INFLUENCE OF AGRONOMIC MANAGEMENTS ON GROWTH AND YIELD OF QUINOA (*Chenopodium quinoa* Willd.)

AFROJA AKTER HOMA

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY,

DHAKA-1207

DECEMBER, 2021

INFLUENCE OF AGRONOMIC MANAGEMENTS ON GROWTH AND YIELD OF QUINOA (*Chenopodium quinoa* Willd.)

BY

AFROJA AKTER HOMA

Reg No : 19-10272

Email Id: homaafroz7@ gmail.com

Phone Number: 01714716005

A Thesis

Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka-1207
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE
IN
AGRONOMY

SEMESTER: JULY-DECEMBER, 2021

Approved By:

………………………………..	………………………………
Prof. Dr. Parimal Kanti Biswas	**Prof. Dr. Tuhin Suvra Roy**
Supervisor	**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: +8801552358082

CERTIFICATE

This is to certify that thesis entitled **"INFLUENCE OF AGRONOMIC MANAGEMENTS ON GROWTH AND YIELD OF QUINOA (*Chenopodium quinoa* Willd.)"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, 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 **AFROJA AKTER HOMA**, Registration No. **19-10272** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: **Prof. Dr. Parimal Kanti Biswas**

Place: Dhaka, Bangladesh **Supervisor**

DEDICATED TO MY BELOVED PARENTS

ACKNOWLEDGEMENTS

*The author would like to express her deepest sense of gratitude, endless praises and thanks to God for her never-ending blessing, it is a great pleasure to express profound thankfulness to the author's respected parents and father in-law's youngest aunt who entitled much hardship inspiring for prosecuting her studies, thereby receiving proper education. The author wishes to express her gratitude, respect and best regards to her respected Supervisor, **Prof. Dr. Parimal Kanti Biswas**, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for his continuous direction, supervision, constructive criticism, unvarying encouragement and valuable suggestions in carrying out the research work and preparation of this thesis.*

*The author wishes to express her respect and best regards to her respected Co-Supervisor, **Prof. Dr. Tuhin Suvra Roy.** Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for his direction, constructive criticism, encouragement and valuable suggestions in carrying out the research work and preparation of this thesis. The author feels to express her heartfelt thanks to Departmental Chairman **Prof. Dr. Md.Abdullahil Baque** along with all other teachers and staff members of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for their co-operation during the period of the study. Heartiest thanks and gratitude are due to the officials of Sher-e-Bangla Agricultural University Research System (SAURES) and Farm Division of Sher-e-Bangla Agricultural University for their support to conduct the research. 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.*

*She feels obligation to express her sincere thanks to her husband **Foysal Ahmed** and her best friend **Mst. Nazmunnahar** for their keen help as well as heartiest co-operation and encouragement during the study period. The author expresses her heartfelt thanks to her beloved parents **Md Azizur Rahman** and **Nazma Akter** and her brothers **Naeem Rahman** and **Abdullah Al Sadik** and all other family members for their prayers, encouragement, constant inspiration and moral support for her higher study. May God bless and protect them all.*

December,2021

The Author

INFLUENCE OF AGRONOMIC MANAGEMENTS ON GROWTH AND YIELD OF QUINOA (*Chenopodium quinoa* Willd.)

ABSTRACT

A field experiment was carried out at Agronomy Research Field, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from December 2020 to March 2021 to study the impact of different agronomic management practices on growth and yield of quinoa. The experiment comprised of seven agronomic management practices (no management, no fertilizer, no weeding, no irrigation, no thinning, no pesticides and complete management) in the plots. The experiment was laid out in RCBD design with three replications. Significant variation was recorded for fertilizer, weeding, irrigation, thinning and pest management on growth and different yield contributing characters and yield of quinoa. The maximum plant height (54.02 cm), number of leaves plant^{-1} (17.53), number of branches plant^{-1}(19.60), fresh weight plant^{-1} (7.08 g), dry weight plant^{-1} (1.39 g), SPAD value (70.24), 1000-grain weight (3.90 g), grain yield (1.55 t ha^{-1}), straw yield (1.47 t ha^{-1}) and biological yield (3.00 t ha^{-1}) were recorded from T_7 (complete management) and also maximum root length (7.44 cm) and shoot length (48.27 cm) were recorded from T_2 (no weeding) and highest harvest index (53.19%) were from T_3 (no fertilizer) respectively. While the minimum plant height (21.24 cm), number of leaves plant^{-1} (9.27), number of branches plant^{-1} (10.53), fresh weight plant^{-1} (1.77 g), dry weight plant^{-1}(0.14 g), root length (4.39 cm), shoot length (18.83 cm), number of inflorescence (11.87), SPAD value (45.73), 1000-grain weight (3.17 g), grain yield (0.24 t ha^{-1}), straw yield (0.23 t ha^{-1}), biological yield (0.48 t ha^{-1}), harvest index (51.06%), were recorded from T_1 (no management). No management reduced (84.52%) yield of quinoa that followed by no irrigation (81.29%), no fertilizer (32.90%), no thinning (13.35%), no weeding (6.45%), and no pesticide (5.41%) application compared to complete management.

LIST OF CONTENTS

LIST OF CONTENTS (CONTD.)

LIST OF CONTENTS (CONTD.)

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
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
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

INTRODUCTION

Quinoa is a highly nutritious food product, being cultivated for several thousand years in South America, with an outstanding protein quality and a high content of a range of vitamins and minerals. Quinoa is one of the main food crops in the Andean mountains, but during recent times there has been increased interest for the product in the United States, Europe, and Asia. Quinoa has been selected by FAO as one of the crops destined to offer food security in the next century.

The main uses of quinoa are for cooking, baking, etc.; various products for people allergic to gluten; animal feed, green fodder, and pellets; modified food products such as breakfast cereals, pasta, and cookies; industrial use of starch, protein, and saponin and as a game-cover crop. In developing countries of Africa and Asia, quinoa may be a crop able to provide highly nutritious food under dry conditions. It is tolerant to environmental stresses and characterized by interesting nutritional traits. Thus, it has the potential to contribute to food and nutrition security in marginal environments.

Quinoa (*Chenopodium quinoa* Willd.) yield potential needs to be further achieved by good management practices to meet the increasing global demand. Two years of orthogonal field experiments were undertaken to investigate the effects of irrigation onset criteria using soil matric potential (SMP) (−15, −25, and −55 kPa), nitrogen fertilizer rate (80, 160, and 240 kg ha^{-1}), and plant density (20, 30, and 40 plants m^{-2}) on quinoa growth, seed yield, weight, and protein content. The 240 kg ha^{-1} nitrogen rate had significantly ($p < 0.05$) greater thousand kernel weight (2.26 g) and protein content (21.3%) than 80 (2.07 g and 19.5%, respectively) and 160 kg ha^{-1}(2.14 g and 20.7%, respectively). Quinoa has been recognized as a climate resilient crop of great value and there is an increasing effort to introduce it in different marginal agriculture production systems of the world. Various quinoa cultivars have been screened for tolerance to abiotic stresses, especially salinity, drought, and frost and the positive attributes of the crop have created wider global interest in its cultivation (Jacobsen, 2003; Jacobsen *et al.*, 2003). Quinoa seed contains high quality protein, which has all of the essential amino acids including lysine, methionine and threonine that are scarce in cereals and legumes. In view of its exceptional nutritional quality and ability to grow under marginal environments, the

Food and Agriculture Organization of the United Nations (FAO) has identified quinoa as one of the crops that will play an important role in ensuring future food security and designated the year 2013 as the “Year of Quinoa” (Bazile *et al*., 2015). Worldwide, the demand for quinoa is growing, especially in the health food segment, but current supplies are unable to match it. Besides the use for human consumption, quinoa seed has other uses as livestock and poultry feed. The whole plant can be used as green fodder and harvest residues can be fed to the animals. In the context of the Middle East and North Africa (MENA) and Central Asia regions, where soil and water salinity is increasingly becoming a constraint to agricultural production, quinoa is seen as an alternative crop with significant potential to have a central role in sustaining farm productivity.

