GROWTH AND YIELD OF QUINOA (*Chenopodium quinoa* Willd.) AS AFFECTED BY SPLIT APPLICATION OF NITROGEN

MST. NAZMUNNAHER

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA -1207

DECEMBER, 2021

GROWTH AND YIELD OF QUINOA (*Chenopodium quinoa* Willd.) AS AFFECTED BY SPLIT APPLICATION OF NITROGEN

BY

MST. NAZMUNNAHER

Reg. No.: 19-10273

Email Id: nazmunnaher094@gmail.com

Phone Number: 01773631327

A Thesis

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 (MS)
IN
AGRONOMY

Semester: July- December, 2021

Approved By:

……………………………………..
(Prof. Dr. Parimal Kanti Biswas)
Supervisor

………………………………
Prof. Dr. Md. Shahidul Islam
Co-supervisor

…………………………………..
Prof. Dr. Md. Abdullahil Baque
Chairman
Examination Committee

DEPARTMENT OF AGRONOMY

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207
Phone: 44814043

CERTIFICATE

This is to certify that the thesis entitled **''GROWTH AND YIELD OF QUINOA (*Chenopodium quinoa* Willd.) AS AFFECTED BY SPLIT APPLICATION OF NITROGEN''** 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 **AGRONOMY**, embodies the result of a piece of *bona fide* research work carried out by **MST. NAZMUNNAHER**, Registration number: **19-10273** 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 this investigation has duly been acknowledged.

Dated:

Dhaka, Bangladesh

(Prof. Dr. Parimal Kanti Biswas)

Supervisor

DEDICATED TO MY BELOVED PARENTS

ACKNOWLEDGEMENTS

All applauses are due to the Almighty Allah the great, the gracious, merciful and utmost ruler of the universe who enabled the Author to complete the research work and thesis successfully for the degree of Master of Science (MS) in Agronomy.

*The Author would like to express her earnest gratitude and profound appreciation to her respected research supervisor **Dr. Parimal Kanti Biswas**, Professor, Department of Agronomy and Dean, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, for his guideness, continuous direction, constructive criticism, encouragement, and valuable advice throughout the period of this research work and preparation of this manuscript of thesis.*

*Heartiest gratitude is due to the respectable co-supervisor **Prof. Dr. Md. Shahidul Islam**, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, for his valuable suggestions, kind co-operation and dynamic guidance throughout the study and research work.*

*The Author also expresses her sincere appreciation, immense indebtedness to the honorable Chairman, **Prof. Dr. Md. Abdullahil Baque**, Department of Agronomy, SAU, Dhaka for valuable suggestions and cooperation during the study period*

The Author would like to express her deepest respect and boundless gratitude to all the respected teachers of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for their valuable teaching, sympathetic co-operation, and inspirations throughout the course of this study and research work.

The Author feels proud of expressing her sincere appreciation and gratitude to Project Implementation Unit, SAURES for giving financial support to conduct the to study.

The Author feels proud to express her sincere appreciation and gratitude to Ministry of Science and Technology, The People's Republic of Bangladesh for providing her National Science and Technology (NST) fellowship.

*The Author feels proud to express her deepest and endless gratitude to all her course mates and friends for their help during experimentation. Special thanks to her best friend **Afroja Akter Homa** for their support and encouragement to complete this study*

*The Author is deeply indebted to her father **Md. Sirazul Islam** and grateful to her respectful mother **Mst. Sabina Yeasmin** and brother **Md. Sohrab Hossain** for their moral support, encouragement and love with cordial understanding during my research work and preparation of thesis.*

The Author

GROWTH AND YIELD OF QUINOA (*Chenopodium quinoa* Willd.) AS AFFECTED BY SPLIT APPLICATION OF NITROGEN

ABSTRACT

An experiment was conducted at the Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka from November, 2020 to February, 2021 to study the performance quinoa in respect to growth and yield that influenced by split application of nitrogen fertilizer. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Seven treatments included in the study as; T_1: Control (1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS), T_2: 2/3 N top dressed at 25 DAS, T_3: 2/3 N top dressed at 45 DAS, T_4: 1/3 N top dressed at 25 DAS and 1/3 N foliar spray at 45 DAS, T_5: 1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS, T_6: 2/3 N foliar spray at 45 DAS, T_7: 1/3 N foliar spray at 25 DAS and rest 1/3 N foliar spray at 45 DAS. One third nitrogen (150 kg N ha^{-1}) along with 50 kg P ha^{-1}, 50 kg K ha^{-1}, 60 kg Gypsum ha^{-1}, 10 kg $ZnSO_4$ and 5 kg Boric acid ha^{-1} was applied as basal dose for all the treatments. The different growth parameters, yield attributes and yield were significantly varied through split applications of nitrogenous fertilizer. The experimental results indicated that seed yield of quinoa was significantly influenced by the split application of nitrogen. The highest plant height (37.09 cm), leaves number plant^{-1} (25.40), fresh weight (12.50 g), dry weight (5.02 g), inflorescence number (20.87), 1000-seed weight (3.79 g), straw yield (1.31 t ha^{-1}), and biological yield (2.85 t ha^{-1}) at harvest was obtained from T_2 treatment that was statistically similar with T_6 treatments, while the highest root length (10.00 cm), highest SPAD value (57.29), highest harvest index (56.49%), highest grain yield (1.56 t ha^{-1}) at harvest was obtained from T_6 that was similar with T_2 (1.54 t ha^{-1}). The lowest plant height (32.81 cm), dry weight plant^{-1} (3.16 g), root length plant^{-1} (6.82 cm) and shoot length plant^{-1} (31.96 cm) at harvest was obtained from T_1 while the lowest leaves number plant^{-1} (16.40), number of branches plant^{-1} (14.33), SPAD value (44.24), number of inflorescence plant^{-1} (12.80), 1000-seed weight (3.30 g), seed yield (0.84 t ha^{-1}), straw yield (0.78 t ha^{-1}), biological yield (1.62 t ha^{-1}) and harvest index (51.91%) at harvest was recorded from T_5 treatments. Therefore, present study suggest that quinoa with 2/3 N top dressed at 25 DAS or 2/3 N foliar spray at 45 DAS is the most compatible in respect of yield.

LIST OF CONTENTS

LIST OF CONTENTS (CONTD.)

LIST OF CONTENTS (CONTD.)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BV	=	Biological value
cm	=	Centimeter
DAS	=	Days After Sowing
CV %	=	Percent Coefficient of Variation
dS/m	=	Deci Siemens per metre
e.g.	=	exempli gratia (L), for example
et al.,	=	And others
etc.	=	Etcetera
EC	=	Electrical conductivity
FAO	=	Food and Agriculture Organization
g	=	Gram
GF	=	Grain filling period
GYP	=	Grain yield per plant
i.e.	=	id est (L), that is
IYQ	=	International Year of Quinoa
Kg	=	Kilograms
LSD	=	Least Significant Difference
M.S.	=	Master of Science
m^2	=	Meter squares
NaCl	=	Sodium Chloride
No.	=	Number
%	=	Percentage
SAU	=	Sher-e-Bangla Agricultural University
TGV	=	Thousand grain volume
WHO	=	World Health Organization

CHAPTER I
INTRODUCTION

Quinoa (*Chenopodium quinoa* Willd.), belonging to Amaranthaceae, has recently been recognized as a strategic plant in the world. About 250 species of this family have been identified worldwide, which are found to be exotic plants in South Africa (Maradini *et al*., 2015; Navruz-Varli and Sanlier, 2016). This family consists of economic species, such as spinach and beetroot (Jacobsen 2003; Vega- Gálvez *et al.,* 2010). Quinoa together with its wild relatives, including (*Chenopodium carnosolum, C. petiolare, C. pallidicaule, C. quinoa melanospermum* subsp., *C. ambrosoides* incisum) are a high diversity of species and applications (Fuentes *et al.,* 2009). These species have traditionally been planted over the years by farmers from the Andes in Colombia, Ecuador, Peru, Bolivia, Chile, and Argentina. Quinoa is a dwarf plant with about 93% self- immolation from the western Andean mountains of South America (Jacobsen *et al.,* 2005; Bazile *et al.,* 2014). To introduce the role and value of this plant in food security, the development of consumption and production, Food and Agriculture Organization (FAO) named 2013 as the International Year of Quinoa (FAO, 2013). Quinoa is highly resistant against abiotic stresses, such as a wide range of cold, drought and salinity of the soil and also has an excellent ability to grow in marginal soils (Jacobsen *et al.,* 2009; Hernández-Ledesma, 2019). Quinoa is considered a climate-resistant, gluten-free, highly nutritious seed product with remarkable agronomic adaptation to adverse climatic conditions (Dallagnol *et al.*, 2013). Therefore, the goal of most countries in the world is to increase and evaluate the production of quinoa (Ruiz *et al.,* 2016). The procurement of sustainable food in noxious environmental conditions, resulting from climate change scenarios for its credentials in nutritional composition and relevance was selected by NASA (National Aeronautics and Space Administration) as a preferred food for its astronauts on board space missions (Jaikishun *et al.,* 2019). Most of the developing countries have to cultivate plants that can meet their nutritional needs and grow properly in the climate of their areas. It can be cultivated from subtropical to cold climate at an altitude, ranging from sea level to 4000 m above mean sea level in 40°S to 2°N latitude and adaptable to broad environmental range (Repo-Carrasco *et al.,* 2010). It is also suitable for cultivation in drier areas with 350 mm of precipitation and colder temperatures up to an average of 12°C. Bolivia and Peru are the countries contributing more than 80% production, followed by Ecuador, United States America, China, Argentina, Chili, French and Canada which together contribute 15–20% of the world production (Bazile *et al.*, 2013). Also, the limited water resources in Iran and the fact that a vast area of the country are climatically among arid and semiarid zones, it is of paramount importance to properly manage water exploitation along with accurate use of agronomic practices, particularly under limited available inputs (Foster, 1999). This plant is cultivated from areas of sea level up to 4000 m above sea level and has several drought tolerance mechanisms and high-water use efficiency (Alvarez-Juete *et al.*, 2010 and Brady *et al.*, 2007).

At recent years there has been an increase in interest in quinoa as a cereal crop, its production has increased exponentially all over the world, because of its good nutritional properties, but also because of its ability to grow and adapt under different climatic conditions, it can withstand frost, salinity, drought and the ability to grow in marginal soils. It could be a suitable alternative food in areas where rice cultivation is limited (Repo-Carrasco-Valencia *et al*., 2010). Increasing agricultural production, along with the increase in population and development programs, has increased the use of chemical fertilizers, nitrogen in particular is believed to be one of the most important nutrients. Quinoa leaves are different in their color (green, purple, red), with the reddish color due to the presence of a type of beta cyanins pigment called betalains (Gallardo *et al*., 1992). They are typically cooked and served as a side dish, similar to amaranth leaves (Mlakar *et al.*, 2010) or spinach. Fresh leaves and sprouts of quinoa are edible and may be consumed in salad, and also used as a valuable supplement for functional or complete foods and fortification (Gawlik Dziki *et al*., 2009 & 2015), also they have a high nutritional value, as well as high antioxidant and anticancer activities (Gawlik-Dziki *et al.*, 2013; Świeca *et al.*, 2014). Young quinoa leaves showed no detectable amounts of saponins approximately less than 0.015% (Burnouf-Radosevich and Paupardin, 1983). Quinoa leaves can be eaten as a leafy vegetable, just like spinach. It is obsessive in broad diversity of forms i.e., grains, flakes, pasta, bread, biscuits, beverages, meals etc. Quinoa can be successfully grown on marginal soils showing its very low nutrient requirements (Jacobsen, 2003). Its seed is reported to contain a well-balanced and significant amount of the nine essential amino acids required to fulfill our daily protein requirement (Miranda *et al.*, 2012). The seed is also an important source of vitamins, unsaturated fatty acids and carotenoids (Hinojosa *et al.*, 2019) which are higher than the local cereals in Zimbabwe. The high nutritional status makes it a most critical crop in addressing the malnutrition and hidden hunger problems in many developing countries. The quinoa grain is highly demanded in the USA, Europe, and Asia (Hinojosa *et al.,* 2019); hence, it is a potentially innovative and economically promising export cash crop for many African countries such as Zimbabwe. Additionally, the quinoa has multi-uses, the seeds and leaves are utilized as food, biomass used as animal feed or cover crop, and can serve as a phytoremediation tool for environmental cleaning. Quinoa seeds have high levels of lysine, methionine, and cysteine and contain about 15% to 20% protein (Matiasevich *et al*., 2006). Its high nutritional value and, most importantly, its resistance to weather and soil conditions, has doubled its value (Navruz-Varli and Sanlier, 2016). Quinoa flour works well as a starch extender when combined with wheat flour or grain, or corn meal in making biscuits, bread and processed food. The seeds are also used for brew beer and for because of its high nutritional value and medicinal use, animal feed. In poultry-feeding trials, chicks fed with aeration containing cooked quinoa made equal gains to those receiving maize and skimmed milk

Increasing agricultural production, along with the increase in population and development programs, has increased the use of chemical fertilizers, nitrogen in particular is believed to be one of the most important nutrients. However, quinoa is also highly responsive to soil nitrogen (Erley *et al.,* 2005; Gomaa, 2013; Biswas *et al*, 2021). The use of modern commercial fertilizers in agricultural production results in increased crop yields in addition to the effect of better plant nutrition through commercial fertilizers signify themselves not only in increasing yields, but also in an increase in the total biomass production (Finck, 1982). Hamid and Sarwar (1976) reported that the split application of phosphorus and nitrogen elements are considered the most important nutrients for root development, seed formation, growth and yield. (Beigzade *et al*., 2013). Potassium is one of the three macro primary nutrients, which is necessary for plant growth (Lakudzala, 2013).

There are no experimental data was available to understand the quinoa responses to split application of nitrogen fertilizer on growth and yield. To gain better understanding of quinoa production as a new crop in Bangladesh, the experiment was aimed to evaluate the growth and yield responses of quinoa under split application of nitrogen fertilizer in Bangladesh climate condition with the subsequent objectives.

i. to find out the contribution of urea split application on quinoa

ii. to find out the best way of urea fertilizer application for maximum yield of quinoa

CHAPTE II

REVIEW OF LITERATURE

In this chapter an attempt has been made to review the pertinent literature on the split application effects of nitrogen on growth, yield attributes, yield of quinoa, which is related matter of present investigation.

2.1 Importance of quinoa

Quinoa is a pseudocereal, distributed and adapted in the different agro climatic zone. Its grains have greater nutritive value than conventional cereals and it is promising worldwide for human intake and nourishment. It has unusual composition and excellent balance between oil, fat, and protein. The quinoa decreases the risk of various diseases therefore; it is a good example of functional food. The crop possesses genetic diversity and is rich in minerals, vitamins, and all essential amino acids. These nutritional and functional characteristics endow the crop with immune regulator, anti-oxidant, anti-diabetic, anti-inflammatory and anti-cancer properties. It provides a gluten-free diet, which is beneficial for celiac patients. The Quinoa is considered for its protein content as it contains all essential amino acids with excellent in vitro digestibility. The present review is an attempt to collect and arrange the facts that establish quinoa as a protein crop. Therefore, the aim of this experiment is to evaluate quinoa yield response to N fertilization, NUE as well as to estimate the path coefficient to determine the important traits that are directly or indirectly involved in determining the productivity of quinoa crop. When ample information on quinoa related to split application of nitrogen fertilizer were not available, relevant literatures on crops associated to family Amaranthaceae were also cited.

2.2 Performance of quinoa at split application of nitrogen fertilizer

2.2.1 Plant height

Tahereh *et al.* (2021) conducted a field experiment and found out that plant height also increased with increasing N levels in each of the studied densities. The split application and stage of N use in each of the applied densities led to increased height of the plant. The results showed the highest plant height (93.6 cm) was obtained from the interaction of the three-stage split application at 180 kg N with a seed density of

10 kg ha^{-1}, which increased by 78.4% compared to the lowest plant height due to the interaction of seed density (6 kg ha^{-1}) and 120 kg N used in the two-stage split application.

Biswas *et al.* (2021) conducted an experiment and they recorded plant height of quinoa was significantly influenced by nitrogen dose. At 21 DAS, the highest plant height (13.07 cm) was recorded in (250 kg N ha^{-1}) whereas the lowest plant height (9.83 cm) by F_4 (150 kg N ha^{-1}) that similar to F_3 (100 kg N ha^{-1}), F_2 (50 kg N ha^{-1}) and F_1 (0 kg N ha^{-1}). Almost similar trend was also observed at 35 DAS but at harvest, application of 150 to 250 kg N ha^{-1} resulted similar and significantly higher plant height and no nitrogen application treatment gave the shortest plant height (47.55 cm).
Youssef and Farag (2021) conducted an experiment on quinoa and obtained the FYM+EM bio-fertilizer treatment had the highest plant height values of 111 cm and 116 cm followed by 110 cm and 114 cm from FYM +TS bio-fertilizer treatment in the two growing seasons, respectively.

Jacline *et al.* (2020) performed an experiment and the result showed that the highest plant height (98.1-99.68 cm) was obtained from (200-150-200 NPK kg ha^{-1}) 1st and 2nd season respectively and lowest plant height (91.93-95.85 cm) was recorded by the treatment (100-75-100 NPK kg ha^{-1}) in the 1st and 2nd season respectively. The highest plant height (103.37 cm) was obtained in four split doses in the 2nd season respectively. Lawlor (2002) proposed that supplying adequate N quantity at appropriate time for growing crops ascertains the patterns of their growth and production, which are consequence of the proteins as basis of metabolic processes with the light energy utilized in reductions of both CO_2 and NO_3^- and synthesis of assimilates that are used in vegetative and reproductive growth and yield developments.

Geren (2015) reported that the plant height of quinoa increased noticeably by increasing nitrogen fertilizer rate up to175 kg Nha^{-1}. Fawy *et al.* (2017) reported 33% higher plant height of quinoa by 240 kg Nha^{-1}whereas Weisany *et al.* (2013) also reported 33 higher plant height of quinoa by soil application of nitrogen than control. The highest plant height was observed in N_3 (125:62.5:62.5 NPK ha^{-1}) is (108.84 cm) whereas lower plant height is observed in N_1 (75:37.5:37.5 NPK ha^{-1}) is 98.50 cm. Nutrients have several functions and affect quinoa yield parameters, the photosynthetic processes in leaves and plant growth are improved by N fertilization, it contributes greatly in protein synthesis, cell structure and carbohydrate production.

