application of different doses of nitrogen and Sulphur fertilizer on the exchangeable K concentration was observed in post harvest soil of black cumin field (Table 7). The highest concentration of exchangeable K in post harvest soil (0.26 meq/100g soil) was recorded in the treatment combination of N_3S_2. On the other hand, the lowest exchangeable K concentration (0.17 meq/100g soil) in post harvest soil was found in N_0S_0.

4.11Available Sulphur concentration in soil of black cumin

4.11.1 Effect of nitrogen

Available S concentration of soil was significantly influenced by application different levels of nitrogen (Table 5). The highest available Sulphur concentration in soil (23.50 ppm) was recorded in N_3 (90 kg ha^{-1}). The lowest available Sulphur concentration in soil (17.67 ppm) was recorded in N_0 treatment where no nitrogen was applied.

4.11.2 Effect of Sulphur

Available S concentration of soil was not significantly influenced by application levels of Sulphur (Table 6). The highest available Sulphur concentration in soil (22.40 ppm) was recorded in S_2 (20 kg ha^{-1}) treatment. The lowest available Sulphur concentration in soil (18.55) was recorded in S_0 treatment where no Sulphur was applied.

4.11.3 Interaction effect of Nitrogen and Sulphur

Significant effect of combined application of different doses of nitrogen and available Sulphur fertilizer on the available Sulphur concentration was observed in soil (Table 6). The highest concentration of available Sulphur in the soil (14.50 ppm) was recorded in the treatment combination of N_3S_2.The lowest available Sulphur concentration (26.02 ppm) in soil was found in N_0S_0.

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted at the Farm of Sher-e-Bangla Agricultural University, Dhaka to during *rabi* season (November to March) of 2018-19 to examine the effect of nitrogen and sulphur on growth & yield of black cumin (*Nigella sativa* L.). The experiment comprised of four levels of nitrogen viz. N_0 (0 kg N ha^{-1}), N_1 (30 kg N ha^{-1}), N_2 (60 kg N ha^{-1}) and N_3 (90 kg N ha^{-1}) and three levels of sulphur viz. S_0 (0 kg S ha^{-1}), S_1 (10 kg S ha^{-1}) and S_2 (20 kg S ha^{-1}). The experiment was set up in Randomized Complete Block Design (factorial) with three replications. There were 12 treatment combinations in all.

Data on different growth and yield parameters such as Plant height, number of primary branches per plant, number of secondary branches per plant, number of capsule per plant, 1000 seed weight, Seed yield per plot and Seed yield per hectare and N, P, K, S concentration in post harvest soil were recorded and analyzed statistically.

Plant height was significantly influenced by different levels of nitrogen. Application of 90 kg N ha^{-1} produced the tallest plant (45.66 cm). Number of primary branches $plant^{-1}$ was significantly influenced by different rates of nitrogen application under the present study. The highest number of primary branches $plant^{-1}$ was recorded from 90 kg N ha^{-1} (N_3) (4.67). The highest number of secondary branches $plant^{-1}$ (5.78) was recorded from 90 kg N ha^{-1}. The number of capsules $plant^{-1}$ was significantly affected by different levels of nitrogenous fertilizers. Number of capsules $plant^{-1}$ increased with the increase level of nitrogen. The highest number of capsules $plant^{-1}$ was recorded at 90 kg N ha^{-1} (10.89). Different levels of N fertilizer had not significant effect on 1000 seed weight of black cumin. Application of nitrogen at different levels increased the 1000-seed weight up to 90 kg ha^{-1} which produced maximum seed weight (1.83 g). In the present study, significant variation was found in seed yield per plot (3.75 m^2) at different nitrogen levels. Application of nitrogen at 90 kg ha^{-1} (N_3) produced the highest seed yield (542.30 g $plot^{-1}$). Significant variation was found in seed yield per hectare at different nitrogen levels. Nitrogen at 90 kg ha^{-1} (N_3) produced the highest seed yield (1446.00 kg ha^{-1}) and control treatment gave the lowest seed yield (1081.00 kg ha^{-1}).

The effect of different doses of nitrogen fertilizer showed a statistically insignificant variation in the N concentration in post harvest soil of black cumin field. Among the different doses of nitrogen fertilizer, N_3 (90 kg ha^{-1}) treatment showed the highest N concentration (0.026 %) in soil. The effect of different doses of nitrogen fertilizer showed a statistically significant variation in the S concentration in post harvest soil of black cumin field. Among the different doses of nitrogen fertilizer, N_2 (60 kg ha^{-1}) treatment showed the highest nitrogen concentration (19.84 ppm) in soil. The effect of different doses of nitrogen fertilizer showed a statistically insignificant variation in the K concentration in post harvest soil of black cumin field. The different doses of nitrogen fertilizer, N_3 (90 kg ha^{-1}) treatment showed the highest K concentration (0.55 meq/100g soil) in soil. S concentration of soil was significantly influenced by application different levels of nitrogen. The highest Sulphur concentration in soil (0.32 %) was recorded in N_3 (90 $kgha^{-1}$).