Quinoa is considered a multipurpose agro-industrial crop (Galwey, 1993). The seed may be utilized for human food and in flour products and in animal feedstocks. The specific advantageous properties of quinoa for industrial uses must be identified and exploited, and process technologies enabling exploitation of such properties must be developed. To be successful these products must compete with other raw materials that are often cheap, readily available, and of acceptable quality. Quinoa starch with its uniformly small granules, has several potential industrial applications. Possible industrial products suggested from quinoa are flow improvers to incorporate into starch flour products, fillers in the plastic industry, anti-offset and dusting powders, and improving amino acid balance of human and animal foods. Saponins may be interesting as potential insecticides, antibiotics, and fungicides, and to the pharmaceutical industry as a mediator of intestinal permeability, which could aid the absorption of specific drugs. In research programs, the entire chain from planting through product should be studied, including primary production, harvesting, storage and processing technologies, product development and evaluation, marketing studies, and economics. A multi-disciplinary approach is needed, with both the public and private sectors as participants. Bazile *et al*. (2015) found that Quinoa seed yields under moderate management were quite low, around 500–700 kg ha^{-1}. However, quinoa yield could be much higher under irrigation (310-1300mm), nitrogen fertilization (120–180 kg ha^{-1}) Jacobsen *et al*. (2016) and plant density (10–300 plants m^{-2}).Therefore, higher quinoa yields may be attained by simultaneously optimizing irrigation, nitrogen fertilization, and plant density. Although quinoa is a drought-tolerant crop with a low water requirement Jacobsen et al. (2003), quinoa seed yields respond positively to irrigation Greets *et al*. (2008). As an efficient water-saving irrigation method, drip irrigation has been widely applied in water-limited regions Wang *et al*. (2011) and could be scientifically scheduled to improve quinoa production. Geerts *et al*.(2008), Hirich *et al*. (2014), Fghire *et al*. (2015), and Rachid *et al*. (2015) scheduled quinoa drip irrigation based on estimated crop evapo-transpiration (ETC) while completely ignoring the influence of the actual soil water status. Razzaghi *et al*. (2012) grew quinoa relying on the measurement of soil water content, paying little attention to the dramatic spatial–temporal variations in soil water. Soil matric potential (SMP) is a useful criterion for characterizing crop soil water availability, and SMP-based drip irrigation management has been successfully applied to improve yields in many crops (Meng *et al*., 2019). The SMP threshold for quinoa drip irrigation scheduling can vary with soil texture, active rooting depth of quinoa, planting configuration, water availability for irrigation, and many other factors. However, there is no reference in the literature to SMP irrigation onset for quinoa. Nitrogen fertilizer should be important for quinoa because quinoa is high in protein content. Quinoa seed yields generally increase with an increasing nitrogen rate. The reported optimal nitrogen application rate varies widely by authors and locations: 120 kg ha $^{-1}$ in Germany, 180 kgha^{-1}in Denmark, and 310 kg ha^{-1}in Egypt. Notably, a small yield decrease was also observed when increasing the nitrogen application up to the highest nitrogen application of 160 kg ha^{-1}. These disparities can be understood by the large variations in soil fertility, varieties, and crop needs, as affected by water, nutrition supply, plant density, and other environmental constraints Van Gaelen *et al*. (2015). Little reported information on the nitrogen application management of quinoa considers nitrogen uptake and soil fertility. Plant density is an important factor to ensure high quinoa seed yield Aguilar *et al*. (2003), which in turn is influenced by many factors, like crop varieties, climate conditions, and cropping strategies. Spehar and Rocha (2009) showed that the plant density varying from 10 to 60 plants m $^{-2}$ did not influence seed yield when irrigated using sprinkling irrigation at approximately seven-day intervals in Brazil. Gimplinger *et al*. (2008) found a quadratic response of seed yield to plant density, and the plant density of 17 plants m^{-2} reached the maximum yield ($p < 0.05$) with no water and fertilizer supply in eastern Austria. The objectives of this study were as follows:

(1) to examine the effects of the agronomic management on quinoa growth and yield

(2) to determine the role of individual agronomic management on yield of quinoa

(3) to find out the proper agronomic management for quinoa cultivation in Bangladesh.

CHAPTER 2
REVIEW OF LITERATURE

In this chapter a brief review of various researchers, that were conducted about different agronomic management practices and their influence on growth and yield of quinoa have been included. An attempt is made to review the available literature those are related to the effect of agronomic management on the growth and yield of quinoa. These reviews are the short summary of research works conducted in Bangladesh and other countries in the world.

2.1Introduction of Quinoa

Quinoa (*Chenopodium quinoa* Willd.) is a pseudocereal native to the Andean regions of South America (Matiacevich *et al*., 2006). Quinoa is one of the oldest crops of the American continent. Archeological findings in northern Chile have shown that quinoa was used prior to 3000 BC. in Ayacucho, Peru, evidence has been obtained that quinoa was cultivated there before 5000 BC. The quinoa plant was widely cultivated in the whole Andrean region, in Columbia, Ecuador, Peru, Bolivia, and Chile, before the Spanish conquest. However, the habits and traditional foods of natives were replaced with foreign crops such as wheat and barley. Therefore, quinoa was cultivated either in small plantations in rural areas for domestic consumption or as borders for other crops such as potatoes or maize. For this reason, it was classified as food for poor people (Valencia-Chamorro, 2003). Bolivia and Peru are the greatest exporters with 88% of the worldwide production (Vilche *et al*., 2003). Quinoa belongs to the Amaranthaceae family, genus Chenopodium. Its botanical name is *Chenopodium quinoa* Willd.(Valencia-Chamorro, 2003). The classification of quinoa was first made from the color of the plant and fruits. Subsequently, it was based on the morphological types of the plant. Two types of inflorescence have been described (Valencia-Chamorro, 2003): (1) Glomerulates – small groups of flowers (glomeruli) originating from tertiary axes. (2) Amaranthiformes have glomeruli originating mainly from secondary axes. Quinoa grows in the altitudes from the sea level to the Andean highlands. Thus, one of the most useful classifications is that describing five ecotypes: sea-level, valley, subtropical, salar, and antiplanic (Valencia-Chamorro, 2003).

2.2 Agronomic managements

Appropriate agronomic management practices greatly influenced on the growth and yield of a crop. Growth and yield of quinoa was hampered due to improper weeding, thinning, irrigation schedule, fertilization and pest managements. Therefore, a complete management package for satisfactory production of quinoa in Bangladesh and their contribution to yield needed of assess. Weed free condition during the critical period of competition, proper plant population maintaining, recommended dose of fertilizer application, controlling of insect-diseases and appropriate amount of water are essential for obtaining optimum growth and yield of a crop. Thus, the appropriate agronomic management practices need to be adopted by the farmers for maximizing yield of quinoa.