Rahman *et al.* (2019) conducted an experiment and the results showed that the average of the plant height ranged from 25.15 cm of the control treatment (0 kg Nha^{-1}) to 75.9 cm for plants with the highest N application treatment (160 kg N ha^{-1}).

Abou-Amer and Kamal (2011) carried out an experiment and they indicated clearly that plant height was increased gradually with increasing nitrogen dose from 60 kg N ha^{-1} to 100 N kg ha^{-1}. These observations were fairly true in both seasons and their averages. The major role of nitrogen is stimulating meristematic activity and consequently lead to internode elongation and increased plant height with increasing N dose. Application of mineral nitrogen and organic fertilizer in split up dose had favorable effect on quinoa plant height when compared with the same respective dose of mineral fertilizer which only indicating the favorable effect when adding organic source of N. These results are in agreement with these obtained by Pospisil *et al.* (2006), who reported nitrogen fertilization affected quinoa plant height. Differences were also significant. Wilefredo *et al.* (2004) also showed the favorable effect of organic fertilizer on growth of quinoa plants.

Basim *et al.* (2021) conducted an experiment and the results also showed that there were significant differences between the means of the treatments when adding the micronutrient fertilizers, the addition of the NF3 (2 kg ha^{-1}seaweed fertilizer and 3 kg ha^{-1} micronutrients fertilizer) significantly performed (68.55 cm), with an increase of 29.12%, compared with comparison treatment, with a non-significant difference from the NF2 (2 kg ha^{-1} seaweed fertilizer and 2 kg ha^{-1} micronutrients fertilizer) addition level (67.31 cm).

Ghada *et al.* (2020) recorded that increasing the level of compost was gradually and significantly increased quinoa plant height, dry weight plant^{-1} and number of leaves/plant. Application of 15 t ha^{-1} compost increased these parameters by about 23.0, 25.6 and 27.0 %. As for nitrogen sources, the data show that growth parameters of quinoa were significantly affected by nitrogen fertilizer forms. Ammonium sulphate (AS) fertilizer had tallest plant height, heaviest dry weight/plant and greatest number of leaves/plant than ammonium nitrate (AN). The data reveal that nitrogen levels was significantly affected growth parameters of quinoa. Added 90 kg N ha^{-1} increased plant height, dry weight $plant^{-1}$ and number of leaves/plant over 60 kg N ha^{-1} by about 6.1, 8.4 and 6.5 in the first season and 7.4, 10.1 and 8.8% in the second one, respectively. Kansomjet *et al*. (2017) who stated that increasing nitrogen levels increased growth parameters of quinoa.

Suresh *et al.* (2019**)** successfully did an experiment and the results revealed that, the treatment with spacing of 45x10 cm and high amounts of nutrient 150:75:75 kg NPK ha^{-1}recorded the highest growth parameters like plant height at 30 DAS (25.91 cm), 60 DAS (119 cm) and at harvest (122.28 cm). Phosphorus and nitrogen elements are considered the most important nutrients for root development, seed formation, growth and yield (Beigzade *et al*., 2013). Potassium is one of the three Macro primary nutrients, which is necessary for plant growth (Lakudzala, 2013). Micronutrients are as important as macronutrients in plant nutrition. The deficiency of micronutrients is considered one of the major causes of declining plant growth and yield of crops productivity (Taiwo *et al*., 2001 and Somani, 2008).

Afrin (2018) conducted an experiment and the result showed that at 30 DAS, the highest plant height (15.22 cm) was obtained from 120-50-50 kg NPK $ha^{-1}$and the lowest plant height (8.593 cm) obtained from at 50 kg P ha^{-1}. At 45 DAS, the highest plant height (27.24 cm) was obtained from 120-50-50 kg NPK ha^{-1} that was statistically similar with 120-50 kg NK ha^{-1} and the lowest plant height (19.12 cm) obtained from 120-50 kg NP ha^{-1}. At 60 DAS, the highest plant height (26.33 cm) was obtained from 120-50 kg NK ha^{-1} and the lowest plant height (17.79 cm) obtained from at 50 kg P ha^{-1}. At harvest, the highest plant height (28.64 cm) was obtained from 120-50 kg NK ha^{-1} and the lowest plant height (17.92 cm) obtained from 50 kg P ha^{-1}.

Hammam and Monsour (2018) performed a research work and found out the best results of the plant height and number of branches $plant^{-1}$ (87.70 and 86.41 cm) and (22.45 and 25.14 branch $plant^{-1}$) in the first and second seasons, respectively) were obtained with irrigation amount of 500 m^3/fed combined with 10 m^3 compost compared with NPK treatment combined with 400 m^3 /fed which gave the lowest values (72.02 and 76.05 cm) and (13.22 and 14.11 branches $plant^{-1}$).

Hakan *et al.* (2015) carried out a field experiment and recorded that the highest plant height (101.1 cm) was obtained from 175 kg N ha^1 application in 2014, whereas the lowest was 43.8 cm for 0 kg N ha^{-1} application in 2013. Nitrogen contributes to the formation of amino acids, vitamins, and chlorophyll. If nitrogen is sufficiently provided to the plant, it can increase plant growth rate and protein storage of grains (Siadat *et al.,* 2013).

Erley *et al.* (2005) reported that quinoa strongly reacts to nitrogen fertilizer use. Nitrogen supplementation increased all growth related traits like crop growth rate, leaf area index, plant height, stem diameter, leaf area duration. The basis of these increments seems due to fact that N is an integral part of photosynthetic machinery (chlorophyll molecule and chloroplast) (Hak *et al.,* 1993), which is conversion unit of light energy to chemical energy of photosynthetic apparatus. More chlorophyll, increased photosynthetic active leaf area, more will be assimilation resulting in better growth and development (Evans, 1983). Nitrogen supply also increases rates of cell division and expansion (Roggatz *et al.,* 1999), photosynthesis and leaf production (Zhao *et al*., 2003, 2005a, b). Nitrogen affects chlorophyll concentration of leaf which results in improved photosynthetic efficiency and outcome is in the form of improved and completion of early vegetative growth phases recorded by (Amaliotis *et al*., 2004).

Abou-Amer and Kamal (2011) indicated clearly that plant height was increased gradually with increasing nitrogen dose from 60 kg N/fed up to 100kg/fed. The highest plant height was obtained (56.9 cm) from 100 kg N, organic manure10m3 /fed, 3% foliar application of N.

2.2.2 **Number of leaves $plant^{-1}$**

Al-Naggar *et al*. (2021) performed a research work and found out that the soil fertilization with organic fertilizer (Compost) by using the highest N rate (214.2 kg N ha^{-1}) the highest number of leaves $plant^{-1}$ (260.9).

Abdulrahman *et al.* (2019) conducted a field experiment and recorded that the N fertilization rates significantly improved number of leaves $plant^{-1}$. The values of number of leaves $plant^{-1}$ were 20, 25 and 43 for plants receiving 0, 80 and 160 kg N ha^{-1} fertilizer, respectively.

Biswas *et al.* (2021) was recorded at 21 DAS, the maximum number of leaves plant^{-1} (27.43) was observed in 180 kg ha^{-1} that similar to 200 kg/ha whereas the lowest number of leaves plant^{-1} in control plants. Similar trend was also shown in 35 DAS/P. Application of 120 kg N ha^{-1} gave 33.80 leaves plant^{-1} of quinoa as reported by Sadia (2018).

Basim *et al.* (2021) showed the significant differences between the average of the seaweed fertilizer addition treatments, as the number of sheets increased, as the increasing level of addition increased, the highest value for this characteristic when transaction SW2 (2 kg ha^{-1} micronutrients fertilizer) was (45.08) with a significant difference from treatment SW1 (1 kg ha^{-1} micronutrients fertilizer), which gave an average of 38.50, while the comparison treatment recorded the lowest average for this trait, which was (23.75). This may be due to seaweed fertilizer, which improved better nutrient absorption by plant root cells, increased photosynthesis, which led to an increase in vegetative growth and then an increase in the average number of leaves in the plant. Nutrients have several functions and affect quinoa growth parameters, the photosynthetic processes in leaves and plant growth are improved by N fertilization, it contributes greatly in protein synthesis, cell structure and carbohydrate production (Weisany *et al.,* 2013).

2.2.3 Fresh and dry weight plant^{-1}

Abdulrahman *et al.* (2019) recorded that both the fresh and dry weights of the plant significantly increased gradually with the addition of N fertilizers from zero to 160 kg N ha^{-1}. Fresh weight averages were (12.14 g), (43.12 g) and (66.56 g) for plants receiving 0, 80 and 160 kg N ha^{-1}, respectively. Also, the plant dry weight values were in consistent with those of plant fresh weight values. The plant dry weight values were 1.52, 6.53 and 18.11 g plant^{-1} for N fertilization levels, respectively. Kaul *et al.* (1996) found that the nitrogen uptake and the amount of the nitrogen residues were correlated with the dry matter production.

2.2.4 Number of branches plant^{-1}

Al-Naggar *et al*. (2021) performed an experiment and recorded that the soil fertilization with organic fertilizer (Compost) by using the highest N rate (214.2 kg

N/ha) recorded the tallest plants (144.8 cm), the thickest stems (8.18 cm), the highest number of branches (12.18).

Jacline *et al*. (2020) conducted a field experiment and that was recorded highest branch number (18.59) was obtained from (150-113-150 NPK kg ha^{-1}) and lowest branch number (17.93) was obtained from (200-150-200 NPK kg ha^{-1}) respectively. The highest branch number (19.36) was obtained from (150-113-150 NPK kg ha^{-1}) with split four doses respectively.

Suresh *et al*. (2019) successfully did a field experiment and found out the highest total number of branches was observed in N_4 (150:75:75 Kg NPK ha^{-1}) was14.57, whereas lower was observed in N_1 (75:37.5:37.5 Kg NPK ha^{-1}) was 11.24.

Hammam and Monsour (2018) recorded that the best results of the plant height and number of branches $plant^{-1}$ (87.70 and 86.41 cm) and (22.45 and 25.14 branch $plant^{-1}$) in the first and second seasons, respectively) were obtained with irrigation amount of 500 m^3/fed combined with 10 m3 compost compared with NPK treatment combined with 400 m^3/fed which gave the lowest values (72.02 and 76.05 cm) and (13.22 and 14.11 branches $plant^{-1}$) in the two season, respectively.

Pospisil *et al.* (2006) recorded that there were also increases in number of basal branches with increasing the N dose of soil or foliar application up to the highest. The split up dose of mineral nitrogen and organic fertilizer was also slightly superior rather than mineral fertilizer only. There were also increases in number of basal branches with increasing the N dose of soil or foliar application up to the highest. These results are in agreement with those recorded by Ahmed *et al.* (2011).

2.2.5 Chlorophyll content (SPAD value)

Abdulrahman *et al*. (2019) conducted a field experiment and the results in showed a significant increase in the chlorophyll content under the influence of N fertilization. The ratio of chlorophyll was 32.1 with control treatment (0 N fertilizer), 48.10 at the addition of 80 kg N $ha^{-1}$and 70.28 when plants fertilized with the highest N fertilizer rate (160 kg N ha^{-1}). On the another crop, Turner and Jund (1991) reported that SPAD value has been tested on rice for its ability to predict response to fertilizer N topdressing in the southern USA.

2.2.6 1000-seed weight

Tahereh *et al*. (2021) performed a field experiment and showed that highest 1000-seed weight was obtained by treatment with 180 kg N using three times (2.8 g) but Dalia *et al.* (2019) reported the highest values of weight of 1000-seeds with application of chicken manure (CHM) + 250 kg N ha^{-1}. 1000 seed weight was obtained (4.77 g) followed by Compost + 250 kg N ha^{-1} (4.15 g) or application of FYM + 250 kg N ha^{-1} (4.65 g) respectively.

Hassan *et al.* (2017) conducted a field experiment and the results obtained assure that the combination between mineral N (238 kg ha^{-1}) + humic acid 600 mg L^{-1} + ascorbic acid 1000 mg L^{-1} with OM application was the most effective treatment on the yield parameters of quinoa plants, which achieved an increase reached about (3.97 and 16.8 g) weight of 1000-seed, respectively. Yassen *et al.* (2010) showed that additional nitrogen as foliar Spray (1% urea) gave significant increases in 1000 grain weight.

2.1.7 Grain yield

Jesús *et al.* (2021) conducted a field experiment and showed that nitrogen fertilization in quinoa is an unsolved issue; the literature data show great variability in results, ranging from very low application (30 kg of N and production of 5.5 tons of grains ha^{-1} to high application (175 kg ha^{-1} with 4.2 tons of grains ha^{-1}).

Tahereh *et al.* (2021) carried out an experiment and found late consumption of nitrogen fertilizer in three-stage split application increased the yield. An increase in the amount of nitrogen increased the yield of quinoa grain s significantly. The lowest average yield (2,393.4 kg ha^{-1}) was recorded with N use of 120 kg ha^{-1} at two-leaf and budding stages, and the highest average (2899.6 kg ha^{-1}) belonged to 180 kg of N treatment at two-leaf, budding, and pollination onset stages. Increasing the stage of N fertilizer use at levels of 120, 150, and 180 kg led to increased yield by 3.4%, 1.5%, and 3.32%, respectively. Increases in the amount of nitrogen from 120 to 150 and 150 to 180 kg ha^{-1} resulted in improved yields of 5.5 and 3.5%, and 11.1 and 13.1%, respectively, in the two- and three-stage split applications. These results are consistent with those obtained by (Wopereis Pura *et al.,* 2002), who concluded that late consumption of nitrogen in rice increased yields by 0.4 and 1 tons/ha in wet and dry seasons, respectively. Therefore, the amount and timing of N fertilizer use is important for optimum grain yield (Walker *et al*., 2006).

Biswas *et al.* (2021) successfully did a research and they found out was obtained application of various doses of nitrogen fertilizer resulted significant variations on seed yield of quinoa and the highest yield (1170.64 kg ha^{-1}) observed in (150 kg N ha^{-1}). The lowest seed yield (538.19 kg ha^{-1}) was found in control treatment.

Tahereh *et al.* (2021) performed an experiment and recorded that the interaction between seed rate and nitrogen on grain yield, the highest yield was obtained at 10 kg ha^{-1} seed with 180 kg ha^{-1} N per hectare divided at 3 times with average yield of 3740 kg ha^{-1} and the lowest grain yield was obtained from interaction of 6 kg ha^{-1} seed with 120 kg ha^{-1} of nitrogen split at two times with average yield of 1305 kg ha^{1}.

Lawlor (2002) proposed that supplying adequate N quantity at appropriate time for growing crops ascertains the patterns of their growth and production, which are consequence of the proteins as basis of metabolic processes with the light energy utilized in reductions of both CO_2 and NO_3 and synthesis of assimilates that are used in vegetative and reproductive growth and yield developments.

Abdulrahman *et al.* (2019) conducted an experiment and found out that the grain yield ha^{-1} significantly increased with increasing N fertilizer application rates. Their values were 101.23, 430.70 and 770.20 kg ha^{-1} for 0, 80 and 160 kg N ha^{-1}, respectively. These increases in grain yields were estimated to be 325.47% and 759.62% for the 80 and 160 kg N ha^{-1} treatments as compared with control.

Nitrogen fractionation leads to higher use of nitrogen by the grain and thus a higher yield compared to once it is applied all at once (Kumar *et al.,* 2018). Nitrogen fractionation is the most prevalent method of seed production worldwide. Splitting nitrogen at planting and 30days after sowing also helps to improve the root yield (Du *et al*., 2019a). Risi and Galwey (1994) and Schulte *et al*. (2005) evaluated the response of the quinoa yield to N fertilization rates and NUE and found that there is a strong response of the grain yield to N fertilization treatments.

Geren (2015) observed that the highest the highest grain yield (3308 kg ha^{-1}) was found in the second year at 150 kg N ha^{-1}, whereas the lowest yield (867 kg ha^{-1}) was in the first year at control plot. Further research on nitrogen (N) suggests that greater

N fertilization can result in a significant yield increase, but having no effect on seed size or weight (Shams, 2012; Benlhabib *et al*., 2013; Piva *et al*., 2015).

Papastylianou *et al.* (2014) was obtained the grain yield of quinoa was observed to be positively correlated to agronomic management and fertilizer type an average yield of 3.87 t ha^{-1} was recorded under good crop management in cool areas. Berti *et al*. (2000) obtained that the highest yield of quinoa grain s with the highest level of nitrogen consumption (225 kg ha^{-1}). Excessive amounts of nitrogen reduce grain yield as it decelerates grain ripening and improves plant vegetative growth. Consumption of nitrogen fertilizer increases both grain yield and protein content (Brenner and Williams, 1995). Nitrogen concentration in grain, straw and protein in wheat grain also increased with increasing N rate. Wilfredo *et al.* (2004) reported the favorable response of different doses of organic fertilizer.

Quinoa needs different levels of nitrogen at different stages of growth; therefore, it is important for this product to consume an adequate amount of nitrogen at the right time (Kansomjet *et al.*, 2017). A study showed that the effects of different levels of nitrogen on quinoa grain yield were significant, and the highest yield was recorded for the treatment of 240 kg ha^{-1} (Wang *et al.*, 2020).
In another study, Awadalla and Morsy (2017) reported that quinoa reacted strongly to nitrogen fertilizer application, and the highest biological yield was obtained from 150 kg ha^{-1}.. The fractionation of nitrogen fertilizer into four equal parts at the pre-planting, tillering, stem formation and flowering stages increased the biological yield (Awan *et al*., 2011). Shi (2012) suggested that dividing nitrogen fertilization into basal and topdressing applications can increase grain yields and the efficiency of nitrogen recovery.

Numerous studies have been conducted on the timing and amount of N fertilizer use to determine fertilizer recommendations for different rice cultivars (Walker *et al*., 2006). During 1970-1980, nitrogen management research mostly focused on increasing nitrogen efficiency by reducing its depletion, hence farmers were advised to use the fertilizer as two- or three-stage split applications during the growing season (Buresh, 2007). Therefore, the amount and timing of N fertilizer use is important for optimum grain yield (Walker *et al.*, 2006). In the present study, the interaction of levels and stages of N fertilizer use on grain yield revealed a rising trend of changes at all N levels with increasing seed density. An increase in the grain yield was observed with increased number of split applications at any level of nitrogen.