Application of sulphur fertilizer significantly increased plant height (Table 2). The tallest plant (45.13 cm) was recorded from 20 kg S ha^{-1}. Application of sulphur fertilizer significantly influenced number of primary branches $plant^{-1}$. The maximum number of primary branches $plant^{-1}$ was recorded 20 kg S ha^{-1} (4.78). Application of sulphur fertilizer insignificantly influenced number of secondary branches $plant^{-1}$. The maximum number of secondary branches $plant^{-1}$ (4.58) was recorded from the application of 20 kg S ha^{-1}. Insignificant variations were clearly evident in case of number of capsules $plant^{-1}$ with different sulphur levels. The highest number of capsules $plant^{-1}$ resulted from 20 kg S ha^{-1} (9.67). It reveals that sulphur levels had not significant effect on 1000-seed weight. The application of sulphur increased 1000-seed weight. Application of 20 kg S ha^{-1} gave the highest 1000-seed weight (1.78g). Significant variation in seed yield per plot (3.75 m^2) was observed among the application of different sulphur levels. Application of sulphur @ 20 kg ha^{-1} gave the highest seed yield (515.60 g $plot^{-1}$). Significant variation was observed in seed yield per hectare among the application of different sulphur levels. Application of 20 kg S ha^{-1} gave the highest seed yield (1375.05). The lowest seed yield was obtained from control treatment (1157.00 kg ha^{-1}).

The effect of different doses of sulphur fertilizer did not show a statistically significant variation in the N concentration in post harvest soil of black cumin field. The highest total N content (0.025 %) was observed in S_2 (20 kgha^{-1}) treatment. The effect of different doses of Sulphur fertilizer showed a statistically significant variation in the P concentration in post harvest soil of black cumin field. The highest total P content (18.57 ppm) was observed in S_2 treatment. The effect of different doses of Sulphur fertilizer showed a statistically insignificant variation in the K concentration in post harvest soil of black cumin field. The highest total K content (0.52) was observed in S_2 and S_1 treatment. S concentration of soil was not significantly influenced by application levels of Sulphur. The highest Sulphur concentration in soil (0.30 %) was recorded in S_2 (20 kg ha^{-1}) treatment.

The combination of nitrogen and sulphur levels had significant effect on all parameter of black cumin. However, application of 90 kg N ha^{-1} coupled with 20 kg S ha^{-1} (N_3S_2) gave the tallest plant (49.40 cm). The highest number of branches $plant^{-1}$ (5.0), number of secondary branches $plant^{-1}$ (4.67), number of capsules $plant^{-1}$ (11.67), 1000-seed weight (1.87 g) and seed yield per plot was observed at 90 kg N ha^{-1} along with 20 kg S ha^{-1} (N_3S_2). Nitrogen and sulphur in combination influenced per hectare seed yield. Application of 90 kg N ha^{-1} coupled with 20 kg S ha^{-1} (N_3S_2) gave the maximum seed yield (1643.00 kg ha^{-1}). The treatment combination (N_0P_0) gave the lowest seed yield (1004.00 kg ha^{-1}).

Effect of combined application of different doses of nitrogen and sulphur fertilizer on the N concentration was not observed significant in post harvest soil of black cumin field. The highest concentration of N in post harvest soil (0.028 %) was recorded in the treatment combination of N_3S_2. Significant effect of combined application of different doses of nitrogen and Sulphur fertilizer on the P concentration was observed in post harvest soil of black cumin field. The highest concentration of P in post harvest soil (22.77) was recorded in the treatment combination of N_2S_2. Significant effect of combined application of different doses of nitrogen and Sulphur fertilizer on the K concentration was observed in post harvest soil of black cumin field. The highest concentration of K in post harvest soil (0.557 meq/100g soil) was recorded in the treatment combination of N_3S_2. Significant effect of combined application of different doses of nitrogen and Sulphur fertilizer on the Sulphur concentration was observed in soil. The highest concentration of Sulphur in the soil (0.34 %) was recorded in the treatment combination of $N_3S_{2.}$

The results of the present study generated some information which may help increase the higher seed yield of black cumin. Hence the present study may be concluded as follows:

I. Application of 90 kg N ha^{-1} coupled with 20 kg S ha^{-1} gave the higher seed yield of black cumin.
II. Application of 90 kg N ha^{-1} in combination with 20 kg S ha^{-1} or application of 60 kg N ha^{-1} coupled with 20 kg S ha^{-1} gave the reasonable seed yield of black cumin.

RECCOMENDATION

i. Application of 90 kg N ha^{-1} coupled with 20 kg S ha^{-1} was suitable for black cumin cultivation.

ii. The study might be conducted at the same Agro Ecological Condition for the conformation of the result.