2.3 Effects of weeding on growth and yield of quinoa

Ali reza and Emanuele (2020) conducted an experiment and found that the highest number of weed seeds were found in the uppermost soil layer (0–10 cm) in both tillage practices, likely due to the shedding of seeds of established weeds at maturity. As expected, in the 0–10 m soil layer, the weed seeds number tended to be higher in ZT than CT, in harmony with the statements reported by Bàrberi *et al*. (2002) which observed that soil management practices based on reduced or no-tillage have an unevenly distributed seed bank between the two depth horizons compared to conventional tillage, showing a greater seed bank in the top soil layer.

The PH, plant biomass, and grain number per plant showed their highest values in those treatments that remained weed free during the experiment, while the lowest values were recorded in the treatments that were weed-infested. This is due to the effect of weeds on the development of crops, competing for water, light, nutrients, CO_2 and space, behaving as hosts of pests and diseases (Page *et al*., 2009)

Akhter *et al*. (2009) reported a decrease in the yield components of a pea crop under weed conditions. Similar studies in other crops have demonstrated decreased yield components due to weed-crop interference. Safdar *et al*. (2016) reported decreased yield components in a corn crop and Singh *et al*. (2016) in a pea crop.

Jorge *et al*. (2019) conducted an experiment and observed that grain yield decreased as weed DM biomass increased; therefore, maximum grain yield was obtained in the treatments that remained weed-free during the whole experiment (0 d with weeds and 105 d weed-free). On the other hand, the lowest grain yields were obtained in the treatments with high weed biomass, that is, the treatments that had weeds during the whole experiment (105 d with weeds and 0 d weed-free). Grain number per plant affected yield because of weed interference ($P < 0.05$), which decreased from 4312 to 162 grains plant-1 in weed growth periods and increased from 181 to 5110 grains plant^{-1} in weed-free growth periods. Total polyphenol content was affected by stress.

2.4 Effects of irrigation on growth and yield of quinoa

Geerts *et al*. (2006) reported that the treatment with continuous water stress (treatment 7) proves that rainfed cultivation of quinoa during dry years (e.g. El Niño years) results in poor yield. This study confirms the conclusions of Garcia (2003) that deficit irrigation strategy in the very dry years is worthwhile to apply. Depending on the specific location within the Bolivian Altiplano, the strategies can vary with the climatic conditions (Geerts *et al*., 2006).

The hardening of quinoa due to water stress in early growth stages as mentioned by Bosque Sanchez *et al*. (2003) is confirmed in this study. The WUE of treatments with stress up till the 12 leaf stage were remarkably higher than the others.

Although quinoa performs such a wide variety of drought resistance mechanisms, lower grain yields are mostly reported due to water stress, except for moderate droughts in initial growth phases which provoke a certain hardening (Bosque Sanchez *et al*., 2003).

In this way, minor water applications during sensitive growth stages can increase yields significantly and can be used to stabilize yields in years of precipitation deficits (Garcia

2003). This practice, called deficit irrigation (English, 1990), aims at obtaining maximum water productivity and at stabilizing yields rather than at obtaining maximum yields.

Hirich *et al.*(2014) conducted an experiment and they indicated that the highest seed yields (3.3 t ha^{-1}) for quinoa and 5.6 t ha^{-1} for pea) were recorded under full irrigation and 10 t ha^{-1} of compost. Results indicated that organic amendment of 10 t ha^{-1} and 5 t ha^{-1}significantly ($P \leq 0.05$) increased seed yield by 18 and 11% under stress conditions and by 13 and 3% under full irrigation for quinoa and by 24 and 11% under full irrigation and by 41 and 25% under water-deficit irrigation for pea. It can be concluded that organic amendment improved significantly yield and biomass production better under deficit irrigation conditions than under full irrigation.

There are several resistance mechanisms to drought for quinoa allowing to this plant to adapt to arid and semi-arid regions (Jensen *et al.*, 2000, Jacobsen, 2003, El youssfi *et al.*, 2012). Potential yield of quinoa in optimal conditions varies according to climate, soil, sowing date and cultivar.

Garcia *et al*. (2003) recorded seed yield equal to 3.7 t ha^{-1} for quinoa under optimal conditions cultivated in lysimeters and 1.1 t ha^{-1} under rainfed conditions, and seed yield of 2.3 t ha^{-1} was obtained under control conditions by Razzaghi *et al*. (2012)

Geerts *et al*. (2008) reported that maximal yield obtained under full irrigation was 2.04 t ha^{-1}, similar to deficit irrigation with 2.01 t ha^{-1}, while rainfed conditions yield was reduced to 1.68 t ha^{-1}.Dry biomass production shown deficit irrigation affected negatively dry matter production for both crops. Statistical analysis revealed significance for deficit irrigation treatments, but not for organic amendment treatments. Differences between deficit irrigation treatments started to be oblivious 40 days after transplanting of quinoa and 70 days after sowing of field pea.

Hirich *et al*. (2014) carried out an experiment and he reported that the highest seed yield (3.3 t ha^{-1} for quinoa and 5.6 t ha^{-1} for pea) has been recorded when both crops were subjected to full irrigation and received 10 t ha1 of compost (T_1). However, the lowest yield was obtained under water-deficit conditions without organic amendment (T_6). Stomatal conductance as an indicator of photosynthetic activity has been affected negatively by deficit irrigation factor. However, stomatal conductance has not varied with organic amendment supplies. Stomatal conductance was affected by drought-inducing stomatal closure and decreasing leaf water status (Jensen *et al*., 2000; Razzaghi *et al*., 2012).

Fatima *et al*.(2020) conducted a field experiment and he documented that irrigation with saline water significantly decreased seed yield, biomass, plant height and all the agronomic yield components studied. Saline water reduced seed yield by about 27 % , and the rest of the traits by less than 20 %. Genotypic variability was also significant within each irrigation regime for seed yield, biomass and the other agronomical traits.

Talebnejad *et al*. (2015) performed a research and he found that the results indicated that 70% reduction of the full irrigation water resulted in only 36% reduction in seed yield (SY) as compared with maximum SY (2.1 Mg ha^{-1} at 0.80 m GD with 0.80FI), whereas water productivity based on SY (WUEI seed) increased 12%. Shoot dry matter (SDM) is not sensitive to water deficit and reducing the irrigation volume from 0.80FI to 0.30FI resulted in only 8% decrease in SDM in presence of shallow groundwater. It is concluded that at moderate deficit irrigation (0.80FI) shallow groundwater should be maintained at 0.55 m or higher to obtained maximum SY; however, in places with shallow groundwater (0.30 m), deficit irrigation should be applied in order to achieve higher SY.

Use of shallow groundwater helps to reduce the volume of water required for irrigation (Satchithanantham *et al*., 2014). Therefore, shallow groundwater is potentially a valuable source of additional water supply to meet crop water requirements in arid and semi arid regions.