Nitrogen is one of the most important elements for plant growth. Researchers reported that quinoa reacts strongly to the N fertilizer (Erley *et al*., 2005). However, it should be noted that N fertilizer should not be over consumed. Research has shown that excessive application of N fertilizer increases the length of the vegetative period and delays the reproductive phase (Marschner, 2011). It seems that split and optimum use of N fertilizer can have an impact on increasing crop yield. In an experiment in Europe, the yield of quinoa was obtained by consuming 120 N kg ha^{-1} at 3500 kg ha^{-1} recorded by (Erley *et al.,* 2005).

Thanapornpoong *et al*. (2004) investigated the impact of different rates of nitrogen on various aspects of quinoa (as plant height, attributes, yield and quality parameters increased with grain yield per plant, harvest index) and noted a positive effect of high levels of nitrogen on these aspects. Schultc *et al*. (2005) observed that with the application of fertilizer, quinoa achieved yield up to 350 kg ha^{-1} at 120 kg protein of oat (10.76%) N ha^{-1} and grain yield boosted by 94%.

2.2.8 Harvest index

Geren (2015) reported that the highest average harvest index (46.6%) was obtained from 150 kg N ha^{-1} treatment, whereas the lowest (13.3%) was in control plot.

Erley *et al.* (2005) conducted a field experiment and recorded that harvest index of quinoa (31%) was not affected by nitrogen fertilization from 0 to 120 kg ha^{-1}. Basra *et al*. (2014) informed that harvest index increased by increasing nitrogen treatments from 0 to 100 kg N ha^{-1} level but later decreased at 120 kg N ha^{-1} level but later decreased at 120 kg N ha^{-1} level. The increases in harvest index of quinoa with increasing nitrogen levels are mainly due to the role of N in stimulating metabolic activity which contributed to the increase in metabolites amount most of which is used building yield and its components (Shams, 2012).

CHAPTER III

MATERIAL AND METHODS

The experiment was accompanied to study the performance of Quinoa in split application of nitrogen. The materials and methods for this experiment comprises a short description of the location of experimental site, soil and climatic condition of the experimental area, materials used for the experiment, design of the experiment, data collection and data analysis procedure. The details report of the materials and methods for this experiment have been presented below under the following headings -

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted during the period from November, 2020 to February, 2021.

3.1.2 Experimental location

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka and it was located in 23° 77' N latitude and 90.26^0E longitudes. As per the Bangladesh Meteorological Department, Agargaon, Dhaka-1207 the altitude of the location was 8 m from the sea level. The location has been shown in Appendix I.

3.1.3 Characteristics of soil

The general soil type of the experimental field was Deep Red Brown Terrace soil and the soil belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ-28). A composite sample of the experimental field was made by collecting soil from several spots of the field at a depth of 0-15 cm before beginning of the experiment. The composed soil was air-dried, grind and passed through 2 mm sieve and analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka for some important physical and chemical properties. The soil was consuming a texture of silty clay with pH and organic matter 5.6 and 0.78%, respectively. The results presented that the soil composed of 26% sand, 45% silt and 29% clay; details have been presented in Appendix III.

3.1.4 Climatic condition

The climate of experimental site was under subtropical climate and characterized by three distinct seasons, the *Rabi* from November to February and the *Kharif-I*, pre-monsoon period or hot season from March to April and the *Kharif-II* monsoon period from May to October. The monthly average temperature, relative humidity and rainfall during the crop growing period were together from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix IV.

3.2 Experimental details

3.2.1 Treatments of the experiment

The experiment comprised of seven treatments

Treatments: Methods of split application of N fertilizer applicatrion

I. T_1: Control (1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS),
II. T_2: 2/3 N top dressed at 25 DAS,
III. T_3: 2/3 N top dressed at 45 DAS,
IV. T_4: 1/3 N top dressed at 25 DAS and 1/3 N foliar spray at 45 DAS,
V. T_5: 1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS,
VI. T_6: 2/3 N foliar spray at 45 DAS,
VII. T_7: 1/3 N foliar spray at 25 DAS and rest 1/3 N foliar spray at 45 DAS

Experiment was conducted by three replication and seven treatments

R_1T_1, R_1T_2, R_1T_3, R_1T_4, R_1T_5, R_1T_6, R_1T_7, R_2T_1, R_2T_2, R_2T_3, R_2T_4, R_2T_5, R_2T_6, R_2T_7, R_3T_1, R_3T_2, R_3T_3, R_3T_4, R_3T_5, R_3T_6, R_3T_7

3.2.2 Planting material

SAU Quinoa-1 seeds were used as planting material for the study. The seeds were collected by the supervisor personally.

3.2.3 Land preparation

The experimental field was first opened on 20 November, 2020 with the help of a power tiller and prepared by three successive ploughings and cross-ploughings. Each plough was followed by laddering to have a desirable fine tilth. The visible larger clods were hammered to break into small pieces. All kinds of weeds and residues of previous crop were removed from the field. Sowing of quinoa seed was made on 20 November 2020 according to design immediately after final land preparation. Individual plots were cleaned and finally leveled with the help of wooden plank.

3.2.4 Fertilizer application

Urea, Triple super phosphate (TSP) and Muriate of potash (MoP), Gypsum (S), Zinc, Boric acid were used in the experimental soil as a source of nitrogen (N), phosphorous (P) and potassium (K), sulpher (S), zinc (Zn), Boric acid respectively. Urea was applied 150 kg N ha^{-1} in the soil as per treatment of the experiment. TSP was applied at the rate of (50 kg P ha^{-1}). MoP was applied at the rate of (50 K kg ha^{-1}), sulpher (60 kg ha^{-1}), zinc (10 kg ha^{-1}), boric acid (5 kg ha^{-1}).

All of the fertilizers of TSP, MoP, Sulpher, Zinc, Boric acid along with one third urea were applied in final land preparation. Rest urea was applied as top dressing and foliar apply at 25 and 45 DAS as per treatment.

3.2.5 Experimental design and layout

The experiment was conducted considering seven treatments and laid out in a Randomized Complete Block Design (RCBD). Each treatment was replicated three times. Field trials were conducted during the winter season in the research field of the Department of Agronomy, Sher-e-Bangla Agricultural University Campus. The whole experimental area was 25.4 m × 12.8 m The distance between plots and blocks were 0.5 m and 1.0 m respectively. Area of each plot was 3.60 m × 3.20 m (Appendix II).

3.3 Growing of crops

3.3.1 Sowing of seeds in the field

The seeds of Quinoa were sown on 20 November, 2020 in solid rows in the furrows having a depth of 2-3 cm and row to row distance was 30 cm.

3.3.2 Intercultural operations

3.3.2.1 Mulching

A natural mulching was done with breaking down the top soil on 1 December, 2020 which was at 11 days after sowing.

3.3.2.2 Thinning

Thinning was done to maintain the uniform population for all plots.

3.3.2.3 Irrigation, drainage and weeding

Irrigation was delivered before 10 and 30 DAS for optimizing the vegetative growth of Quinoa for all the experimental plots equally. But additionally supplementary irrigation was delivered before flowering. Proper drain also made for drained out excess irrigation water from the experimental plot. The field was weeded at 10 DAS, 20 DAS and 35 DAS by hand weeding.

3.4 Crop sampling and data collection

Five plants from each treatment were randomly selected and marked with sample card. Number of leaves plant^{-1}, plant height, number of branches plant^{-1}, fresh weight (g) plant^{-1}, dry weight (g) plant^{-1}, root length (cm), shoot length (cm), number of inflorescence plant^{-1}, SPAD Value, seed weight plant $^{-1}$, thousand seed weight, seed yield, straw yield, was recorded at different DAS and at harvest following standard procedure. The husk and straws were also dried in the sun weight was recorded. The biological yield was calculated as the sum of the seed yield and straw yield.

3.5 Harvest and post harvesting operations

Harvesting was done when 90% of the grain became green to yellow and red in color and it was carried out 28 February, 2021. The matured crops were collected by hand picking from each plot. The collected crops were sun dried, threshed and weighted to a constant moisture level. The seeds were separated, cleaned and dried in the sun for 3 to 5 consecutive days for achieving safe moisture of seed.

3.6 Threshing

The crop was sun dried for three days by placing them on the open threshing floor. Seeds were separated from the plant by threshing with hand.

3.7 Drying, cleaning and weighing

The seeds thus collected were dried in the sun for tumbling the moisture in the seeds to a constant level. The dried seeds and straw were cleaned and weighed.

3.8 Data collection

The data were recorded on the following parameters during the experimentation.

A. Crop growth characters

a. Plant height at 35 DAS, 50 DAS and 65 DAS and harvest
b. Leaf number at 35 DAS, 50 DAS and 65 DAS and at harvest
c. Root length at 40 DAS, 60 DAS, 80 DAS
d. Shoot length at 40 DAS, 60 DAS, 80 DAS
e. Number of branches plant^{-1} 50 DAS, 60 DAS and at harvest
f. Fresh weight plant^{-1} 40 DAS, 60 DAS and 80 DAS
g. Dry weight plant^{-1} 40 DAS, 60 DAS and 80 DAS
h. Number of inflorescence plant^{-1}at harvest
i. SPAD value at 50 DAS and 70 DAS

B. Yield and other crop characters

a. 1000-seed weight (g)
b. Seed weight plant^{-1}
c. Seed yield (kg ha^{-1})
d. Straw weight plant^{-1}
e. Straw yield (kg ha^{-1})
f. Biological yield (Kg ha^{-1})
g. Harvest Index (%)

3.9 Procedure of data collection

3.9.1 Crop growth characters

3.9.1.1 Plant height

The height of plant was recorded in centimeter (cm) at 35 DAS, 50 DAS, 65 DAS and at harvest. Data were recorded from randomly selected 5 plants from each plot and average plant height plant^{-1} was documented as per treatment. The height was measured from the ground level to the tip of the leaf of main shoot.

3.9.1.2 Leaf number plant^{-1}

The leaf number of plant was recorded at 35 DAS, 50 DAS, 65 DAS and at harvest. Data were recorded from randomly selected 5 plants from each plot and average plant height plant^{-1} was documented as per treatment.

3.9.1.3 Number of branches plant^{-1}

The number of branches was counted and recorded from five tagged plant of each plot at 50, 65 DAS and at harvest. Average value was recorded as number of branches plant $^{-1}$.

3.9.1.4 Fresh weight plant^{-1}

Fresh weight of plant was recorded from five randomly selected plants of each plot at 40, 60 DAS and at harvest. Average value was recorded as fresh weight plant^{-1}.

3.9.1.5 Dry weight plant^{-1}

Dry weight of plant was recorded from five randomly selected plants of each plot at 40, 60 DAS and at harvest. Average value was recorded as dry weight plant^{-1}.

3.9.1.6 Root length plant^{-1}

Root length of plant was recorded from five randomly selected plants of each plot at 40, 60 DAS and at harvest. Average value was recorded as root length plant^{-1}.

3.9.1.7 Shoot length plant^{-1}

Shoot length of plant was recorded from five randomly selected plants of each plot at 40, 60 DAS and at harvest. Average value was recorded as soot length plant^{-1}.

3.9.2 Yield and other crop characters

3.9.2.1 Straw weight plant^{-1}

Fresh weight of five selected plants from each plot was recorded at harvest. The dry weight plant^{-1} was counted from five randomly sampled plants. It was completed by counting total fresh weight of all sampled plants then the average data were recorded.

3.9.2.2 Seed weight plant^{-1}

Dry weight of seed from each plot was counted at harvest. Seed weight plant^{-1} was counted from five randomly sampled plants. It was completed by counting total seed weight of all sampled plants then the average data were recorded.

3.9.2.3 1000-seed weight

The 1000 seeds were counted manually, which were taken from the seeds sample of each plot separately during at harvest, then weighed in an electrical balance and data were recorded in gram.

3.9.2.4 Seed yield

The crops from harvested area were harvested as per experimental treatments and were threshed. Seeds were cleaned and properly dried under sun. Then seed yield plot^{-1} was recorded at 12% moisture level & converted into kg ha^{-1}.

3.9.2.5 Straw yield

Dry weight of total plants from harvested was measured at harvest. It was completed by measuring total dry weight of all plants then the average data were recorded.

3.9.2.6 Biological yield

Biological yield was determined by adding seed weight (t ha^{-1}) and straw weight (t ha^{-1}).

Biological yield = Seed yield + Straw yield.

3.9.2.7 Harvest index

Harvest index (%) was determined by dividing the economic (grain) yield by the total biological yield (grain yield + straw yield) from the same area and multiplying by 100.

$$\% \text{ Harvest index (HI)} = \frac{\text{Seed yield}}{\text{Biological yield}} \times 100$$

3.10 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program CropStat and the mean differences were adjudged by Least Significance Difference (LSD) test at 5% level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Plant height

The result showed that the effect of split application of nitrogen on plant height was significant at 35 DAS and 65 DAS but insignificant at 50 DAS and at harvest (Table 1 and Appendix V). At 35 DAS, the highest plant height (13.19 cm) was obtained from T_6 (2/3 nitrogen foliar spray at 45 DAS) which was statistically similar with the height of all other treatments except T_7 (1/3 nitrogen foliar spray at 25 DAS and the rest 1/3 nitrogen foliar spray at 45 DAS). The T_7 treatment showed the lowest plant height (10.45 cm) that also similar with all other treatments except T_6 and followed the trend as T_3 (11.24 cm), T_5 (11.55 cm), T_1 (12.11 cm), T_4 (12.63 cm) and T_2 (12.71 cm). The T_7 treatment reduced 20.77% plant height compared to that of T_6 at 35 DAS. At 50 DAS, statistically no significant variation found among the treatments though numerically maximum plant height (28.72 cm) found in T_3 and minimum in T_4 (23.65 cm).

Table1. Effects of split application nitrogen on plant height of quinoa

Treatments	Plant height (cm) at			
	35 DAS	50 DAS	65 DAS	Harvest
T_1	12.11ab	26.09	30.70bc	32.81
T_2	12.71ab	28.58	37.09a	39.18
T_3	11.24ab	28.72	34.41ab	34.89
T_4	12.63ab	23.65	32.18abc	33.36
T_5	11.55ab	25.33	28.49c	33.78
T_6	13.19a	26.18	34.17abc	36.32
T_7	10.45b	24.55	31.07bc	33.17
$LSD_{(0.05)}$	2.611	NS	5.812	NS
CV (%)	12.25	18.24	10.17	15.00

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability, NS = non-significant.

T_1: Control (1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS), T_2: 2/3 N top dressed at 25 DAS, T_3: 2/3 N top dressed at 45 DAS, T_4: 1/3 N top dressed at 25 DAS and 1/3 N foliar spray at 45 DAS, T_5: 1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS, T_6: 2/3 N foliar spray at 45 DAS, T_7: 1/3 N foliar spray at 25 DAS and rest 1/3 N foliar spray at 45 DAS

At 65 DAS, the highest plant height (37.09 cm) was obtained from T_2 (2/3 N top dress at 25 DAS) that statistically similar with T_3 (34.41 cm), T_6 (34.17 cm) and T_4 (32.18 cm). The lowest plant height (28.49 cm) obtained from T_5 that statistically similar with other treatments except T_2 and T_3. Foliar application of nitrogen ($1/3^{rd}$) at 25 DAS and rest $1/3^{rd}$ nitrogen top dressed at 45 DAS (T_5) decreased plant height (23.19%) compared to T_2 at 65 DAS. Nitrogen contributes to the formation of amino acids, vitamins, and chlorophyll. If nitrogen is sufficiently provided to the plant, it can increase plant growth rate as reported by Siadat *et al*. (2013). At harvest, no significant variation of plant height found among the treatments though numerically maximum plant height (39.18 cm) was obtained from T_2 and the minimum plant height (32.18 cm) was obtained from T_1.

4.2 Number of leaves plant^{-1}

Number of leaves plant^{-1} at 35, 50 & 65 DAS, and at harvest was showed significant variation for split application of nitrogen (Table 2 and Appendix VI). The result revealed that at 35 DAS, the highest leaf number plant^{-1} (15.93) was obtained from F_6 (2/3 nitrogen foliar spray at 45 DAS) which was statistically similar with the leaf number plant^{-1} of all other treatments except T_5 and T_1. The T_5 treatment showed the lowest leaf number plant^{-1} (13.73) obtained from T_5 (1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS) that also statistically similar with T_1 (13.73). The T_5 treatments reduced 13.81% leaf number plant^{-1} compared to that of T_6 at 35 DAS. At 50 DAS, the highest leaf number plant^{-1} (33.53) was obtained from T_6 (2/3 nitrogen foliar spray at 45 DAS) which was statistically similar with T_2 (31.33). The lowest leaf number obtained from T_4 (21.93) that also similar with all other treatments except T_6 and T_2 and followed the trend as T_5 (24.00), T_1 (25.00), T_3 (25.87), and T_7 (25.93). 1/3 N top dressed at 25 DAS and 1/3 N foliar spray at 45 DAS decreased leaf number plant^{-1} (34.59%) and (30.00%) compared to T_6 and T_2 respectively at 50 DAS. Foliar application of urea has been proved to be an effective technique of N fertilization and it is distributed quickly from the treated leaves to other plant parts reported by Ahmed *et al.* (2011). At 60 DAS, the highest leaf number plant^{-1} (39.40) was obtained from T_2 (2/3 N top dressed at 25 DAS) that statistically similar with T_6 (35.60). The lowest leaf number plant^{-1} (26.87) obtained from T_5 that statistically similar with other treatments except T_2 and T_6 followed the trend as T_7 (27.5), T_4 (27.93), T_3 (28.43) and T_1 (30.02).

The T_5 treatment reduced (33.32%) leaf number plant^{-1} compared to that T_2. At harvest the maximum number of leaves plant^{-1} (25.40) was recorded from T_2 (2/3 N top dressed at 25 DAS) that also similar with T_6 (24.13) and T_3 (22.80). The lowest leaf number plant^{-1} (16.40) obtained from T_5 that statistically similar with other treatments except T_3, T_6 and T_2. Foliar application of nitrogen (1/3rd) at 25 DAS and rest 1/3rd nitrogen top dressed at 45 DAS (T_3) decreased plant height (35.43%) compared to T_2 at harvest.