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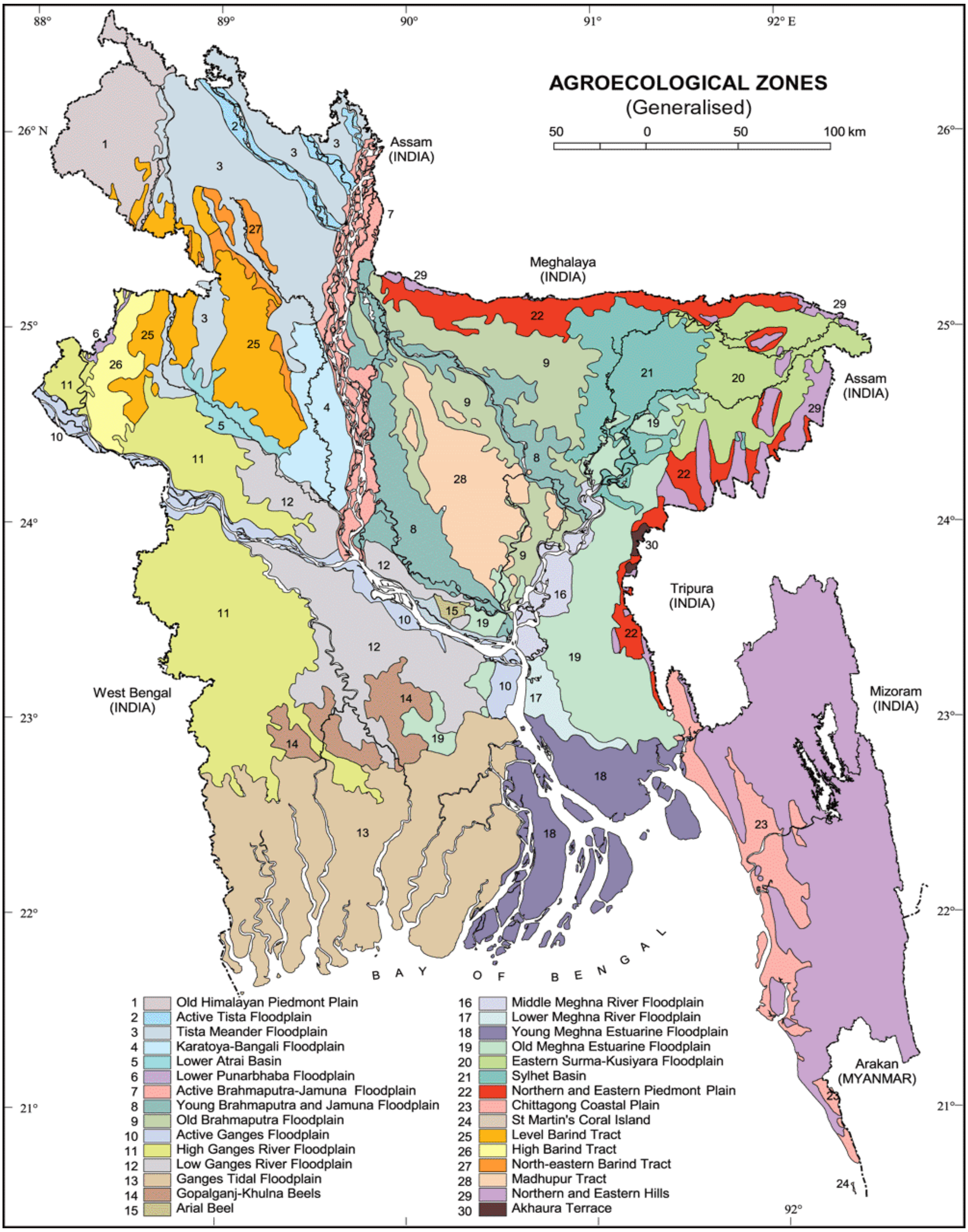
APPENDICES

Appendix I: Experimental location on the map of agro-ecological zones of Bangladesh



Appendix II: **Soil characteristics of Sher-e-Bangla Agricultural University Farm, Dhaka analyzed by Soil Resources Development Institute (SRDI), Farmgate, Dhaka.**

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy farm, SAU, Dhaka
AEZ	Modhupur tract (28)
General soil type	Shallow Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	**N/A**

Source: Soil Resources Development Institute (SRDI)

B. Physical and Chemical properties of the Initial soil

Characteristics	**Value**
Practical size analysis	
Sand (%)	16
Silt (%)	56
Clay (%)	28
Textural class	Silty clay loam
pH	6.27-6.49
Organic matter (%)	0.93
Total N (%)	0.04
Available P (ppm)	22.77
Available K (meq/100g soil)	0.15
Available S (%)	15

Source: Soil Resources Development Institute (SRDI).