Talebnejad and sepaskhan (2015) carried out a field experiment and found out that the results indicated that increasing in GD significantly decreased SY at 0.55FI and 0.30FI. However, there was no significant difference between SY at 0.55 and 0.80 m GD in 0.80FI. At 0.80 m GD, reducing the irrigation volume resulted in 27 and 36% decrease in SY in 0.55FI and 0.30FI as compared with 0.80FI, respectively.

Effect of irrigation management or water availability on different quinoa traits such as growth and physiological characteristics (Jacobsen *et al*., 2009; Razzaghi *et al*., 2012b),morphological characteristics (Geerts *et al*., 2006; Razzaghi *et al*., 2012) and chemical composition of seeds have been investigated.SY ranged from 1.32 to 2.10 Mg ha^{-1}. In the Andean countries, different quinoa genotypes showed a yield ranging from 0.5 to 3.5 t ha^{-1} (Mujica *et al*., 2000).

Delgado *et al*. (2009) recorded yield values from 1.7 to 2.7 t ha^{-1} comparing 16 quinoa genotypes in the open field experiment. However, Geerts *et al*. (2008) stated that with half of the required irrigation water, 1.2 up to 2.0 Mg ha^{-1} SY can be obtained in Bolivian weather conditions when DI was used in the vegetative stage.

Talebnejad and sepaskhan (2015b) successfully did a research and gave the opinion that the plant heights (PH) indifferent GD and DI are presented in. There was no significant difference between quinoa heights at 0.80FI at all GDs. However, PH decreased 8% and 20% by increasing GD from 0.30 m to 0.80 m, respectively at severe DIs (0.55FI and 0.30FI).

Usually, full irrigation to increase yield is not an option in water scarce regions. But deficit irrigation (DI), where water is only provided during critical growth stages, might be a solution. Geerts *et al*. (2008) proved in an extensive study that deficit irrigation can be very beneficial for quinoa in the semi-arid Central Bolivian Altiplano.

Quinoa is able to accumulate salt ions in its tissues in order to control and adjust leaf water potential (Jacobsen, 2003). Highest seed yield and harvest indexes can often be obtained under moderately saline conditions (10–20 dsm^{-1}), with a high varietal difference (Jacobsen, 2003), although Koyro and Eisa (2008) indicate that plant growth, total seed yield, seed size and seed number of quinoa cv. 'Hualhuas' were all significantly reduced in the presence of salinity.

Moses (2019) carried out the experiment and indicated that the highest yielding genotype at Bunda was Titicaca (3019 kg/ha) whereas Multi-Hued was the highest (692 kg/ha) at Bembeke. Strong positive correlations between seed yield and (1) plant height (r = 0.74), (2) days to maturity (r = 0.76), and (3) biomass (r = 0.87) were found under irrigated condition.

Abdullah *et al*.,(2020) performed a field experiment and found that the results also confirmed that the increase in water reduced the agronomic traits such as harvest index, number of seeds and yield of seeds and straw/m^2. Also it showed that the pH values in soils were not significantly affected by irrigation, while EC significantly affected. Correlation coefficient was negative with the most traits and low with the number of grain (0.34) under overall studied treatments which confirms that quinoa is a plant that needs limited amounts of irrigation water. On the other hand there was positive strong correlation between the harvest index and grain yield (0.92).

Walter Valdivia-Cea *et al*. (2021) conducted an experiment and recorded that the effect of diminishing soil water content in the grain filling (GF) stage, throughout physiological maturity (GM), on the yield and grain quality, leaf water potential (LWP), and maximum quantum yield (Fv/Fm) in four long photoperiod quinoa genotypes was evaluated in the South-Central zone of Chile, during the 2014–2015 and 2015–2016 seasons. Five irrigation treatments (T) were established. Irrigation was carried out when the available water (AW) of the root zone reached values of 100%, 70%, 40%, 20%, and 0%. The lowest LWP values were obtained by T20 and T0 (−1.95 MPa). The 'Morado' genotype reached the lowest LWP at both seasons, while the highest average LWP was achieved by the 'AG 2010' (2014–2015) and 'Cahuil' genotypes (2015–2016). A global trend of Fv/Fm values was observed from GF to GM: 0.74 toward 0.79 (2014/2015), and 0.74 toward 0.82 (2015/2016). Only during the second season, Fv/Fm showed differences among irrigation treatments. Total average grain yields in the second season (2.97 t ha^{-1}) were greater than those in the first season (1.43 t ha^{-1}). In both seasons, the 'Cahuil' genotype and T100 reached the highest yields. A significant decrease in yield was observed when AW diminished. A direct relationship between seed yield and leaf water potential ($\Delta Y/\Delta LWP$) was found in all genotypes, varying between 5.53 ('Cahuil') and 2.86 t ha^{-1} MPa^{-1} ('AG 2010'). Total proteins, albumins, and globulins varied between seasons, with almost no differences among irrigation treatments. Only the 'Morado' genotype showed a slight trend to obtain a higher content of total protein in both seasons. It is possible to grow quinoa under irrigation deficit conditions between GF throughout GM, maintaining yield parameters and nutritional quality.

Jorge Alvar-Beltrán *et al*. (2019) successfully did a field experiment conducted in Burkina Faso has determined the response of two quinoa varieties (Titicaca sand Negra Collana) to different planting dates (November vs December), irrigation levels (Potential evapotranspiration-PET, 100, 80 and 60% PET), and N fertilization rates (100, 50 and 25 kg N ha^{-1}). Main research findings have shown that quinoa can be highly performant under drought stress conditions and low nitrogen inputs, besides of coping with high temperatures typically of the Sahel. The highest yields (1.9 t ha^{-1}) were achieved when sown in November at 60 % PET and 25 kg N ha^{-1}. For this location, short cycle varieties, such as Titicaca, were recommended in order to avoid thermic stress conditions occurring prior to the onset of the rainy season (May-October).

2.5 Effects of thinning on growth and yield of quinoa

Deng Yan *et al*. (2021) conducted a field experiment and recorded that as the planting density increases the overall plant height shows a downward trend. Compared with different density treatments, the plant height was highest under 6×104 plants ha^{-1} in both years which was decreased by increasing planting density. Under most of the seeding density, the plant height was highest under the 60 cm row spacing treatment except under 6×104 plants ha^{-1} in 2019 where plant height was highest at 50 cm row spacing.

With the increase of planting density, the overall difference in stem diameter is relatively small but the highest stem diameter was recorded at 9×104 and 10.5×104 plants ha^{-1} In 2018, the stalk diameter at 6×104 and 7.5×104 plants ha^{-1} were highest at the row spacing of 80 cm-40 cm, while the optimal row spacings at 9 and 10.5×104 plants ha^{-1} were 60 cm and 40 cm respectively. Although in 2019, stem diameter at all planting densities was highest at 60 cm row spacing. It can be seen that there were significant differences between plant densities for all the studied morphological and productive characteristics. Significant differences were found for plant height, stalk diameter, lodging rate, chlorophyll content, photosynthetic traits, and grain yield with the highest values at the optimum density of 9×104 plants ha^{-1}.

Grain yield is regulated and affected by various morphological traits such as plant height, stem diameter, and inflorescence length. The previous studies showing that the planting density of 10-20 plants m^2 could improve the yield of quinoa. (Pathan *et al*., 2019, Mlakar *et al*., 2010).