Table 2. effects of split application effects of nitrogen on number of leaves plant^{-1} of quinoa

Treatments	Number of leaves plant^{-1} at			
	35 DAS	50 DAS	65 DAS	Harvest
T_1	14.17c	25.00c	30.02b	20.13bc
T_2	15.73ab	31.33ab	39.40a	25.40a
T_3	14.53b	25.87c	28.43b	22.80ab
T_4	14.87ab	21.93c	27.93b	20.33bc
T_5	13.73c	24.00c	26.87b	16.40c
T_6	15.93a	33.53a	35.60a	24.13ab
T_7	15.73ab	25.93bc	27.15b	18.66c
$LSD_{(0.05)}$	1.396	5.433	4.095	4.034
CV (%)	5.25	11.39	7.48	10.74

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

T_1: Control (1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS), T_2: 2/3 N top dressed at 25 DAS, T_3: 2/3 N top dressed at 45 DAS, T_4: 1/3 N top dressed at 25 DAS and 1/3 N foliar spray at 45 DAS, T_5: 1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS, T_6: 2/3 N foliar spray at 45 DAS, T_7: 1/3 N foliar spray at 25 DAS and rest 1/3 N foliar spray at 45 DAS

4.3 Number of branches plant^{-1}

The result showed that the effect of split application of nitrogen on number of branches plant^{-1} was significant at 50 DAS, 65 DAS and at harvest (Table 3 and Appendix VII). At 50 DAS where T2 gave significantly the highest number of branches plant-1 (13.88) that similar to T_6 (13.30) and T_1 (12.53). The lowest number of branches plant^{-1} in T_4 (10.40) that similar to all other nitrogen application method except T_1, T_2 and T_6 (Table 4). The 1/3 N top dressed at 25 DAS and 1/3 N foliar spray at 45 DAS decreased branches number plant^{-1} (25.07%) compared to T_2 at 50 DAS. These results were similar with the findings of Pospisil *et al.* (2006) who reported the increased in number of basal branches with increasing the N dose of soil or foliar application up to the highest. At 65 DAS, the highest number of branches plant^{-1} (19.93) was obtained from T_2 (2/3 N top dressed at 25 DAS) which was statistically similar with the T_6 (18.23). The lowest number of branches plant^{-1} (14.00) obtained from T_4 (1/3 N top dressed at 25 DAS and the rest 1/3 N foliar spray at 45 DAS) that also similar with all other treatments except T_2 and T_6 and followed the trend as T_5 (14.00), T_1 (14.67), T_3 (14.93) and T_7 (15.20). The T_4 treatment reduced 32.11% number of branches plant^{-1} compared to that of T_2 at 65 DAS. At harvest, the maximum number of branches plant^{-1} (21.33) was recorded from T_2 (2/3 N top dressed at 25 DAS) that also similar with T_6 (19.93). The lowest branch number plant^{-1} (14.33) obtained from T_5 (1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS) that statistically similar with other treatments except T_2 and T_6. Foliar application of nitrogen (1/3rd) at 25 DAS and rest 1/3rd nitrogen top dressed at 45 DAS (T_5) decreased plant height (32.81%) compared to T_2 at harvest.

Table 3. Effects of split application nitrogen on number of branches plant^{-1} of quinoa

Treatments	Number of branches plant^{-1} at		
	50 DAS	65 DAS	Harvest
T_1	12.53ab	14.67c	15.80c
T_2	13.88a	19.93a	21.33a
T_3	11.62bc	14.93bc	15.87c
T_4	10.40c	13.53c	14.67c
T_5	10.60c	14.00c	14.33c
T_6	13.30ab	18.23ab	19.93ab
T_7	11.16c	15.20bc	16.93bc
$LSD_{(0.05)}$	1.843	3.354	3.059
CV (%)	8.68	11.94	10.13

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

T_1: Control (1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS), T_2: 2/3 N top dressed at 25 DAS, T_3: 2/3 N top dressed at 45 DAS, T_4: 1/3 N top dressed at 25 DAS and 1/3 N foliar spray at 45 DAS, T_5: 1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS, T_6: 2/3 N foliar spray at 45 DAS, T_7: 1/3 N foliar spray at 25 DAS and rest 1/3 N foliar spray at 45 DAS.

4.4 Fresh weight plant^{-1}

The result showed that the effect of split application of nitrogen on fresh weight (g) plant^{-1} was significant at 40 DAS, 60 DAS and at harvest (Table 4 and Appendix VIII). At 40 DAS, the highest fresh weight plant^{-1} (8.54 g) was recorded from T_6 (2/3 N foliar spray at 45 DAS) which was statistically similar with the fresh weight plant^{-1} of all other treatments except T_5 (1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS) that showed lowest fresh weight (5.02 g) that also similar with T_3 (7.07 g). The T_5 treatment reduced 41.21% fresh weight compared to that of T_6 at 40 DAS.

Table 4. Effects of split application nitrogen on fresh weight plant^{-1} of quinoa

Treatments	**Fresh weight (g) plant^{-1} at**		
	40 DAS	60 DAS	Harvest
T_1	7.53a	12.65c	8.32b
T_2	8.45a	22.85a	12.50a
T_3	7.07ab	12.91c	7.18b
T_4	7.78a	15.33b	7.53b
T_5	5.02b	10.96d	7.26b
T_6	8.54a	15.79b	8.06b
T_7	7.79a	13.87c	6.91b
$LSD_{(0.05)}$	2.132	1.223	2.130
CV (%)	16.08	4.61	14.52

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

T_1: Control (1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS), T_2: 2/3 N top dressed at 25 DAS, T_3: 2/3 N top dressed at 45 DAS, T_4: 1/3 N top dressed at 25 DAS and 1/3 N foliar spray at 45 DAS, T_5: 1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS, T_6: 2/3 N foliar spray at 45 DAS, T_7: 1/3 N foliar spray at 25 DAS and rest 1/3 N foliar spray at 45 DAS.

At 60 DAS the highest fresh weight plant^{-1} (22.85 g) was recorded from T_2 (2/3 N top dressed at 25 DAS). The second highest fresh weight plant^{-1} was found in T_6 (15.79 g) that statistically similar with T_4 (15.33 g). The third highest fresh weight plant^{-1} was observed in T_7 (13.87 g) that statistically similar with T_3 (12.91 g) and T_1 (12.65 g). The lowest fresh weight plant^{-1} (10.96 g) was found in T_5 (1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS) which was statistically different from others. The reduction of fresh weight plant^{-1} due to 1/3 N foliar spray at 25 DAS and rest 1/3 N top dressed at 45 DAS was recorded as 52.04 % compared to T_2 at 60 DAS. At harvest, the highest fresh weight plant^{-1} (12.50 g) was obtained from T_2 (2/3 N top dressed at 25 DAS). The lowest fresh weight obtained from T_7 (6.91 g) that also similar with all other treatments except T_2 and followed the trend as T_3 (7.18 g), T_5 (7.26 g), T_6 (8.06 g) and T_1 (8.32 g). The 1/3 N foliar spray at 25 DAS and rest 1/3 N foliar spray at 45 DAS decreased fresh weight plant^{-1} (44.72%) compared to T_2 at harvest.

4.5 Dry weight plant^{-1}

The result showed that the effect of split application of nitrogen on dry weight plant^{-1} was insignificant at 40 DAS but significant at 60 DAS and at harvest (Table 5 and Appendix IX).

Table 5. Effects of split application nitrogen on dry weight plant^{-1} of quinoa

Treatments	Dry weight (g) plant^{-1} at		
	40 DAS	60 DAS	Harvest
T_1	0.26	2.29bc	3.16c
T_2	0.34	3.58a	5.07a
T_3	0.27	2.57b	3.45c
T_4	0.27	3.26a	3.83bc
T_5	0.24	1.89c	3.40c
T_6	0.32	3.62a	4.66ab
T_7	0.24	2.49b	3.54c
$LSD_{(0.05)}$	NS	0.454	0.875
CV (%)	3.47	10.95	12.69

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability, NS = non-significant.

T_1: Control (1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS), T_2: 2/3 N top dressed at 25 DAS, T_3: 2/3 N top dressed at 45 DAS, T_4: 1/3 N top dressed at 25 DAS and 1/3 N foliar spray at 45 DAS, T_5: 1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS, T_6: 2/3 N foliar spray at 45 DAS, T_7: 1/3 N foliar spray at 25 DAS and rest 1/3 N foliar spray at 45 DAS.

At 40 DAS, statistically no significant variation found among the treatments though numerically maximum dry weight plant^{-1} (0.34 g) found in T_2 (2/3 N top dressed at 25 DAS) and minimum (0.24 g) found in T_5 (1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS) and T_7. At 60 DAS, the highest dry weight plant^{-1} was (3.62 g) recorded from T_6 (2/3 N foliar spray at 45 DAS) that statistically similar with T_2 (3.58

g). The second highest dry weight plant^{-1} was found in T_3 (2.57 g) statistically similar with T_7 (2.49 g) and T_1 (2.29 g). The lowest dry weight plant^{-1} (1.89 g) was found in T_5 (1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS) that statistically similar with T_1 (Control 1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS). The T_5 treatment reduced 47.79% dry weight compared to that of T_6 at 40 DAS. At harvest the maximum dry weight (5.07 g) was obtained from T_2 (2/3 N top dress at 25 DAS) that statistically similar with T_6 (4.66 g). The lowest dry weight (3.16 g) was obtained from T_1 that statistically similar with other treatments except T_6 and T_2. The 1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS (T_1) decreased dry weight (37.67%) compared to T_2.

4.6. Root length plant^{-1}

Root length plant^{-1} at 40 DAS, 60 DAS, and at harvest was showed significant variation for split application of nitrogen (Table 6 and Appendix X). At 40 DAS, the highest root length (6.82 cm) was obtained from T_6 (2/3 nitrogen foliar spray at 45 DAS) which was statistically similar with the root length of all other treatments except T_5 (1/3 nitrogen foliar spray at 25 DAS and the rest 1/3 nitrogen foliar spray at 45 DAS). The T_5 treatment showed the lowest root length (5.28 cm) that also similar with all other treatments except T_6 and followed the trend as T_1 (5.65 cm), T_7 (5.69 cm), T_4 (5.71 cm), T_3 (5.87 cm) and T_2 (6.54 cm). The T_5 treatment reduced 22.58% root length compared to that of T_6 at 35 DAS. Phosphorus and nitrogen elements are considered the most important nutrients for root development, seed formation, growth and yield reported by Beigzade *et al.* (2013). At 60 DAS, the highest root length (10.36 cm) was obtained from T_6 (2/3 N foliar spray at 45 DAS) that statistically similar with T_2 (9.91cm), and T_5 (9.10 cm). The lowest root length (7.29 cm) was obtained from T_3 (2/3 N top dressed at 45 DAS) that statistically similar with other treatments except T_2, T_5, and T_6. The 2/3 N top dressed at 45 DAS decreased root length (29.63%) compared to T_6 at 65 DAS. At harvest the highest root length (10.00 cm) was obtained from T_6 (2/3 N foliar spray at 45 DAS) which was statistically similar with T_2 (9.93 cm), T_5 (9.05cm) and T_4 (8.13 cm). The lowest root length obtained from T_1 (7.14 cm) that also similar with all other treatments except T_6 and T_2, T_5, and T_4 and followed the trend as T_3 (7.14 cm), T_7 (7.48 cm), and T_4 (8.13 cm). Top dressing one third of nitrogen (1/3) at 25 DAS and rest 1/3 N top dressed at 45 DAS decreased root length (31.8 %) compared to T_6 at 50 DAS

Table 5. Effects of split application nitrogen on root length (cm) plant^{-1} of quinoa

Treatments	Root length (cm) plant^{-1} at		
	40 DAS	60 DAS	Harvest
T_1	5.65ab	6.93c	6.82c
T_2	6.54ab	9.91a	9.93a
T_3	5.87ab	7.29bc	7.14bc
T_4	5.71ab	7.87bc	8.13abc
T_5	5.28b	9.10ab	9.05ab
T_6	6.82a	10.36a	10.00a
T_7	5.69ab	7.49bc	7.48bc
$LSD_{(0.05)}$	1.355	1.882	2.015
CV (%)	12.81	12.57	13.54

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability

T_1: Control (1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS), T_2: 2/3 N top dressed at 25 DAS, T_3: 2/3 N top dressed at 45 DAS, T_4: 1/3 N top dressed at 25 DAS and 1/3 N foliar spray at 45 DAS, T_5: 1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS, T_6: 2/3 N foliar spray at 45 DAS, T_7: 1/3 N foliar spray at 25 DAS and rest 1/3 N foliar spray at 45 DAS.

4.7. Shoot length

The result showed that the effect of split application of nitrogen on shoot length was significant at 40 DAS and 60 DAS and at harvest (Table 6 and Appendix XI). At 40 DAS, the highest shoot length (18.70 cm) was obtained from T_2 (2/3 nitrogen top dressed at 25 DAS) which was statistically similar with T_6 (17.21 cm). The lowest shoot length (14.13 cm) that also similar with all other treatments except T_2 and T_6 and followed the trend as T_7 (15.12 cm), T_1 (15.48 cm), T_3 (115.93 cm) and T_4 (15.95 cm). The T_5 treatment reduced 24.44% shoot length compared to that of T_2 at 40 DAS. At 60 DAS, the highest shoot length (35.38 cm) was obtained from T_6 (2/3 nitrogen foliar spray at 45 DAS. The second highest shoot length plant^{-1} was found in T_3 (31.65 cm) that statistically similar with T_7 (31.61 cm), T_2 (31.35 cm) and T_5 (29.22 cm). The lowest shoot length (26.85 cm) that also similar with T_4 (27.91 cm) and T_5 (2.22 cm). The T_1 (1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS) reduced

15.05% shoot length compared to that of T_7 and 15.16% shoot length reduced compared to that of T_3 at 60 DAS.

Table 7. Effects of split application nitrogen on shoot length of quinoa

Treatments	Shoot length (cm) plant^{-1} at		
	40 DAS	60 DAS	Harvest
T_1	15.48bc	26.85c	31.96c
T_2	18.70a	31.35b	39.51a
T_3	15.93bc	31.65b	33.95bc
T_4	15.95bc	27.91c	32.01c
T_5	14.13c	29.22bc	35.12abc
T_6	17.21ab	35.38a	39.36ab
T_7	15.12bc	31.61b	34.03abc
$LSD_{(0.05)}$	2.394	3.304	5.500
CV (%)	8.37	6.08	8.84

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability

T_1: Control (1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS), T_2: 2/3 N top dressed at 25 DAS, T_3: 2/3 N top dressed at 45 DAS, T_4: 1/3 N top dressed at 25 DAS and 1/3 N foliar spray at 45 DAS, T_5: 1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS, T_6: 2/3 N foliar spray at 45 DAS, T_7: 1/3 N foliar spray at 25 DAS and rest 1/3 N foliar spray at 45 DAS

At harvest, the highest shoot length (39.51 cm) was obtained from T_2 (2/3 N top dress at 25 DAS) that statistically similar with T_6 (39.36 cm), T_5 (35.12 cm) and T_7 (34.03 cm). The lowest shoot length (31.96 cm) obtained from T_1 ((1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS) that statistically similar with other treatments except T_2 and T_6. Top dressed of nitrogen (1/3rd) at 25 DAS and rest 1/3rd nitrogen foliar spray at 45 DAS (T_1) decreased shoot length (19.10%) compared to T_2 at harvest.

4.8. SPAD Value

The result showed that the effect of split application of nitrogen on SPAD value was significant at 50 DAS but insignificant at harvest (Table 8 and Appendix XII). At 50 DAS, the highest SPAD value (69.61) was obtained from T_2 (2/3 nitrogen top dressed at 25 DAS) which was statistically similar with the SPAD value of all other treatments except T_7 (1/3 nitrogen foliar spray at 25 DAS and the rest 1/3 nitrogen foliar spray at 45 DAS) that showed the lowest SPAD value (56.40) obtained from T_7 that also similar with all other treatments except T_6 and followed the trend as T_5 (58.17), T_1 (59.06), T_6 (64.25), T_4 (64.59) and T_3 (65.34). The T_7 treatment reduced 18.98% SPAD value compared to that of T_2 at 50 DAS. Rahman and Ahmed, (2019) reported significant increase in the chlorophyll content under the influence of N fertilization. At 70 DAS, statistically no significant variation found among the treatments though numerically maximum SPAD value (57.29) found in T_6 and minimum in T_5 (44.24).

Table 8. Effects of split application nitrogen on SPAD value of quinoa

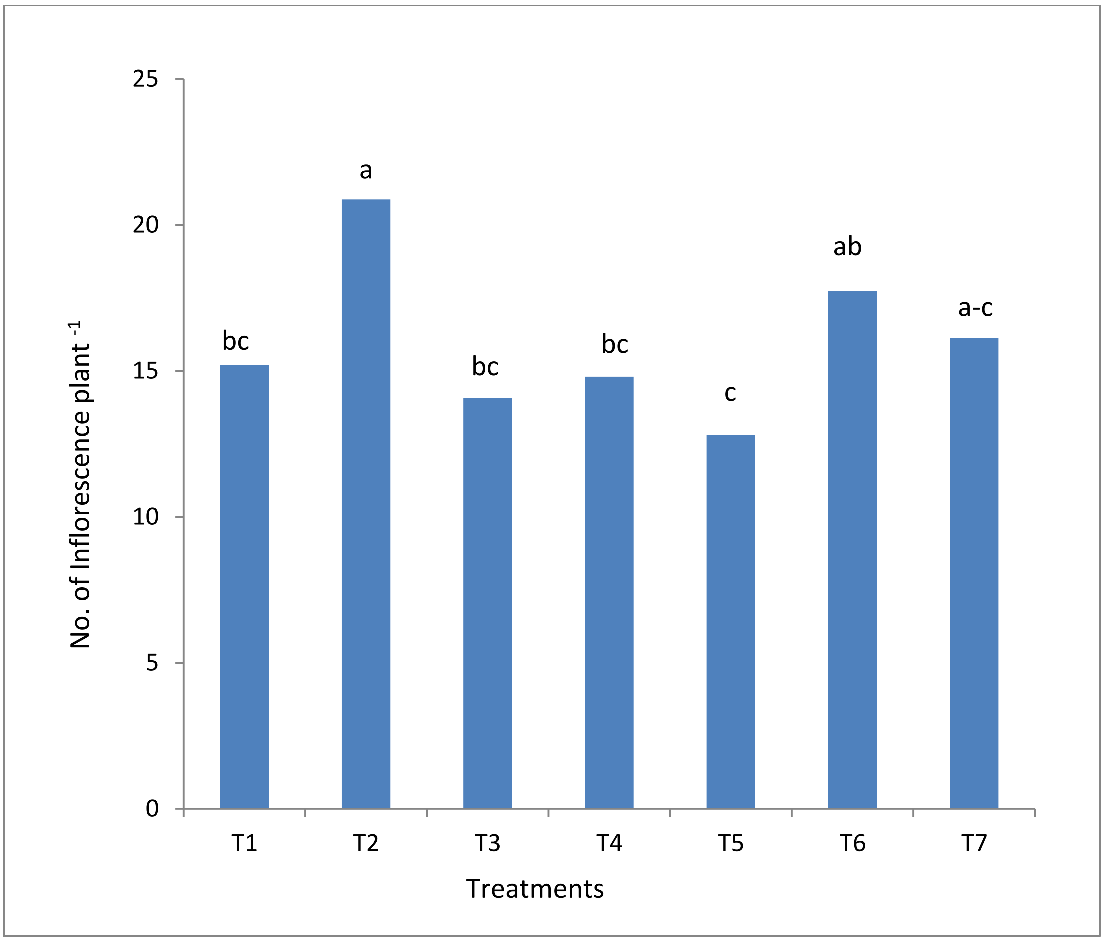
Treatments	SPAD value	
	50 DAS	70 DAS
T_1	59.06ab	55.80
T_2	69.61a	54.93
T_3	65.34ab	53.49
T_4	64.59ab	51.09
T_5	58.17b	44.24
T_6	64.25ab	57.29
T_7	56.40b	48.29
$LSD_{(0.05)}$	10.098	NS
CV (%)	1.0	17.36

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability, NS = non-significant.