Pasko *et al*. (2009) reported that the quinoa plants under low density showed higher stem diameters and number of branches and higher diameter which in turn were found positively correlated to yield. On one hand, a sub-optimal density could result in less yield per unit area, while a very dense population could cause the ears to remain barren with smaller size and higher risk of lodging (Gawlik *et al*., 2015).

The closer row spacing could reduce evaporation by increasing the rate of canopy closure, control weeds, and could make more efficient use of available light (Tang and Tsao , 2017, Choukr Allah *et al*., 2016).

Hirich *et al*. (2014a) reported that a higher grain yield of quinoa could be achieved with narrowing row spacing of 20 cm which might be because of the even and appropriate distribution of plants.

Deng Yan *et al*. (2021) conducted an experiment and found out that under the density of 9×104 plants ha^{-1}, 10.5×104 plants h^{-1}, and 12×104 plants ha^{-1}, the SPAD value were highest at a row spacing of 60 cm in both years. Overall, chlorophyll content was highest under 60 cm treatment in both years and was significantly higher than other row spacing.

2.6 Effects of fertilizer on growth and yield of quinoa

Jesús E. Cárdenas-Castillo *et al*. (2021) performed a field experiment and recorded that quinoa can produce 1850 kg grains ha^{-1} with 50 kg N ha^{-1} under irrigated conditions, and 670 kg grains ha^{-1} with 15 kg N ha^{-1} in rainfed conditions. Quinoa increases seed yield and HarvN increases N fertilization, but decreases nitrogen efficiency. In Altiplano, without nitrogen fertilizer, the quinoa yield relies on between 500 and 1000 kg ha^{-1}, which shows that in the soil, there are other nitrogen sources.

Youssef and Ibrahim (2021) carried out an experiment and recorded that the highest improvement in seed quinoa yield was 15.22 and 15.26 t ha^{-1}, oil content was 9.76 and10.72% during two growing seasons, and were achieved when FYM and bio-fertilizers were used. Organic matter incorporation in the soil has also a positive effect on growth, productivity and yield (Parr *et al*., 1989, Ouedraogo *et al*., 2001, Gopinath *et al*., 2008, Ibrahim *et al*., 2008).

Hartley *et al*. (2010) evaluated that adding organic manure in to the soil will improve the soil content in terms of nutrients after mineralization of the organic matter and will increase the nutrients availability for plants; therefore, the nutrients uptake will be increased and the plant growth and productivity will be improved.

Plants sprayed with seaweed extracts also exhibit enhanced salt and freezing tolerance. The analysis of variance for plant length showed a significant ($P \leq 0.05$) effect of irrigation level, organic amendment and the interaction on this character. Full irrigation FI and Deficit Irrigation DI 80 gave the highest values (11.7 and 105.8 cm respectively) with no significant differences. Also, the organic treatment (108.6 cm) surpassed significantly the control (95.0 cm). The treatment FI 100 with the addition of organic amendment accounted the highest value (125 cm).

Entessar *et al*. (2018) performed a field experiment and found that the analysis of variance for grain yield trait showed a significant ($P \leq 0.05$) effect of sea weeds extracts treatment (2.02 Kg ha^{-1}) which surpassed significantly the control (1.49 Kg ha^{-1}). This could be explained by the fact that seaweed components in treated plants led to enhanced growth and crop yield.

Adding organic manure in to the soil will improve the soil content in terms of nutrients after mineralization of the organic matter and will increase the nutrients availability for plants; therefore, the nutrients uptake will be increased and the plant growth and productivity will be improved (Hartley *et al*., 2010).

Katarzyna *et al*. (2021) showed that a significant effect of sowing date was found only for phosphorus and nitrate contents. Quinoa sown in early August accumulated 44.4% more P and 39.4% less $N\text{-}NO_3$. A gradual delay of harvest resulted in a decrease in potassium content from 11,215 mg 100 g^{-1} in D.M. at the 1st date to 8433 mg 100 g^{-1} DM at the fifth date. At the same time, during the last harvest date, there was an increase in the amount of Ca in the plants, on average by 27.1% compared to the amount determined at all earlier dates. In addition, it was shown that plants with a longer growth period accumulated fewer nitrates. Agronomic practices such as tillage system and nitrogen fertilization influence weed emergence, growth and competition in a crop.

Ioanna *et al*. (2015) conducted an experiment and recorded that the highest total weed density was recorded in manure plots, followed by N_2, N_1 and the untreated control in 2011 and 2012 under both tillage systems. Similar trends were also found in weed biomass. Under MT, the treatment of cow manure and N_2 resulted in the highest weed biomass (1522 and 1545 kg ha^{-1} in 2011 and 1453 and 1441 kg ha^{-1}in 2012, respectively), followed by N_1 (1429 kg ha^{-1} in 2011 and 1311 kg ha^{-1} in 2012) and the untreated control (1182 kg ha^{-1} in 2011 and 1156 kg ha^{-1} in 2012). The weed biomass under CT was also ranking in decreasing order as N_2, cow manure treatment, N_1 and untreated control.

Panayiota *et al*. (2014) carried out a field experiment and found significant differentiation of plant height between the two species of quinoa, the lowest values were found in green amaranth. Fertilization had a positive effect on plant height compared with the control. In particular, inorganic N fertilization and cow manure showed higher values in quinoa crop, while there were no significant differences between the fertilization treatments in green amaranth.

The grain yield of quinoa was significantly increased by increasing N fertilization from 40 to 160 kg ha^{-1}, the yield response, however, was only moderate (Jacobsen *et al*., 1994).

Papastylinou *et al*. (2014) indicated a clear superiority of quinoa over the amaranth in height and dry matter, while there were no differences in the nutritional value of biomass between the two species. In general, fertilization had a positive impact on growth and yield of both pseudo cereals. Fertilization with compost showed higher values in most quality traits of biomass in the quinoa crop, while inorganic fertilization had better results in amaranth. The results of this study suggest that the quinoa and amaranth crops could be used as an alternative feed over spring legumes in drywarm Mediterranean areas.

Suresh *et al*. (2019) successfully did an experiment and showed significant difference among the different nutrient levels and spacing significant difference was observed for plant height. At 30 DAS plant height was significantly influenced by different spacing and varied amounts of nutrients at 30 DAS. Highest plant height was observed in N_3 (125:62.5:62.5 NPK ha^{-1}) is (108.84 cm) where as lower plant height is observed in N_1 (75:37.5:37.5 NPK ha^{-1}) is 98.50 cm.

Moses *et al*.(2019) showed that plant height at physiological maturity significantly varied among the nine genotypes under rainfed conditions in Bunda. In the 2012/13 season, the plant heights of most of the genotypes ranged from 88 to 131 cm, with the exception of Ecuadorian (12 cm) and Inca Red (20.40 cm), which were far shorter than most genotypes evaluated.

Jacobsen and Christiansen (2016) conducted a field experiment and found that the yield increased significantly ($P \leq 0.05$) with an application up to 180 kg N ha^{-1}, reaching 2200 kg ha^{-1}. Increasing N also caused a significantly increased seed weight (up to 3.3 mg) and protein content (up to 17 %). N level did not affect number and amount of weeds.

In Colombia, under the edapho climatic conditions of tropical regions, the average yields were between 1.5 and 2.6 t/ha depending on the variety and the agronomic management of the crops (Garcı´a *et al*., 2015).

El-Gamal and Hamed (2020) carried out a field experiment and recorded that the maximum grain and straw yields of quinoa reached 3.48 and 6.28 Mg ha^{-1}, respectively in clay soil, while in calcareous soil, they were 1.78 and 4.30 Mg ha^{-1}, respectively in comparison to just 1.16 and 2.72 Mg ha^{-1}, respectively in sandy soil. Also, results revealed that values of selective plant growth, physical, chemical and biochemical soil parameters were improved significantly by applied organic fertilizers in particular soybean straw plus chicken manure in all three type soils.

Nitrogen is the most important macronutrients, which is a major components of various plant substances, such as it comprised from 40 to 50% of the dry matter of protoplasm, amino acids which consider the building blocks of protein, chlorophyll formation (Roy, 2007).

Zedan *et al*. (2021) performed a field experiment and found out that the using bio-fertilizer had a significant positive effect on (PL) and (DW) of quinoa at flowering stage and (PL), (SY), (GY), (BY) and (HI) at harvesting stage. As an average, using bio-fertilizer (2 L fed^{-1}) gave the best values of (52.70 cm and 11.77 g pot^{-1}) with increases of (6.77, 9.90 %) for PL and DW at flowering stage while the values of (75.36 cm), (50.83 g pot^{-1}), (32.20 g pot^{-1}), (83.03 g pot^{-1}) and (39.98 %) with increments of 4.15, 9.29, 10.77, 9.87 and 0.93 % for (PL), (SY), (GY), (BY) and (HI) were realized at harvesting stage, respectively comparing to control treatment (zero bio- fertilizer).

2.7 Effects of pesticide on growth and yield of quinoa

Luis *et al*. (2020) recorded that all estimators used suggest that the expected species richness at all field sites would be considerably superior to the observed richness. According to these indices, San Lorenzo had higher expected species richness than the other field sites; using the Chao1 estimator, the expected number is up to 484 species (which is more than twice the number of species than in La Molina and more than three times than in Majes).

The distribution and abundance of crop pests is often indirectly regulated planting date, and fertilization regime (Pedigo and Rice, 2009, Geiger *et al*., 2010, Brévault and Clouvel, 2019). For example, irrigation practices can increase Lygus bug (Hemiptera: Miridae) populations in cotton (Asiimwe *et al*., 2014).

Actual loss caused by insects depends on many factors and varies over and within season and location. The loss due to attack of *Eurysacca* spp. is considered severe and is estimated to range from an average yield loss of 15–18% and up to 50% in dry years in Peru (Blanco, 1982, Mujica, 1993; Zanabria and Banegas, 1997). Studies with manipulated infestations have given some insight to insect density to damage relationships for *E. melanocampta* (Blanco, 1994, Villanueva, 1978).

One study included 14 levels of infestation (from three to 70 larvae per plant) of quinoa in the field, as well as a control without larvae infestation (Villanueva, 1978). The average yield loss of the Bolivian cultivar sajama in Puno was 58.8% at an infestation of

30 larvae and 85.0% at an infestation of 70 larvae, compared to the control. Infestation was made with II–III in star larvae exposed to quinoa for 36 days.

The conclusions from the studies were that the economic threshold level was three to 15 larvae per plant (Blanco, 1994; Villanueva, 1978). In heavily infested quinoa fields of Puno and Bolivia, single plants have been recorded to host up to 150–200 larvae, with an average of 46 larvae during the peak season in favorable years (Mujica, 1993, Zanabria and Banegas, 1997).

Cultural practices making the environment less favorable for pest invasion include recommendation of sowing date, nutrient management and irrigation, planting density, and thinning crop rotation, mixed cropping, phytosanitation, and tillage practices (Dent, 1995)

In quinoa production, crop rotation is recommended to break the continuity of the food chain for oligophagous pests (Mujica, 1993, Zanabria and Banegas, 1997). Quinoa is rotated in 3- to five-year cycles with potato cereals, and legumes, such as tarwi (*Lupinus mutabilis*), oat, barley, or beans (*Vicia faba*) (Mujica, 1993, Zanabria and Banegas, 1997).

Potato is always followed by quinoa, with residues from the previous year's fertilizer sufficient for the quinoa. Thus little to no additional fertilizer is required (Orellano and Tillmann, 1984, Aroni, 2000). For small-scale farming, intercropping in the field with beans, tarwi and corn is recommended in Peru and Bolivia (Tapia, 1997, Zanabria and Banegas, 1997).

In Ecuador, peas, *Pisum sativum* L. (Fabaceae), and flax *Linum usitatissimum* L. (Linaceae) is further used for intercropping (Alissie and Onore, 1988). Other recommendations to reduce pest attacks are to avoid quinoa in dry years and in poor soils, and to clear the field and surroundings effectively, in particular, for alternative host plants (Tapia, 1997, Zanabria and Banegas, 1997).

Potential control of pests with biopesticides involves the use of pheromones, bacteria, viruses, and anti feedant. Experiments have been carried out with infestation of the granulosis virus reaching levels of 50% control of Eurysacca melanocampta (Caldero´n *et al*., 1996, Zanabria and Banegas, 1997).

Pest attacks are currently not controlled in Peru and Bolivia, or if so, only controlled with insecticides. Andean farmers mainly use pesticides of the synthetic pirethroids type and even the use of a kerosene solution has been described as well as the burning of rubber in the field to repel adult moths (Zanabria and Banegas, 1997). In central Peru, traditional farming practice includes application of ashes to the soil after sowing to prevent abundance of lepidopteran larvae (Orellano and Tillmann, 1984).

Claus *et al*. (2003) conducted an experiment and recorded that integrated pest management (IPM) for the control of pest attacks in quinoa is still not well implemented. Chemical control is the only control in many parts of Peru because of lack of data on proper cultural and biological control of pests. Current recommendations to avoid high pest populations include the use of crop rotation and general application of chemical pesticides.

CHAPTER III

MATERIALS AND METHODS

The present investigation entitled **“**Influence of agronomic managements on growth and yield of Quinoa” was carried out during Rabi season at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka-1207**.** The details of materials used, experimental procedures followed and techniques adopted during investigation are being described in this chapter. Climatic and edaphic conditions prevailing during crop season, selection of site, cropping history of field and other experimental details are also being presented.

3.1 Location and time

The experiment was carried out at the Agronomy field under the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka (90°35' E longitude and 23°77' N latitude) during the period from December 2020 to March 2021.As per the Bangladesh Meteorological Department, Agargaon, Dhaka-1207 the altitude of the location was 8 m from the sea level.

3.2 Weather and climate

The geographical location of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon period or hot season from March to April and monsoon period from May to October.

3.3 Soil characteristics

The research work was conducted in a high land belonging to the AEZ Madhupur tract (Tejgaon soil series). The structure of the soil was fine with an organic carbon content of 0.45%. The texture was silty clay with a pH of 5.6. The general soil type was non-calcareous dark grey. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The experimental site has been presented in Appendix I.

3.4 Planting materials

Seeds of quinoa variety 'SAU Quinoa-1' was collected from Agronomy department of Sher-e-Bangla Agricultural University. Before sowing, the seed was tested for germination.