T_1: Control (1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS), T_2: 2/3 N top dressed at 25 DAS, T_3: 2/3 N top dressed at 45 DAS, T_4: 1/3 N top dressed at 25 DAS and 1/3 N foliar spray at 45 DAS, T_5: 1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS, T_6: 2/3 N foliar spray at 45 DAS, T_7: 1/3 N foliar spray at 25 DAS and rest 1/3 N foliar spray at 45 DAS.

4.9 No. of inflorescence plant^{-1}

Significant variation was observed on inflorescence plant^{-1} as influenced by split application of nitrogen (Figure 1 and Appendix XII). The highest number of inflorescence plant^{-1} (20.87) was found in T_2 (2/3 N top dressed at 25 DAS) which statistically similar with T_6 (17.73) and T_7 (16.13). The lowest number of inflorescence plant^{-1} (12.80) was obtained from T_5 (1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS) that also similar with all other treatments except T_7, T_6 and T_2. The T_5 treatment reduced 38.67% inflorescence compared to that of T_2.

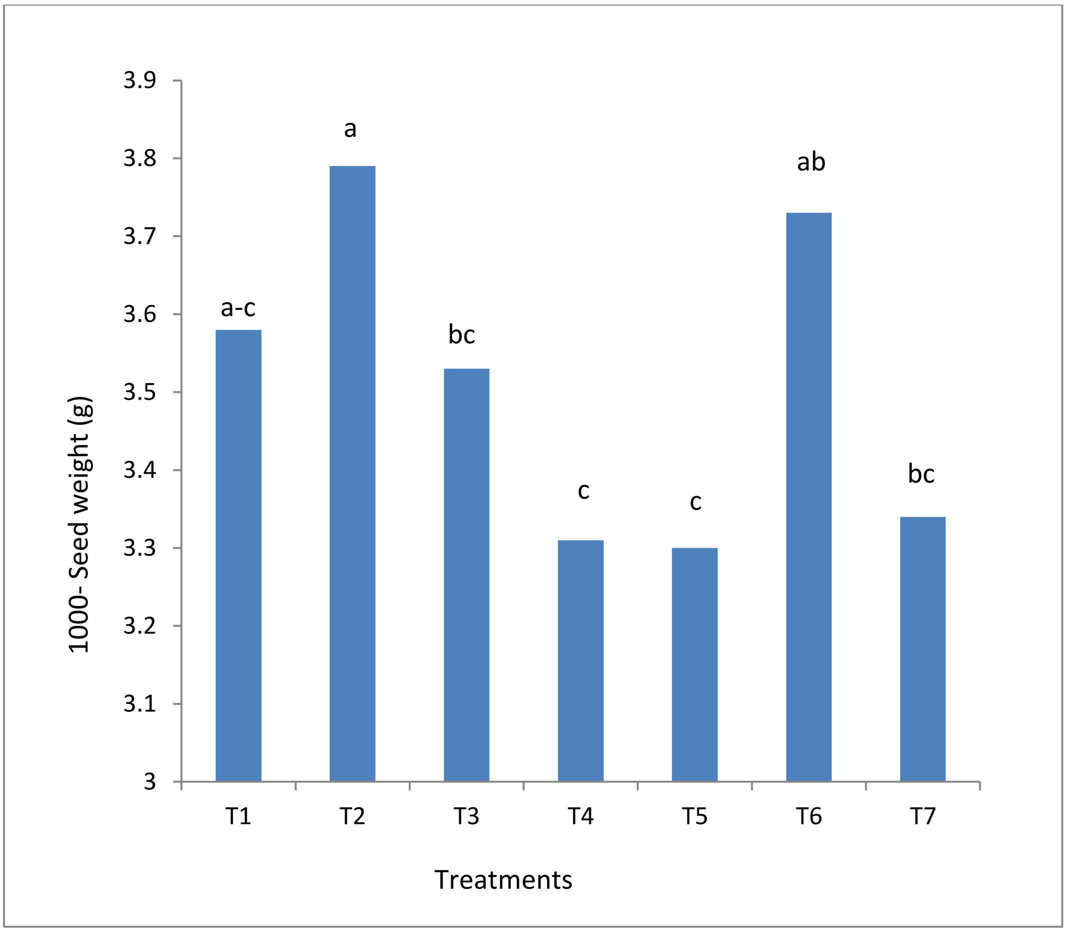


T_1: Control (1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS), T_2: 2/3 N top dressed at 25 DAS, T_3: 2/3 N top dressed at 45 DAS, T_4: 1/3 N top dressed at 25 DAS and 1/3 N foliar spray at 45 DAS, T_5: 1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS, T_6: 2/3 N foliar spray at 45 DAS, T_7: 1/3 N foliar spray at 25 DAS and rest 1/3 N foliar spray at 45 DAS.

Figure 1. Number of inflorescence plant^{-1} of quinoa as affected by split application of nitrogen fertilizer ($LSD_{(0.05)}$ = 4.368).

4.10 1000-seed weight

Thousand seed weight at harvest showed significant variation for split application of nitrogen fertilizer (Figure 2 and Appendix XIII). The result revealed that at harvest, the highest thousand seed weight (3.79 g) was obtained from T_2 (2/3 N top dressed at 25 DAS) that statistically similar with T_6 (3.73 g) and T_1 (3.58 g). The lowest thousand seed weight (3.30 g) obtained from T_5 (1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS) which was statistically similar with T_4, T_7, T_3 and T_1. Foliar application of nitrogen (1/3rd) at 25 DAS and rest 1/3rd nitrogen top dressed at 45 DAS (T_5) decreased plant height (23.19%) compared to T_2 at harvest.

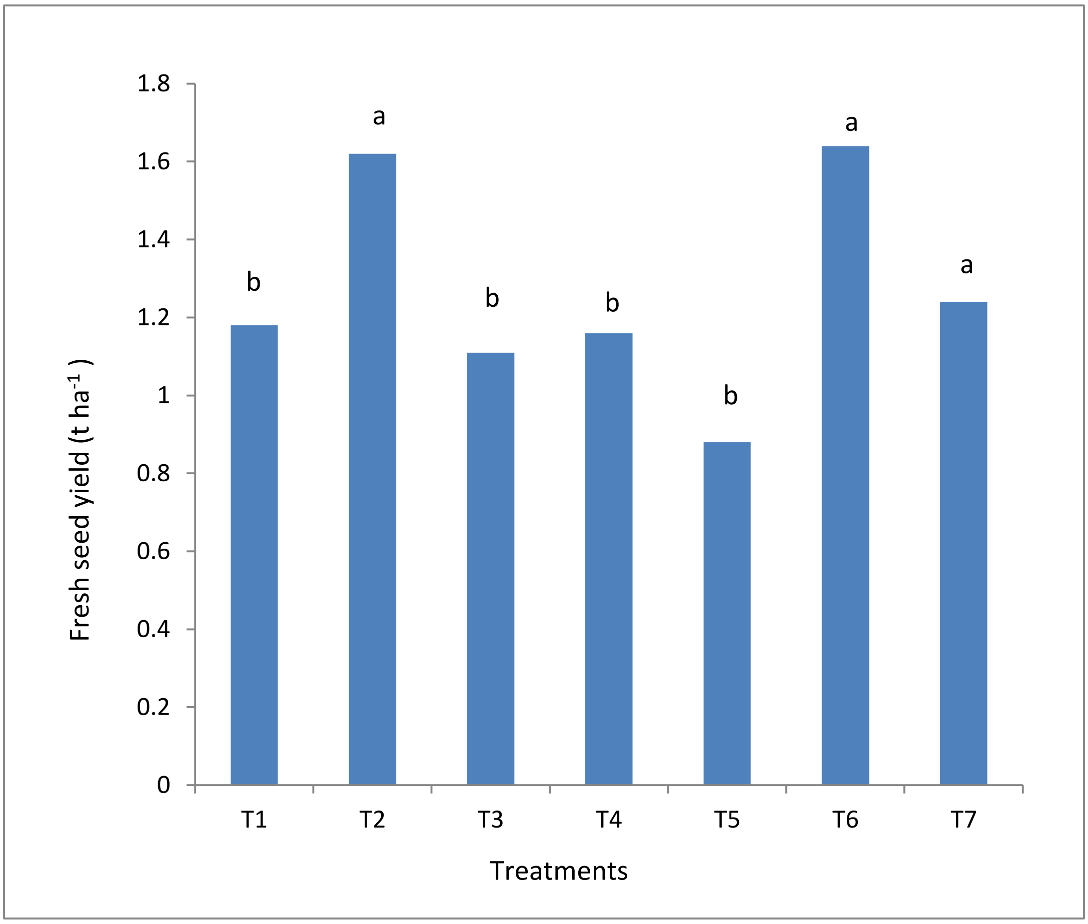


T_1: Control (1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS), T_2: 2/3 N top dressed at 25 DAS, T_3: 2/3 N top dressed at 45 DAS, T_4: 1/3 N top dressed at 25 DAS and 1/3 N foliar spray at 45 DAS, T_5: 1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS, T_6: 2/3 N foliar spray at 45 DAS, T_7: 1/3 N foliar spray at 25 DAS and rest 1/3 N foliar spray at 45 DAS.

Figure 2. 1000-seed weight of quinoa as affected by split application of nitrogen fertilizer ($LSD_{(0.05)}$ = 0.423).

4.11 Fresh seed yield

The result showed that the effect of split application of nitrogen on fresh seed yield was significant at harvest (Figure 3 and Appendix XIII). The result revealed that at harvest, the highest fresh seed yield weight (1.64 t ha^{-1}) was obtained from T_6 (2/3 N foliar spray at 45 DAS) which was statistically similar with T_2 (1.62 t ha^{-1}) and T_7 (1.24 t ha^{-1}). The lowest seed yield fresh (0.88 t ha^{-1}) was obtained from T_5 (1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS) that also similar with all other treatments except T_7, T_6 and T_2. The T_5 treatment reduced 46.34% fresh seed yield compared to that of T_6 at harvest.

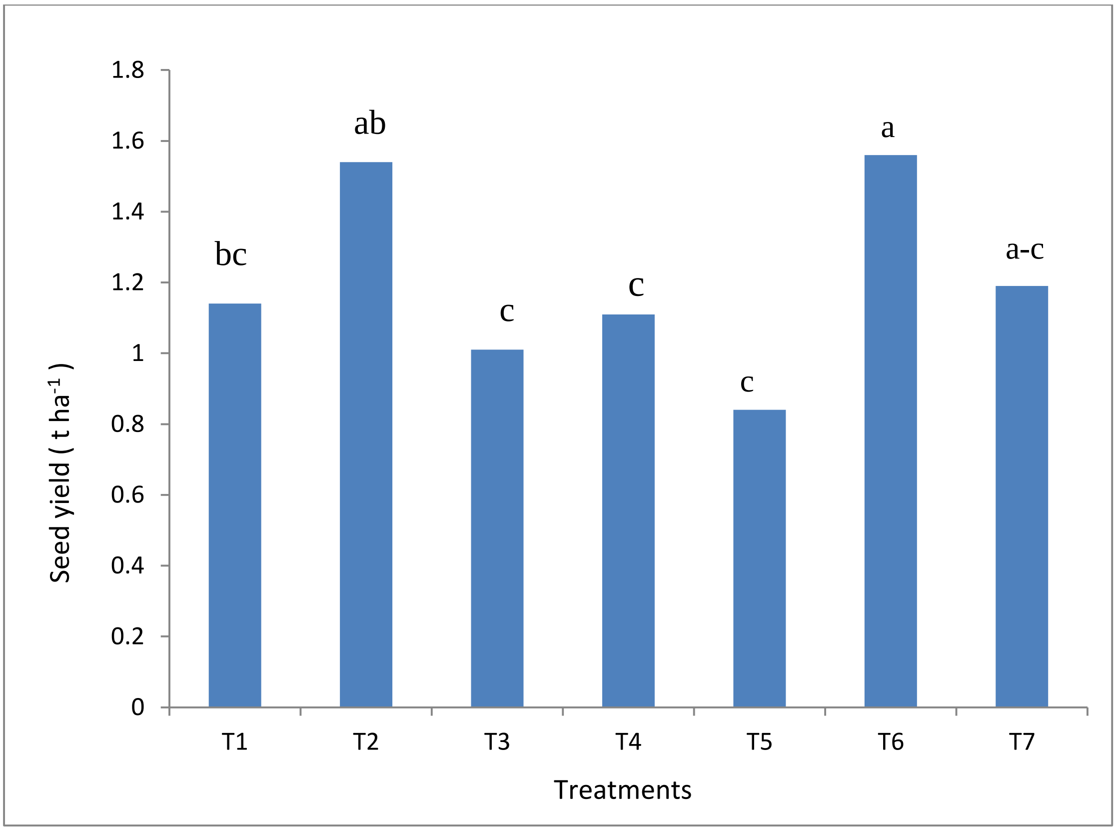


T_1: Control (1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS), T_2: 2/3 N top dressed at 25 DAS, T_3: 2/3 N top dressed at 45 DAS, T_4: 1/3 N top dressed at 25 DAS and 1/3 N foliar spray at 45 DAS, T_5: 1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS, T_6: 2/3 N foliar spray at 45 DAS, T_7: 1/3 N foliar spray at 25 DAS and rest 1/3 N foliar spray at 45 DAS.

Figure 3. Fresh seed yield of quinoa as affected by split application of nitrogen fertilizer ($LSD_{(0.05)}$ = 0.438).

4.12. Seed yield

The result showed that the effect of split application of nitrogen on seed yield was significant (Figure 4 and Appendix XIII). The result revealed that the highest seed yield (1.56 t ha^{-1}) was obtained from T_6 (2/3 N foliar spray at 45 DAS) which was statistically similar with T_2 (1.62 t ha^{-1}) and T_7 (1.24 t ha^{-1}). The T_6, T_2, and T_7 reduced moisture very low percentage that was 4.87%, 4.93% and 4.03% respectively. The lowest seed yield (0.84 t ha^{-1}) was obtained from T_5 (1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS) that also similar with all other treatments except T_7, T_6 and T_2. The T_5 treatment reduced 4.55% moisture from fresh seed yield. Tahereh *et al*. (2021) reported that late consumption of nitrogen fertilizer in three-stage split application increased the yield.

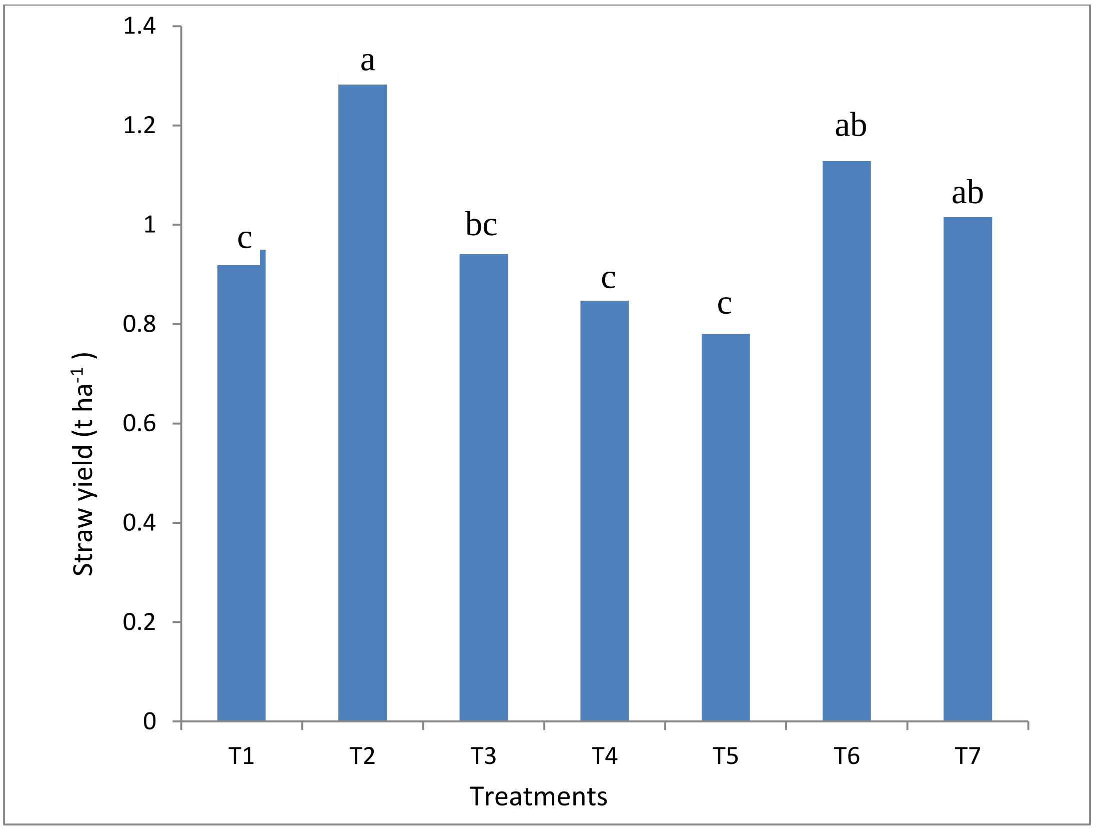


T_1: Control (1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS), T_2: 2/3 N top dressed at 25 DAS, T_3: 2/3 N top dressed at 45 DAS, T_4: 1/3 N top dressed at 25 DAS and 1/3 N foliar spray at 45 DAS, T_5: 1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS, T_6: 2/3 N foliar spray at 45 DAS, T_7: 1/3 N foliar spray at 25 DAS and rest 1/3 N foliar spray at 45 DAS.