3.5 Germination test

Germination test was done before sowing the seeds in the field. Filter paper was placed on petri dishes and the papers were soaked with water. Seeds were distributed at random in petri dishes. The seed emergence was observed after 24 hours and completed by 48 hours. The percentage of germination was found to be over 80% for the variety.

3.6 Experimental treatments

The experimental treatments were as follows:

T_1: Control (no management),

T_2: No weeding but all other managements,

T_3: No fertilizer but all other managements,

T_4: No thinning but all other managements,

T_5: No irrigation but all other managements,

T_6: No pesticides but all other managements and

T_7: Complete management (Recommended weeding, fertilizer, thinning, irrigation, pesticide)

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 and R_3T_7.

3.7 Experimental design and layout

The experiment was laid out in a randomized complete block design having three replications. The experimental design has been shown in Appendix II.

3.8 Land Preparation

The experimental field was ploughed on 8thDecember 2020 with the help of a tractor drawn disc plough, later 13th December the land was irrigated and prepared by three successive ploughing and cross ploughing with a tractor drawn plough and laddering. All weeds were removed from the field. The field layout was made on 18th December 2020 according to experimental specification.

3.9 Crop establishment and management

Quinoa seeds were sown in the experimental plot on 18th December 2020 by line sowing method at a spacing of row-to-row distance (30cm) and plant to plant distance (20cm).

3.10 Management practices

3.10.1 Fertilizer application

Urea (150 kg N ha^{-1}), TSP (50 kg P_2O_5 ha^{-1}), MoP (50 kg K_2O ha^{-1}), Gypsum (60 kg ha^{-1}) and $ZnSO_4$ (5 kg ha^{-1}) were used for this experiment. One third urea and the entire amounts of other fertilizers and cowdung (10 t ha^{-1}) was applied into the experimental field during final land preparation. Rest Urea was applied as per treatments.

3.10.2 Weeding and irrigation

The crop was infested with some weeds during the early stage of crop establishment. First weeding was done at 30 days after sowing followed by second weeding at 30 days after sowing. Third weeding was done at 15 days after second weeding as per treatment. The first irrigation was done at 20 days after sowing followed by second irrigation at 30 days, third irrigation 45 days and fourth irrigation were done 20 days before harvesting, as per treatment.

3.10.3 Thinning

First emergence of Quinoa was observed at 24 hours of sowing. First thinning was done 15 days after sowing followed by final thinning at 25 days after sowing to maintain the population density as per treatments.

3.10.4 Pest and disease management

No pesticide and insecticides were applied as the crop was not infected by any pest and diseases.

3.11 Harvesting and processing

The experimental crop was harvested at maturity when 80% of the inflorescence turned reddish yellow in color. Harvesting was done in the morning. The crop was sun dried properly by spreading them over floor and seeds were separated from the inflorescence by beating the bundles with the help of bamboo sticks. The seeds thus collected were dried in the sun for reducing the moisture in the seed to about 9% level. The husk and straws were also dried in the sun and weight was recorded. The biological yield was calculated as the sum of the seed yield and straw yield.

3.12 Data collection

The following data on growth and yield of quinoa were collected

1. Plant height at different days after sowing
2. Number of leaves plant $^{-1}$ at different days after sowing
3. Number of branches plant $^{-1}$ at different days after sowing
4. Dry weight plant^{-1}at different days after sowing
5. Fresh weight plant^{-1}at different days after sowing
6. Root length plant^{-1}at different days after sowing
7. Shoot length plant^{-1}at different days after sowing

8. Number of effective inflorescences plant $^{-1}$

9. SPAD value at 50 DAS

10. 1000-seedweight

11. Seed yield

12. Straw yield

13. Biological yield

14. Harvest index

Procedure of recording data

3.12.1 Plant height

Plant height was measured in centimeter (cm) by using a scale at 25, 40, 55, 70 DAS (days after sowing) and at harvest. The height of five tagged quinoa plants in net plot area was measured from the base of the plant to the tip of the plant and averaged.

3.12.2 Number of leaves plant^{-1}

Total numbers of leaves from five tagged plant of each plot was counted at 25, 40, 55, 70 DAS and at harvest and average was recorded as number of leaves plant^{-1}.

3.12.3 Number of branches plant^{-1}

The number of branches was counted and recorded from five tagged plant of each plot at 55, 70 DAS and at harvest. Average value was recorded as number of branches plant^{-1}.

3.12.4 Fresh weight plant^{-1}

Fresh weight of plant was recorded from five randomly selected plants of each plot at 30, 60 DAS and at harvest. Average value was recorded as fresh weight plant^{-1}.

3.12.5 Dry weight plant^{-1}

Dry weight of plant was recorded from five randomly selected plants of each plot at 30, 60 DAS and at harvest. Average value was recorded as dry weight plant^{-1}.

3.12.6 Root length plant^{-1}

Root length of plant was recorded from five randomly selected plants of each plot at 30, 60 DAS and at harvest. Average value was recorded as root length plant^{-1}.

3.12.7 Shoot length plant^{-1}

Shoot length of plant was recorded from five randomly selected plants of each plot at 30, 60 DAS and at harvest. Average value was recorded as shoot length plant^{-1}.

3.12.8 Number of effective inflorescences plant^{-1}

Inflorescence plant^{-1} was counted and recorded from five randomly selected plant of each plot at harvest. The inflorescence having seed was considered as effective one. Average value was recorded as effective inflorescence plant^{-1}.

3.12.9 SPAD value

The SPAD value of leaves was measured by placing the SPAD meter in middle point of any 5 leaves of each 5 tagged plants plot-1 and then the reading showed by the SPAD meter was recorded. Two times reading was recorded and then the average of 5 leaves plot $^{-1}$ reading was recorded.

3.12.10 1000-seed weight

The 1000 cleaned, dried seeds were counted manually from the seeds sample of each plot. The seeds were then weighed in an electrical balance. Finally, data were recorded in gram.

3.12.11 Seed yield

Total seed yield was weighed and recorded based on total harvested area plot^{-1}leaving the boarder lines and was expressed as t ha^{-1} basis.

3.12.12 Straw yield

Total straw yield was recorded based on total harvested straw plot^{-1}leaving the border lines and the straw of harvested area from each plot was sun dried and the weight of straw was taken and converted the yield as t ha^{-1} basis.

3.12.13 Biological yield

The summation of seed yield and straw yield was regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Seed yield + Straw yield.

3.12.14 Harvest index

The harvest index was calculated by the ratio of seed yield to biological yield of quinoa for each plot and expressed in percentage.