Figure 4. Seed yield of quinoa as affected by split application of nitrogen fertilizer ($LSD_{(0.05)}$ = 0.409).

4.13 Straw yield

The variation for split application of nitrogen on straw yield was significant at harvest (Figure 5 and Appendix XIII). The result showed that the highest straw yield (1.31 t ha^{-1}) was from T_2 (2/3 N top dressed at 25 DAS) which was statistically similar with T_6 (1.19 t ha^{-1}) and T_7 (1.05 t ha^{-1}). The lowest straw yield (0.78 t ha^{-1}) was obtained from T_5 (1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS) that also similar with all other treatments except T_7, T_6 and T_2.

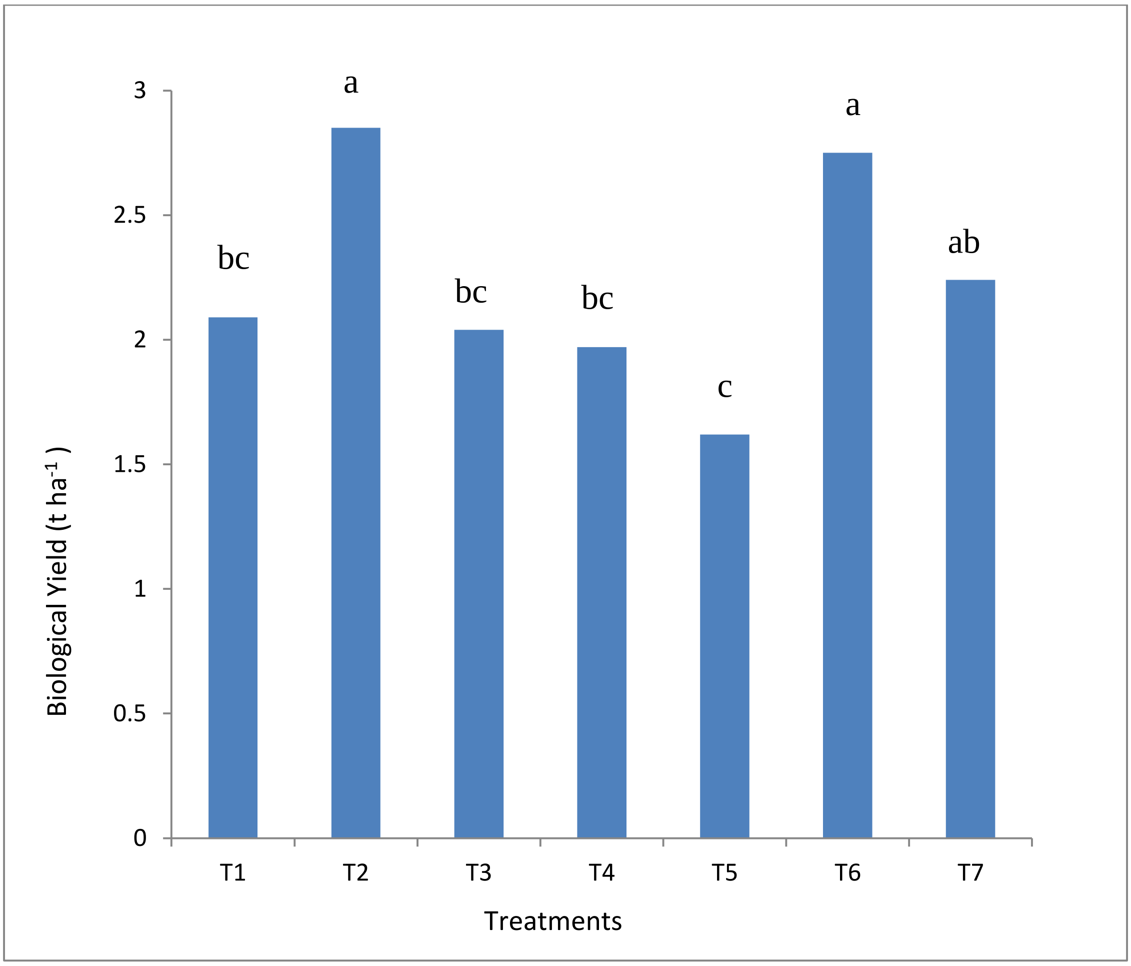


T_1: Control (1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS), T_2: 2/3 N top dressed at 25 DAS, T_3: 2/3 N top dressed at 45 DAS, T_4: 1/3 N top dressed at 25 DAS and 1/3 N foliar spray at 45 DAS, T_5: 1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS, T_6: 2/3 N foliar spray at 45 DAS, T_7: 1/3 N foliar spray at 25 DAS and rest 1/3 N foliar spray at 45 DAS.

Figure 5. Straw yield of quinoa as affected by split application of nitrogen fertilizer ($LSD_{(0.05)}$ = 0.235).

4.14 Biological yield

The result showed that the effect of split application of nitrogen on biological yield was significant at harvest (Figure 6 and Appendix XIII). The highest biological yield (2.85 t ha^{-1}) was obtained from T_2 (2/3 N top dressed at 25 DAS) that was statistically similar with T_6 (2.75 t ha^{-1}) and T_7 (2.24 t ha^{-1}). The lowest biological yield (1.62 t ha^{-1}) obtained from T_5 (1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS) that was statistically similar with T_4 (N top dressed at 25 DAS and 1/3 N foliar spray at 45 DAS), T_3 (2/3 N top dressed at 45 DAS), and T_1 (1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS).



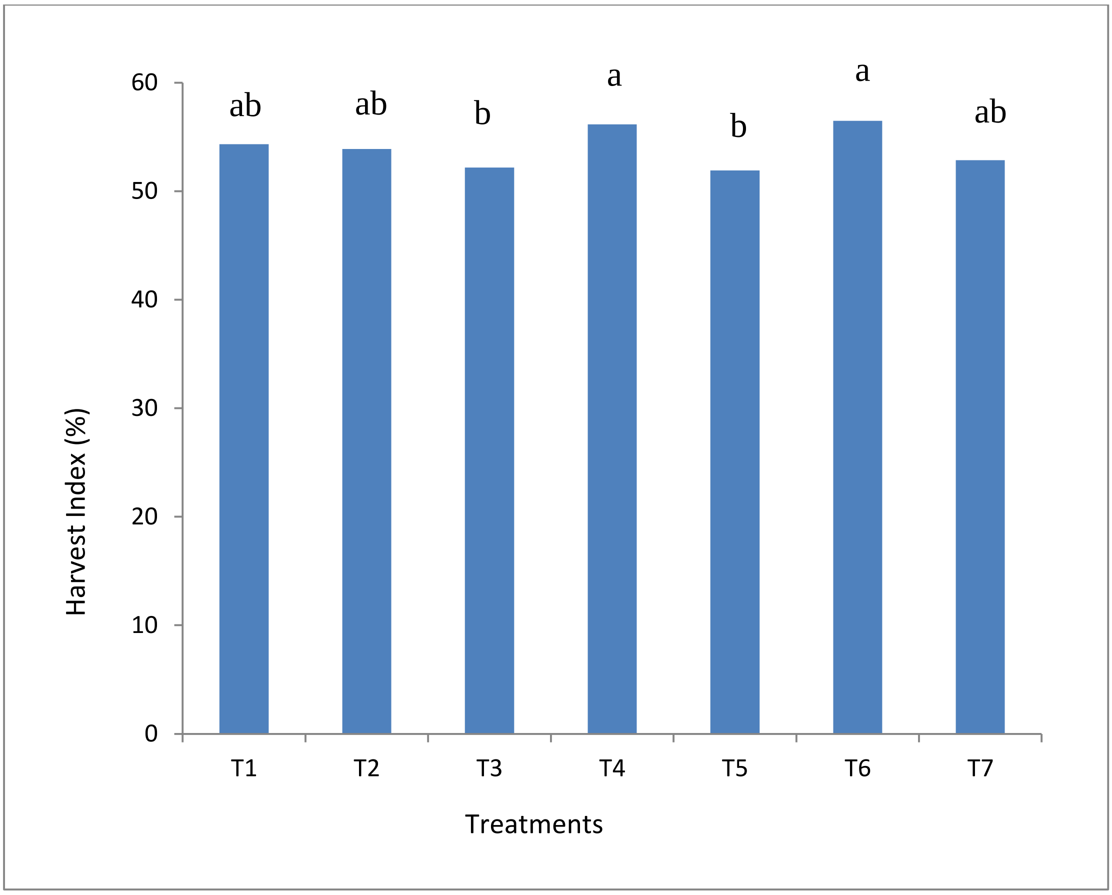
T_1: Control (1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS), T_2: 2/3 N top dressed at 25 DAS, T_3: 2/3 N top dressed at 45 DAS, T_4: 1/3 N top dressed at 25 DAS and 1/3 N foliar spray at 45 DAS, T_5: 1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS, T_6: 2/3 N foliar spray at 45 DAS, T_7: 1/3 N foliar spray at 25 DAS and rest 1/3 N foliar spray at 45 DAS.

Figure 6. Biological yield of quinoa as affected by split application of nitrogen fertilizer ($LSD_{(0.05)}$ = 0.613).

4.15 Harvest index

Harvest index showed significant variation for split application of nitrogen (Figure 7 and Appendix XIII). The result revealed that the highest harvest index (56.49%) was obtained from T_6 (2/3 N foliar spray at 45 DAS) that was statistically similar with T_4

(56.16%), T_1 (54.32%), T_2 (53.89%) and T_7 (52.85%) and the lowest harvest index (51.91%) obtained from T5 (1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS) that was statistically similar with all other treatments except T_6 and T_4.



T_1: Control (1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS), T_2: 2/3 N top dressed at 25 DAS, T_3: 2/3 N top dressed at 45 DAS, T_4: 1/3 N top dressed at 25 DAS and 1/3 N foliar spray at 45 DAS, T_5: 1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS, T_6: 2/3 N foliar spray at 45 DAS, T_7: 1/3 N foliar spray at 25 DAS and rest 1/3 N foliar spray at 45 DAS.

Figure 7. Harvest index of quinoa as affected by split application of nitrogen fertilizer ($LSD_{(0.05)}$ = 0.61).

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was conducted at the Agronomy farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the period from November 2020 to January 2021 to study the growth and yield of quinoa (*Chenopodium quinoa)* as influenced by different levels of fertilizer in Rabi season under the Modhupur Tract (AEZ-28). The treatment of the experiment consists of seven fertilizer treatments T_1 (1/3 N top dressed at 25 DAS and rest 1/3 N top dressed at 45 DAS)), T_2 (2/3 N top dressed at 25 DAS), T_3 (2/3 N top dressed at 45 DAS), T_4 (1/3 N top dressed at 25 DAS and 1/3 N foliar spray at 45 DAS), T_5 (1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS), T_6 (2/3 N foliar spray at 45 DAS), T_7 (1/3 N foliar spray at 25 DAS and rest 1/3 N foliar spray at 45 DAS). The experiment was laid out in Randomized Complete Block design following the principles of randomization with three replications. Data on different growth parameters, yield contributing characters and yield were recorded and statistically variation was observed for different treatment. The one third of urea (N) and whole amount of TSP (P), MOP (K), gypsum (S), ZnO (Zn), and boric acid were applied as basal dose during final land preparation. The remaining two third of urea was top dressed and foliar applied at 25 DAS and 45 DAS as per treatments.

Plant height was measured at 35, 50, 65, and harvest. By the influence of split application of nitrogen, the tallest plant (13.19, 28.58, 37.09, and 39.18 cm) was found in T_6 and T_2 while the shortest plant (10.45, 23.65, 28.49 and 32.81 cm) in T_7, T_4, T_5, and T_1 at 35, 50, 65 and harvest, respectively. Number of leaves plant^{-1} was counted at 35, 50, 65, and harvest. By the effects of split application of nitrogen, the highest number of leaves (15.93, 33.53, 39.40, and 25.40) were observed in T_2, T_6 whereas the lowest (13.73, 21.93, 26.87, and 16.40) in T_5 and T_4, at 35, 50 ,65, and harvest respectively. Number of branches plant^{-1} was counted at 50, 65 DAS and harvest. By the effects of split application of nitrogen, the highest number of branches (13.88, 19.93 and 21.33) were observed in T_2 whereas the lowest (10.40, 13.53 and 14.33) in T_4 and T_5 at 50, 65 DAS and harvest respectively. The maximum fresh weight plant^{-1} (8.54 g), (22.85 g) and (12.50 g) was recorded from T_2 and T_6, while the minimum fresh weight

(5.02 g), (10.96 g) and (7.26 g) from T_5 at different stages. The maximum dry weight (0.34 g), (3.62 g) and (5.07 g) was recorded from T_2 and T_6, while the minimum dry weight (0.24 g), (1.89 g) and (3.16 g) from T_5 and T_1 at different stages. The maximum root length (6.82, 10.36 and 10.00 cm) was recorded from T_6, while the minimum root length (5.28, 6.93 and 6.82 cm) from T_5 and T_1 at different stages. The maximum sooth length (18.70, 35.38 and 39.51 cm) was recorded from T_2 and T_6, while the minimum sooth length (14.13, 27.91 and 31.96 cm) from T_5, T_4 and T_1 at different stages. The maximum SPAD value (59.61 and 57.29) was recorded from T_2 and T_6. The maximum inflorescence number plant^{-1} (20.87) was recorded from T_2 while the minimum inflorescence number plant^{-1} (12.80) from T_5 at harvest. The highest 1000-seed weight (3.79 g) was recorded from T_2 (2/3 N top dressed at 45 DAS,). The lowest 1000-seed weight (3.30 g) was recorded from T_5 (1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS). For split application of nitrogen, maximum straw weight plant^{-1} at harvest (1.31 t ha^{-1}) was recorded from T_2 (two third nitrogen at 25 DAS) and minimum weight (0.78 t ha^{-1}) was recorded from T_5 (1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS). Like all other plant characters, seed yield of quinoa was influenced significantly due to split application of nitrogen. The highest seed yield of quinoa (1.56 t ha^{-1}) was recorded from T_6 (2/3 N foliar spray at 45 DAS) treatments. The lowest seed yield (0.84 t ha^{-1}) was recorded from T_5 treatments. The higher biological yield (2.85 t ha^{-1}) was recorded from T_2 (2/3 N top dressed at 25 DAS) and the minimum biological yield (1.62 t ha^{-1}) was recorded from T_5 (1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS). The higher harvest index (56.49 %) was recorded by T_6 (2/3 N foliar spray at 45 DAS) and the minimum harvest index (51.91 %) was recorded from T_5 (1/3 N foliar spray at 25 DAS and 1/3 N top dressed at 45 DAS).

Considering the findings of the present experiment, following conclusions may be drawn:

Most of the highest production of quinoa obtained from T_2 and T_6 treatments. For quinoa cultivation the highest seed yield (1.64 t ha^{-1}) was recorded from T_6 (2/3 N foliar spray at 45 DAS) that was statistically similar with T_2 (1.62 t ha^{-1}). In the same treatments T_2 and T_6 also showed the highest plant height (37.09 cm), leaves number plant^{-1} (25.40), fresh weight (12.50 g), dry weight (5.02 g), inflorescence number (20.87), 1000-seed weight (3.79 g), straw yield (1.31 t ha^{-1}), and biological yield (2.85

t ha^{-1}) and highest root length (10.00 cm), SPAD value (57.29), harvest index (56.49%), seed yield (1.56 t ha^{-1}) was obtained from T_6 treatment. Out of the split nitrogen fertilizer treatments 2/3 N top dressed at 25 DAS or 2/3 N foliar spray at 45 DAS showed maximum growth and yield in quinoa.

Before recommendation of split application of nitrogen fertilizer to optimize quinoa production further study is needed in different agro-ecological zones of Bangladesh for regional adaptability.

REFFERENCES

Abou-Amer, A.I. and Kamel, A.S. (2011). Growth, yield and nitrogen utilization efficiency of Quinoa (*Chenopodium quinoa*) under different rates and methods of nitrogen fertilization. *Egypt. J. Agron*. **33**(2): 155-166.

Ahmed, A.G., Tawfik, M.M. and Hasanein, M.S. (2011). Foliar feeding of potassium and urea for maximizing wheat productivity in sandy soil. *Australian J. Basic Appl. Sci.* **5**(5): 1197-1203.

AL-Nagger, A.M.M., Atta, M.M., Lotfy, M., EL-Moneim, A. and AL-Metwally, M.S. (2021). Effects of organic and inorganic fertilizer with reduced nitrogen level on growth, nitrogen use efficiency, seed yield and quality traits of Chenopodium quinoa. *Plant Cell Biotechnol. Mol. Biol.* **22**(71 and 72): 438-453.

Alvarez-Jubete, L., Wijngaard, H. and Arendt, E.K. (2010). Polyphenol composition and in vitro antioxidant activity of amaranth, quinoa buckwheat and wheat as affected by sprouting and baking. *Food Chem.* **119**(2): 770-778.

Amaliotis, D., Therios, I. and Karatissiou, M. (2004). Effect of nitrogen fertilization on growth, leaf nutrient concentration and photosynthesis in three peach cultivars. *ISHS Acta Hort*. **449**: 36–42.

Awadalla, A. and Morsy, A.S.M. (2017). Influence of planting dates and nitrogen fertilization on the performance of quinoa genotypes under toshka conditions. *Egyptian J. Agron.* **39**(1): 27-40.

Awan, T.H., Ali, R.I., Manzoor, Z., Ahmad, M. and Akhtar, M. (2011). Effect of different nitrogen levels and row spacing on the performance of newly evolved medium grain rice variety, KSK-133. *The J. Anim. Plant Sci.* **2**: 231-234.

Basim, K.H., Mahmood, T.A. and Hayder, R.L. (2021). Effects of seaweed and micro nutrients nano-fertilizers on growth and yield of quinoa plant growth under soil conditions. *Int. J. Agric. Stat. Sci.* **17**(1): 347-352.

Basra, S.M.A., Iqbal, S. and Afzal, I. (2014). Evaluating the response of nitrogen application on growth, development and yield of quinoa genotypes. *Int. J. Agric. Biol.* **16**: 886–892.

Bazile, D., Bertero, D. and Nieto, C. (2013). State of the art report on Quinoa around the World. In Rome: Food and Agriculture Organization of the United Nations (FAO) & CIRAD (Centre de Cooperation Internationale en Recherche Agronomique pour le Developpe-ment), p.589.

Bazile, D., Martinez, E.A. and Fuentes, F. (2014). Diversity of quinoa in a biogeographical Island: a review of constraints and potential from arid to temperate regions of Chile. *Not. Bot. Horti. Agrobot. Cluj Napoca*. **42**: 289–298.

Beigzade, M., Maleki, A., Siaddat, S.A. and Mohammadi, M.M. (2013). Effect of combined application of phosphate fertilizers and phosphate solubilizing bacteria on yield and yield components of maize single cross. *Int. J. Agric. Crop Sci.* **6**(17): 1179-1185.

Benlhabib, O., Jacobsen, S.E., Jellen, E.N., Maughan, P.J. and Choukr-Allah, R. (2015). In: State of the Art Report of Quinoa in the World in 2013. Chapter 6.1.5: Status of quinoa production and research in Morocco, pp. 478-491.

Berti, M., Wilckens, R., Hevia, F., Serri, H., Vidal, I. and Mendes, C. (2000). Fertilizaction nitrogenada en quinoa (*Chenopodium quinoa* Willd). *Ciencia Investig. Agraria*. **27**: 81- 90.

Biswas, P.K., Fatema, K. and Rahman, A. (2021). Influence of planting method and nitrogen dose on growth and yield of quinoa (*Chenopodium quinoa* Willd.). *Bangladesh Agron. J*. **24**(1): 83-92.

Brady, K., Ho, C.T. and Rosen, R.T. (2007). Effects of processing on the nutraceutical profile of quinoa. *Od Chem.* **100**(3): 1209-1216.

Brenner, D. and Williams, J.T. (1995). Grain amaranth (Amaranthus species). In: Cereals and pseudocereals. Chapman and Hall. London. pp.129-186.

Buresh, R.J. (2007). Fertile Progress. Rice Today, pp. 32-33.

Burnouf-Radosevich, M. and Paupardin, C. (1983). Triterpenoid saponins from plant organs and in vitro tissue cultures of *Chenopodium quinoa* Willd. (French), C, R. *Acad, Sci, Paris.* **296**: 429.

Dalia, A., Soliman, A.S., Attaya, K.A.S. and Eman, I.E. (2019). Response of quinoa yield and seed chemical composition to organic fertilization and nitrogen level. *SINAI J. Appl. Sci.* **8**(2): 101-102.

Dallagnol, A.M., Pescuma, M., De Valdez, G.F. and Rollán, G. (2013). Fermentation of quinoa and wheat slurries by *Lactobacillus plantarum* CRL 778: proteolytic activity. *App. Microb. Biotechnol.* **97**(7): 3129-3140.

Daughtry, C.S.T., Walthall, C.I., Kim, M.S. Brown, E. Colstoun J.E. and Mcmurtrey, J.E. (2000). Estimating corn leaf chlorophyll concentration from leaf and canopy reflectance. *Rem. Sens. Environ.* **74**: 229–239.

Du, X.B., Kong, L.C., Xi, M. and Zhang, X.Y. (2019 a). Split application improving sweet potato yield by enhancing photosynthetic and sink capacity under reduced nitrogen condition. *Field Crops Res.* **238**: 56-63.

Erley, G.S., Kaul, H.P. Kruse, M. and Aufhammer, W. (2005). Yield and nitrogen utilization efficiency of the pseudocereals amaranth, quinoa, and buckwheat under differing nitrogen fertilization, *European J. Agron.* **22**(1): 95-100.

Evans, J.R. (1983). Nitrogen and photosynthesis in the flag leaf of wheat (*Triticum aestivum* L.). *Plant Physiol.* **72**: 297–302.

FAO (Food and Agriculture Organization of the United Nations). (2013). Economic growth is nec- essary but not sufficient to accelerate reduction of hunger and malnutrition. Rome: FAO.

Fawy, H.A., Attia, M.F. and Hagab, R.H. (2017). Effect of nitrogen fertilization and organic acids on grains productivity and biochemical contents of Quinoa plant grown under soil conditions of Ras Sader-Sinai. *Egyptian J*. **67**(1): 169-18.

Finck, A. (1982). Fertilizer and fertilization “Introduction and practical guide to crop fertilization”. Weinheim; Deerfield Beach, Florida; Basel: Verlag Chemie. ISBN 3-527-25891- (Weinheim).

Foster, S. (1999). Peppermint (*Mentha piperita* L). *American Botanical* Council Series, **78**(4): 3-8.

Fuentes, F.F., Martinez, E.A., Hinrichsen, P.V., Jellen, E.N. and Maughan, P.J. (2009). Assessment of genetic diversity patterns in Chilean quinoa (*Chenopodium quinoa* Willd.) germplasm using multiplex fluorescent micro satellite markers. *Conserv, Genet.* **10**(2): 369-377.

Gallardo, M. and González, J.A. (1992). Efecto de algunos facto res ambientales sobre la germinación de la quinoa (*Chenopodium quinoa* Willd.*). Sus posibilidades como cultivo en Tucumán. Lilloa*. **38**: 55-64.

Gawlik-Dziki, U., Dziki, D., Swieca, M., Se˛czyk, Ł., o´zyło, R.R.˙ and Szymanowska, U. (2015). "Bread enriched with Chenopodium quinoa leaves powder - the procedures for assessing the fortification efficiency," LWT-Food *Sci. Technol.* **62**(2): 1226–1234.

Gawlik-Dziki, U., Świeca, M., Sułkowski, M., Dziki, D., Baraniak, B. and Czyz, J. (2013). Antioxidant and anticancer activities of *Chenopodium quinoa* leaves extracts- in vitro study. *Food Chem. Toxicol.* **57**: 154–160.

Geren, H. (2015). Effects of different nitrogen levels on the grain yield and some yield components of quinoa (*Chenopodium quinoa* Willd.) under Mediterranean climatic conditions. *Turkish J. Field Crops* **20**(1): 59-64.

Ghada, F.H. and El-Sheref. (2020). Influence of nitrogen sources and levels along with different levels of compost on quinoa (*Chenopedium quinoa* Willd.) productivity grown in newly reclaimed soils. *J. Soil Sci. Agric. Eng.* Mansoura Univ. **11**(7): 315-323.

Gomaa, E.F. (2013). Effect of nitrogen, phosphorus and biofertilizers on quinoa plant, *J. Appl. Sci. Res.* **9**(8): 5210-5222.

Hak, R., Rinderle-Zimmer, U., Lichtenthaler, H.K. and Natr, L. (1993). Chlorophyll a fluorescence signatures of nitrogen deficient barley leaves. *Photosynthetica,* **28**: 151–159.

Hakan, G. (2015). Effect of different nitrogen levels on the grain yield and some yield components of quinoa (*Chenopodium quinoa* Willd.) under Mediterranean climatic conditions. *Turkish J. Field Crops.* **20**(1): 59-64.

Hamid, A. and Sarwar, G. (1976). Effect of split application on N uptake by wheat from N15 labelled ammonium nitrate and urea. *Expt. Cien. Investig. Agric*. **12**(2): 189-193.

Hammam, K.A. and Mansour, S.F. (2018). Effect of irrigation rates and organic fertilization on growth and yield and active constituents of quinoa (*Chenopodium quinoa Wild*.) plant. *Egypt J. Agric. Res*. **96**(4): 1473.

Hassan, A. F., Moharam, F.A. and Rehab, H. H. (2017). Effect of nitrogen fertilization and organic acids on grains productivity and biochemical contents of quinoa plant growth under soil conditions. *Egyptian J. Desert Res*. **67**(1): 171-185.

Hernández-Ledesma, B. (2019). Quinoa (*Chenopodium quinoa* Willd.) as source of bioactive compounds: A review. *Bio. Com. Health and Disease*, **2**: 27-47.

Hinojosa, L., Matanguihan, J. and Murphy, K.M. (2019). Effect of high temperature on pollen morphology, plant growth and seed yield in quinoa (*Chenopodium quinoa* Willd.), *J. Agron. Crop Sci.* **205**(1): 33–45.

Jacline, F., Ibrahim, S.A., Seif, H.R.A., El-Deepah and Saad, A.M. (2020). Impact of different rates and split application of NPK fertilizer on quinoa (*Chenopoduim quinoa Willd*.) in sandy Soil. *American-Eurasian J. Agron.* **13**(3): 70-77.

Jacobsen, S.E. (2003). The worldwide potential for quinoa (*Chenopodium quinoa* Willd.), *Food Rev. Int*. **19**(1–2): 167– 177.

Jacobsen, S.E., Liu, F. and Jensen, C.R. (2009). Does root-sourced ABA play a role for regulation of stomata under drought in quinoa (*Chenopodium quinoa* Willd.). *Sci. Hort*. **122**(2): 281-287.

Jacobsen, S.E., Monteros, C., Christiansen, J., Bravo, L., Corcuera, L. and Mujica, A. (2005). Plant responses of quinoa (*Chenopodium quinoa* Willd.) to frost at various phonological stages. *Europian J. Agron.* **22**: 131-139.

Jaikishun, S., Li, W., Yang, Z. and Song, S. (2019). Quinoa: in perspective of global challenges. *Agron*. **9**(4): 176.

Jesús, E.C., José, D.H., Luisa, B.G. and Juan, P.R. (2021). Quinoa (*Chenopodium quinoa* Wild.) seed yield and efficiency in soils deficient of nitrogen. *An Anal. Rev.* **10**: 2479.

Kansomjet, P.S., Thobunluepop, S., Sarobol, L.E., Kaewsuwan, P., Jumhaeng, P., Pipattanawong, N. and Ivan, M.I. (2017). Response of physiological characteristics, seed yield and seed quality of quinoa under different of nitrogen fertilizer management. *Am. J. Plant Physiol*. **12**(1): 20-27.

Kaul, H.P., Aufhammer, W. and Wägner, W. (1996). Dry matter and nitrogen accumulation and residues of oil and protein crops. *Eur. J. Agron*. **5**: 137-147.

Kumar, K.A., Swaina, D.K. and Bhadori, P.B.S. (2018). Split application of organic nutrient improved productivity, nutritional quality and economics of rice-chickpea croppingsystem in lateritic soil. *Field Crops Res*. **223**: 125-136.

Lakudzala, D.D. (2013). Potassium response in some Malawi soils. *Int. Letters Chem. Phy. Astronom.* **8**(2): 175-181.

Lawlor, D.W. (2002). Carbon and nitrogen assimilation in relation to yield: Mechanisms are the key to understanding production systems. *J. Exp. Bot.* **53**(370): 773–787.

Maradini, F., Mônica R.P., João T.D.S.B., Helena M.P.S., Chaves, José B.P., Coimbra, J. and Sélia, D.R. (2015). Quinoa: nutritional, functional and antinutritional aspects. *Critic. Rev. Food Sci. Nutri*. **1**: 52.

Marschner, H. (2011). Marschner's Mineral Nutrition of Higher Plants. 3rd Edition, Amsterdam, Netherlands: Elsevier/Academic Press, pp. 684, ISBN 978-0-12-384905-2.

Matiasevich, S.B., Castellion, M.L., Maldonado, S.B. and Buera, M.P. (2006). Water-dependent thermal transition in quinoa embroys. *Thermochim. Acta.* **448:** 117-122.

Miranda, M., Vega-Gálvez, A., Quispe-Fuentes, I., Rodríguez, M.J., Maureira, H. and Martínez, E.A. (2012). Nutritional aspects of six Quinoa (*Chenopodium quinoa* Willd.). Ecotypes from three geographical areas of Chile. *Chilean J. Agric. Res.* **72**(2): 175–181.

Mlakar, S.G., Turinek, M., Jakop, M., Bavec, M. and Bavec, F. (2010). Grain amaranth as an alternative and perspective crop in temperate climate. *J. Geogr.* **5**(1): 135-145.

Navruz-Varli S. and Sanlier, N. (2016). Nutritional and healthbenefits of quinoa (*Chenopodium quinoa* Willd.). *J. Cereal Sci.* **69**: 371-376.

Papastylianou, P., Kakabouki, I.P., Hela., D., Roussis, I., Sestras, A.F. and Bilalis, D.J. (2018). Influence of fertilization and soil tillage on nitrogen uptake and utilization efficiency of quinoa crop (*Chenopodium quinoa* Willd*.). J. Soil Sci. Plant Nutr.* **18**: 1.

Piva, G., Brasse, C. and Mehinagic, E. (2015). In: State of the Art Report of Quinoa in the World in 2013. Chapter 6.1.2: Quinoa D'Anjou: Te beginning of a French quinoa sector. pp. 447-453.

Pospisil, A., Pospisil, M., Varga, B. and Svecnjak, Z. (2006). Grain yield and protein concentration of two amaranth species as influenced by nitrogen fertilization. *Europ. J. Agron.* **25**(3): 250-253.

Rahman, M., Almadini, A.E., Badran and Abdullah, M.A. (2019). Evaluation of efficiency and response of quinoa plant to nitrogen fertilization levels. *Middle East J. Appl. Sci*. **09**: 839-849.

Rahman, M.H.U. and Ahmad, A. (2019). Application of CSM-CROPGRO cotton model for cultivars and optimum planting dates: evaluation in changing semiarid climate. *Field Crop Res*. **238**(139-152).

Repo-Carrasco-Valencia, Hellstrom, R.J.K., Pihlava, J.M. and Mattila. P.H. (2010). Flavonoids and other phenolic compounds in Andean indigenous grains: Quinoa

(*Chenopodium quinoa*), kañiwa (*Chenopodium pallidicaule*) and kiwicha (*Amaranthus caudatus*). *Food Chem.* **120**: 128-133.

Risi, J.C. and Galwey, N.W. (1994). The chenopodium grains of the Andes - Inca crops for modern Agriculture. *Ad. Appl. Biol.* **10**: 145-216.

Roggatz, U., Mcdonald, A.J.S., Stadenberg, I. and Schurr, U. (1999). Effects of nitrogen deprivation on cell division and expansion in leaves of *Ricinus communis* L. *Plant Cell Environ*. **22**: 81–89.

Ruiz, K.B., Biondi, S., Martínez, E.A., Orsini, F., Antognoni, F. and Jacobsen, S.E. (2016). Quinoa a model crop for understanding salt-tolerance mechanisms in halophytes. *Plant Biosyst.* **150**(2): 357-371.

Sadia, A. (2018). Influence of fertilizer levels on growth and yield of quinoa (*Chenopodium quinoa*). MS. Thesis, Dept. of Agronomy, SAU, Dhaka, Bangladesh.

Saeidi, S., Siadat, S. A., Moshatati, A., Moradi-Telavat, A. and Sepahvand, N. (2020). Effect of sowing time and nitrogen fertilizer rates on growth, seed yield and nitrogen use efficiency of quinoa (*Chenopodium quinoa* Willd.) in Ahvaz, Iran. *Iranian Agric. Sci. J*. **21**(4): 354-367.

Sakr, W.R.A., Elbagoury, H.M. Sidky, M.A. and Ali, S.A. (2014). Production of organic roselle by natural minerals and biofertilizers. *American-Eurasian J. Agric. Environ. Sci*. **14**(10): 985-995.

Salem, A.K.M. (2006). Effect of nitrogen levels, plant spacing and time of farmyard manure application on the productivity of rice. *J. Appl. Sci. Res.* **2**(11): 980-987.

Schulte, A.E.G., Kaul, H.P., Kruse, M. and Aufhammer, W. (2005). Yield and nitrogen utilization efficiency of the pseudocereals amaranth, quinoa, and buckwheat under differing nitrogen fertilization. *European J. Agron.* **22**(1): 95-100.

Shams, A.S. (2012). Response of quinoa to nitrogen fertilizer rates under sandy soil conditions. Proceedings of the 13th International Conference Agronomy. Faculty of Agriculture, Benha University, Egypt, 9-10.

Shi, Y. (2012). Study on the effects of nitrogen fertilizer rate and ratio of base and topdressing on winter wheat yield and fate of fertilizer nitrogen by 15N. In Proceedings of the 15th Chinese wheat cultivation science conference in 2012, Beijing, China, 9-10 December, 2012 (pp. 248-249). Editorial Office of Acta Entomologica Sinica.

Siadat, S.A., Modhej, A. and Esfahani, M. (2013). Effect of sowing time and nitrogen fertilizer rates on growth, seed yield and nitrogen use efficiency of quinoa (*Chenopodium quinoa* Willd.), *Iranian J. Crop Sci.* **21**(4): 354-367.

Somani, L.L. (2008). Micronutrients for soil and plant health. Agrotech Publishing Academy. pp.14 -74.

Suresh, N., Paramesh, R., Siddaraju, R., Ravi Shankar, P. and Mudalagiriyappa. (2019). Studies on growth parameters in quinoa (*Chenopodium quinoa* Willd.). *Int. J. Chem. Stud*. **8**(1): 393-397.

Swieca, M., Sęczyk, L. and Gawlik-Dziki, U. (2014). Elicitation and precursor feeding as tools for the improvement of the phenolic content and antioxidant activity of lentil sprouts, *Food Chem.* **161**: 288–295.

Tahereh, O., Farhad, M., Mehdi, M. and Masoumeh, S. (2021). Evaluation of the effect of seed rate and nitrogen fertilizer management on agronomic characteristics and grain yield components in quinoa summer cultivation in fars province. *Int. J. Modern Agric.* **10**(1): 2305-7246.

Taiwo, L.B., Adediran, J.A., Akande, M.O., Banjoko, V.A. and Oluwatosin, G.A. (2001). Influence of legume fallow on soil properties and yield of maize in southwestern *Nigerian J. Agric. Trop. Subtrop.* **102**: 109-117.

Thanapornpoong, S.N. (2004). Effect of nitrogen fertilizer on nitrogen assimilation and seed Quality of amaranth (*Amaranthus* spp.) and quinoa (*Chenopodium quinoa* willd). Ph.D. Thesis. Faculty Chile, pp. 20-48.

Turner, F.T. and Jund, M.F. (1991). Chlorophyll meter to predict nitrogen topdress requirement for semi dwarf rice. *Agron. J.* **83**: 926-928.

Walker, T.W., Martin, S.W. and Gerard, P.D. (2006). Grain yield and milling quality response of two rice cultivars to top-dress nitrogen application timings. *Agron. J.* **l98**: 1495-1500.

Wang, N., Wang, F., Shock, C.C., Meng, C. and Qiao, L. (2020). Effects of management practices on quinoa growth, seed yield and quality. *Agron.* **10**(3): 445.

Weisany, W., Raei, Y. and Allahverdipoor, K.H. (2013). Role of some of mineral nutrients in biological nitrogen fixation. *Bull. Env. Pharmacol. Life Sci.* **2**(4): 77-84.

Wilfredo, R., Soto, T.L. and Carasco, E. (2004). Study on the social, environmental and economic impacts of quinoa promotion in Bolevia. *Proinp Foundation*. *Bull*. **8**: 51-72.

Wopereis-Pura, M.M., Watanabe, H., Moreira, J. and Wopereis, M.C.S. (2002). Effect of late nitrogen application on rice yield, grain quality and profitability in the Senegal River valley. *Eur. J. Agron.* **17**: 191-198.

Yassen, A., Abou ElNour, E. A. A. and Shedeed, S. (2010) Response of wheat to foliar spray with urea and micronutrients. *J. Am. Sci.* **6**(9): 14-22.

Youssef, A.M. and Farag, M.I.H. (2021). Co-application of Organic Manure and bio-fertilizer to improve soil fertility and production of quinoa and proceeding Jew's mallow crops. Department of Soils and Water Sciences, Faculty of Agriculture, Al-Azhar University, Assiut 71524, Egypt.

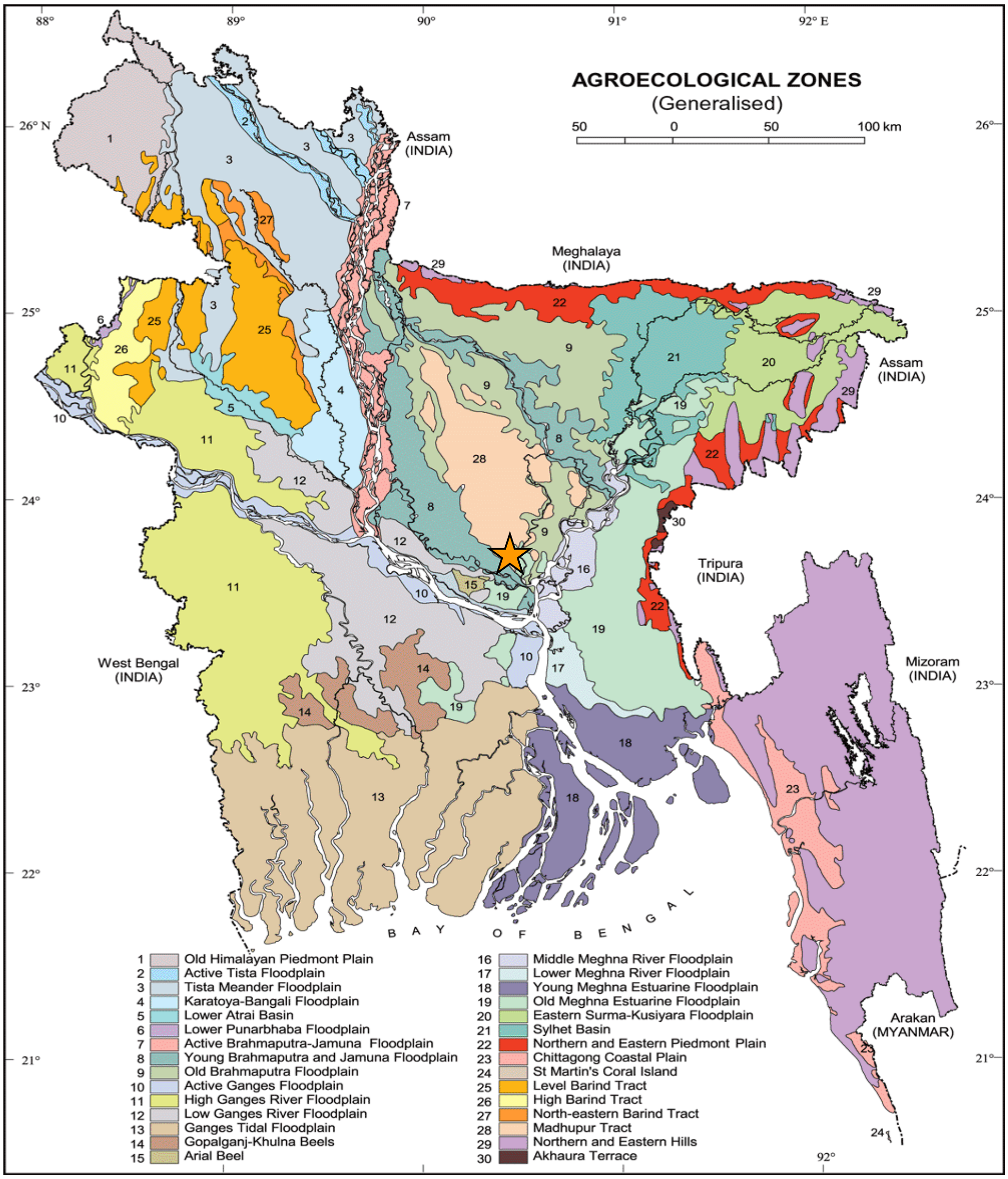
Zhao, D., Reddy, K.R. Kakani, V.G. and Reddy, V.R. (2005 a). Nitrogen deficiency effects on plant growth, leaf photosynthesis, and hyperspectral reflectance properties of sorghum. *Eur. J. Agron.* **22**: 391–4.

Zhao, D., Reddy, K.R., Kakani, V.G. Read, J.J. and Koti, S. (2005 b). Selection of optimum reflectance ratios for estimating leaf nitrogen and chlorophyll concentrations of field-grown cotton. *Agron. J.* **97**: 89–98.

Zhao, D., Reddy, K.R., Kakani, V.G., Read, J.J. and Carter, G.A. (2003). Corn (*Zea mays* L.) growth, leaf pigment concentration, photosynthesis and leaf hyperspectral reflectance properties as affected by nitrogen supply. *Plant Soil*, **257**: 205–217.

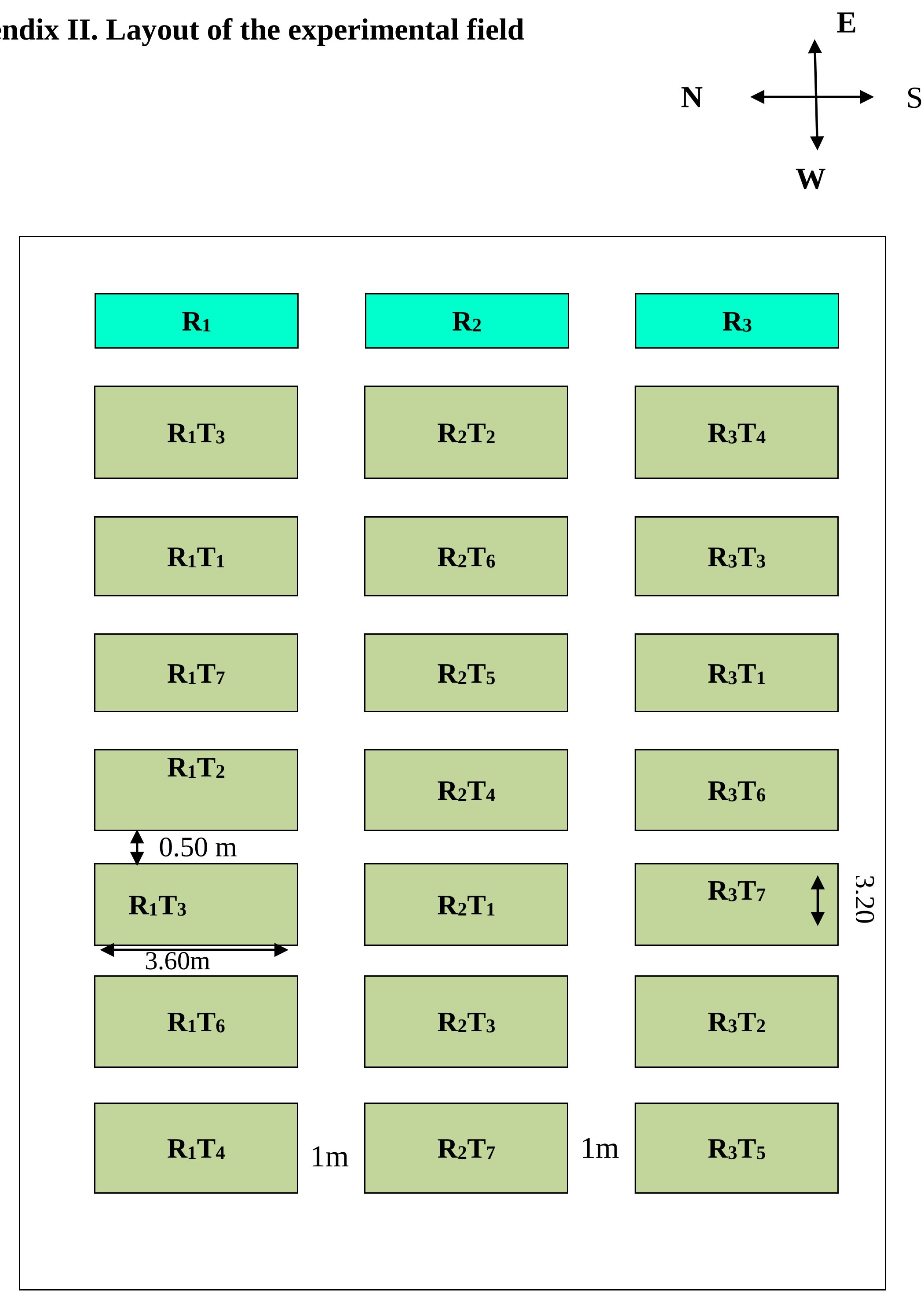
APPENDICES

Appendix I. Map showing the experimental sites under study



 The experimental site under study

Appendix II. Layout of the experimental field



Appendix III. Soil characteristics of experimental field as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological properties of the soil

Morphological features	Characteristics
Location	Agronomy field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical properties of the soil

Particle size analysis	Results
Sand (%) (0.0-0.02 mm)	21.75
Silt (1%) (0.02-0.002 mm)	66.60
Clay (%) (<0.002 mm)	11.65
Soil textural class	Silty loam
Color	Dark grey
Consistency	Grounder

Source: Soil Resources Development Institute (SRDI), Dhaka

Appendix IV. Monthly average air temperature, relative humidity and total rainfall of the experimental site during the period from November 2020 to February 2021

Month (2020-2021)	*Air temperature (^{o} C)		*Relative humidity (%)	*Rainfall (mm) (total)
	Maximum	Minimum		
November	29.2	20.5	67	9
December	26.4	17	60	9
January	26	15.3	53	2
February	29.8	17.4	45	10

* Monthly average

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka-1212

Appendix V. Analysis of variance of the data on plant height of quinoa as influenced by split application of nitrogen

Sources of variation	Degrees of freedom	Mean square value of plant height at			
		35 DAS	50 DAS	65 DAS	Harvest
Replication	2	25.643	107.435	59.080	76.102
Treatment	6	2.760*	11.065NS	24.473*	15.621*
Error	12	2.155	23.268	10.673	27.232
Total	20				

* Significant at 5% level, NS = non-significant

Appendix VI. Analysis of variance of the data on number of leaves plant^{-1} of quinoa as influenced by split application of nitrogen

Sources of variation	Degrees of freedom	Mean square value of number of leaves plant^{-1} at			
		35 DAS	50 DAS	65 DAS	Harvest
Replication	2	3.324	16.549	5.782	34.071
Treatment	6	2.234*	51.138*	70.108*	30.055*
Error	12	0.616	9.333	5.297	5.144
Total	20				

* Significant at 5% level

Appendix VII. Analysis of variance of the data on number of branches plant^{-1} of quinoa as influenced by split application of nitrogen

Sources of variation	Degrees of freedom	Mean square value of branch plant^{-1} at		
		50 DAS	65 DAS	Harvest
Replication	2	0.853	14.610	17.613
Treatment	6	5.424*	16.889*	21.332*
Error	12	1.073	3.554	2.958
Total	20			

* Significant at 5% level

Appendix VIII. Analysis of variance of the data on fresh weight plant^{-1} of quinoa as influenced by split application of nitrogen

Sources of variation	Degrees of freedom	Mean square value of fresh weight plant^{-1} at		
		40 DAS	65 DAS	Harvest
Replication	2	3.854	3.463	1.082
Treatment	6	4.234*	44.910*	11.277*
Error	12	1.436	0.473	1.434
Total	20			

* Significant at 5% level

Appendix IX. Analysis of variance of the data on dry weight plant^{-1} of quinoa as influenced by split application of nitrogen

Sources of variation	Degrees of freedom	Mean square value of dry weight plant^{-1} at		
		40 DAS	65 DAS	Harvest
Replication	2	0.00024	0.009	1.780
Treatment	6	0.0050*	1.368*	1.537*
Error	12	0.00009	0.065	0.242
Total	20			

* Significant at 5% level

Appendix X. Analysis of variance of the data on root length plant^{-1} of quinoa as influenced by split application of nitrogen

Sources of variation	Degrees of freedom	Mean square value of root length plant^{-1} at		
		40 DAS	65 DAS	Harvest
Replication	2	1.198	0.154	0.084
Treatment	6	0.887*	5.557*	5.161*
Error	12	0.579	1.120	1.283
Total	20			

* Significant at 5% level

Appendix XI. Analysis of variance of the data on shoot length plant^{-1} of quinoa as influenced by split application of nitrogen

Sources of variation	Degrees of freedom	Mean square value of shoot length plant^{-1} at		
		50 DAS	65 DAS	Harvest
Replication	2	2.806	3.448	38.645
Treatment	6	6.621*	24.362*	30.176*
Error	12	1.811	3.449	9.560
Total	20			

* Significant at 5% level

Appendix XII. Analysis of variance of the data on SPAD value, inflorescence plant^{-1} of quinoa as influenced by split application of nitrogen

Sources of variation	Degrees of freedom	Mean square values of		
		SPAD value plant^{-1} at		Inflorescence plant^{-1}
		50 DAS	65 DAS	
Replication	2	25.126	9.926	6.760
Treatment	6	66.961*	63.903NS	18.571*
Error	12	37.597	82.019	6.029
Total	20			

* Significant at 5% level, NS = non-significant

Appendix XIII. Analysis of variance of the data on yield of quinoa as influenced by split application of nitrogen

Sources of variation	Degrees of freedom	Mean square values of					
		Fresh grain yield	Dry grain yield	1000-seed weight	Straw yield	Biological yield	Harvest index
Replication	2	0.239	0.216	0.023	0.780	0.512	22.831
Treatment	6	0.231*	0.202*	0.122*	0.101*	0.571*	9.976*
Error	12	0.605	0.527	0.057	0.174	0.118	5.512
Total	20						

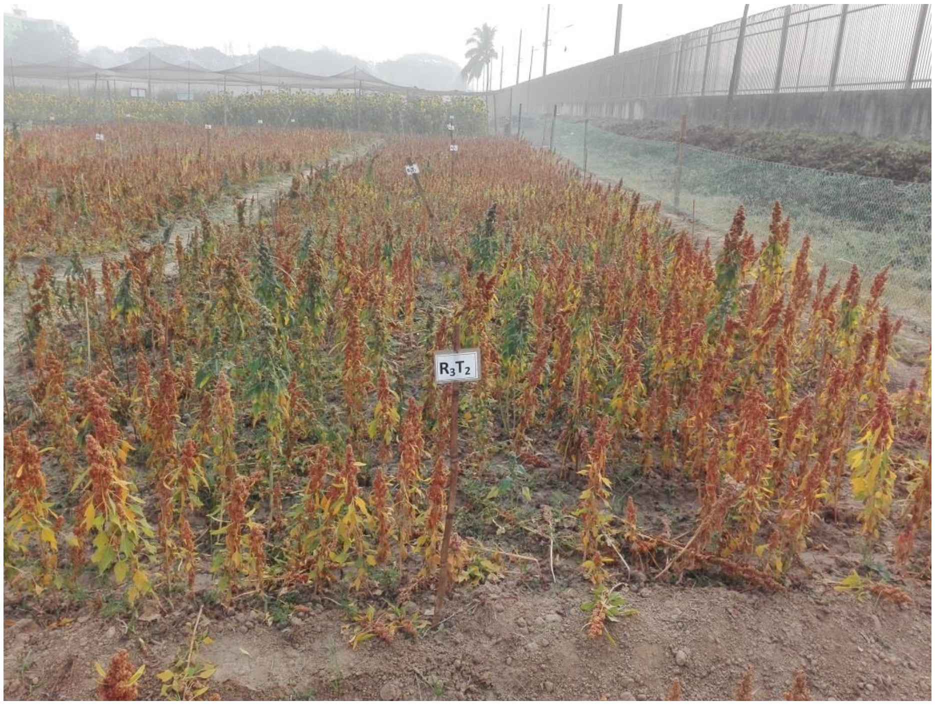
* Significant at 5% level,

PLATES

Department of Agronomy
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
Sher-e-Bangla Nagar, Dhaka-1207.
Financial Support: SAURES
Title: SPLIT APPLICATION EFFECTS OF NITROGEN FERTILIZER ON GROWTH AND YIELD OF QUINOA (*Chenopodium quinoa* Willd.)
Treatments: Split Application of Urea - 7
i. Control (1/3 top dress at 25 DAS+1/3 top dress at 45 DAS) – T_1
ii. 2/3 top dress at 25 DAS – T_2
iii. 2/3 top dress at 45 DAS– T_3
iv. 1/3 top dress at 25 DAS + 1/3 foliar spray at 45 DAS – T_4
v. 1/3 foliar spray at 25 DAS + 1/3 top dress at 45 DAS – T5
vi. 2/3 foliar spray at 45 DAS – T_6
vii. 1/3 foliar spray at 25 DAS + 1/3 foliar spray at 45 DAS – T_7
Design: RCBD
Replication: 3
Supervisor
Prof. Dr. Parimal Kanti Biswas
Department of Agronomy
Sher-e-Bangla Agricultural University
Researcher
Mst. Nazmunnaher
Reg. No. 19-10273
Department of Agronomy
Sher-e-Bangla Agricultural University

Plates 2. Field visit with respected supervisor

Plates 3. Data collection of the experiment



Plates 4. Highest plant height at harvest with T_2 and T_6 treatments

Plates 5. Lowest plant height at harvest with T_5 treatment