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

3.13 Statistical analysis

The data obtained for different parameters were statistically analyzed following computer-based software CropStat and mean differences among treatments were tested with LSD test at 5% level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Plant height

A statistically significant influence was noticed on plant height of quinoa by the effects of agronomic managements at different studied durations except 25 DAS (Table 1 and Appendix V). At 25 DAS, the numerically maximum plant height (7.73 cm) was recorded in T_7 (complete management) while the minimum plant height (6.26 cm) was observed in T_1 treatment (no management). No management reduced 19.02% plant height compared to complete management. At 40 DAS, the highest plant height (21.53 cm) was determined in T_2 (no weeding) that statistically similar with all other treatments except T_1 and T_5 (no irrigation). The second highest plant height (21.30 cm) was recorded in T_6 (no pesticides) which statistically similar with other treatments except T_1 and T_5. The lowest plant height (10.09 cm) was found in T_1 (no management) that statistically similar to T_5 (no irrigation). The T_1 and T_5 treatments showed 50.02 % and 29.12% lower plant height compared to T_7. Similar lower plant height with no management was also found by Atikullah (2014), Klikocka *et al*. (2016). Statistically significant variation of plant height of quinoa was also observed at 55 DAS where the highest plant height (47.96 cm) was recorded in T_2 (no weeding) that statistically non-significant with T_7 (45.08 cm) (complete management), T_6 (44.09 cm) (no pesticide), T_4 (41.98 cm) (no thinning) and T_3 (38.87 cm) (no fertilizer). The second highest plant height (45.08 cm) at 55 DAS was recorded in T_7 (complete management) which also statistically similar to T_6. On the other hand, the lowest plant height (13.98 cm) was found in T_1 (no management) that statistically different from others. The T_1 treatment reduced 69% plant height compared to T_7. Plant height was boosted up 40.60% due to agronomic managements compared to control at this growth stage. The result also supported by the findings of Ali *et al.* (2011) who reported the reduction of plant height of wheat due to no management. At 70 DAS, the highest plant height (50.62cm) was recorded from T_6 (no pesticide) which was statistically similar with T_2 (49.70 cm) (no weeding). The second highest plant height was found in T_3 (46.42 cm) (no fertilizer) that statistically similar with T_2. The lowest plant height (18.32 cm) was found in T_1 (no management) which was statistically different from all other treatments. The reduction of plant height due to no management was recorded as 58.74% compared to T_7 (complete management). At harvest, the plant height of quinoa was varied statistically due to the influence of agronomic managements. The highest plant height (54.02 cm) was measured in T_6 (no pesticides) that statistically insignificant with T_2 (no weeding). The second highest plant height (49.14 cm) was recorded in T_3 which also statistically similar with T_7 (complete management), T_4 (no thinning) while the lowest plant height (21.24 cm) was reported in T_1 (no management) that statistically similar with T_5 (no irrigation). The T_1 (no management) and T_5 (no irrigation) treatments showed 53.93 and 45.16%, respectively lower plant height compared to T_7. Kabir *et al*. (2009) and Ali and Amin (2007) also observed lower plant height of wheat due to no management.

Table 1. Effect of agronomic managements on plant height of quinoa at different studied durations

Treatments	Plant height (cm) at				
	25 DAS	40 DAS	55 DAS	70 DAS	Harvest
T_1	6.26	10.09 c	13.98 b	18.32 e	21.24 d
T_2	7.60	21.53 a	47.96 a	49.70 ab	53.21 ab
T_3	7.57	19.27 ab	38.87 a	46.42 bc	49.14 bc
T_4	7.66	20.46 a	41.98 a	43.52 c	45.64 c
T_5	7.40	14.31 bc	19.15 b	23.79 d	25.28 d
T_6	7.73	21.30 a	44.09 a	50.62 a	54.02 a
T_7	7.24	20.19 a	45.08 a	44.40 c	46.10 c
$LSD_{(0.05)}$	NS	5.369	9.586	4.114	4.873
CV (%)	14.36	16.62	15.02	5.85	6.51

T_1: Control (no management), T_2: No weeding but all other managements, T_3: No fertilizer but all other managements, T_4: No thinning but all other managements, T_5: No irrigation but all other managements, T_6: No pesticides but all other managements and T_7: Complete management

4.2 Number of leaves plant^{-1}

Different agronomic managements showed statistically significant variation on leaves number at 25, 40 and 55, 70 DAS and at harvest (Table 2 and Appendix VI). At 25 DAS, maximum leaves were recorded in T_4 (11.07) which was statistically different from others and second maximum was recorded in T_6 (10.40) that was similar to others except T_5 and T_1. Third maximum leaves number were counted in T_6 (10.40), T_3 (10.13) and T_2 they were statistically similar. On the other hand, the minimum leaves number (9.47) were counted in T_5 (No irrigation) that was statistically similar with others. The second minimum leaves number were counted in T_1 (9.33) and it was statistically similar with others. The T_4 showed maximum leaf number compared to T_1 (control) due to complete agronomic managements. Different agronomic managements showed significant variation on number of leaves plant^{-1} was also found by Mahmud (2017).

Table 2. Effect of agronomic managements on number of leaves plant^{-1} of quinoa at different studied durations

Treatments	No of leaves plant^{-1} at				
	25 DAS	40 DAS	55 DAS	70 DAS	Harvest
T_1	9.33b	10.73d	11.40c	14.20c	9.27e
T_2	10.00ab	16.87a	19.22a	27.32ab	18.33a
T_3	10.13ab	15.93ab	19.47a	24.13b	13.20cd
T_4	11.07a	15.27b	17.33ab	24.93b	16.47ab
T_5	9.47b	13.20c	14.20bc	16.20c	10.87d
T_6	10.40ab	16.53ab	19.67a	28.27ab	14.40bc
T_7	10.27ab	15.73ab	21.13a	32.00a	17.53a
$LSD_{(0.05)}$	1.586	1.391	4.258	5.911	2.873
CV(%)	8.83	5.24	13.68	13.92	10.97

T_1: Control (no management), T_2: No weeding but all other managements, T_3: No fertilizer but all other managements, T_4: No thinning but all other managements, T_5: No irrigation but all other managements, T_6: No pesticides but all other managements and T_7: Complete management

At 40 DAS, the highest leaves number plant^{-1} (16.87) was enumerated in T_2 (no weeding) that statistically similar with T_6 (16.53), T_7 (15.73) and T_3 (15.93). The second and third highest leaves number recorded in T_6 (16.53) and T_7 (15.73), respectively and they were statistically similar with each other. While the lowest leaves number (10.73) was counted in T_1 due to no management. The second lowest leaf number was reported in T_5 (13.20) and it was statistically dissimilar.

At 55 DAS, the highest leaves number (21.13) was reported in T_7 (complete management) which was statistically similar with T_6 (19.67), T_3 (19.47), T_2 (19.22) and T_4 (17.33). The next highest leaves number counted in T_4 (17.33) that was similar with T_5 (14.20). The minimum number of leaves plant^{-1} was found in T_1 (11.40) due to no management which was statistically similar with T_5 (14.20).

At 70 DAS, the maximum leaf number (30.00) was counted in T_7 (complete management) which was statistically similar with T_6 (no pesticide). The second highest leaf number (27.32) was recorded in T_2 (no weeding) which was similar with T_3 (24.13) and T_4 (24.93). The minimum number of leaves (14.20) found in T_1 due to no management which was statistically non- significant with T_5 (16.20).

At harvest, the maximum leaf number (18.33) was reported in T_2 (no weeding) which was statistically non-significant with T_7 (complete management) and T_4 (no thinning). The next maximum leaf number (14.40) was recorded in T_6 (no pesticides) that was also statistically similar to T_4. The T_5 and T_6 showed 13.80% and 16.69% lower leaves number compared to T_7 (complete management). On the contrary, the minimum leaves number (9.27) was also counted in T_1 (no management) that was statistically different to others. The second minimum leaves number (10.87) was reported in T_5 (no irrigation) which was statistically dissimilar with others.

4.3 Number of branches plant^{-1}

A statistically significant effect of agronomic managements was observed on number of branches at different growth stages of quinoa (Table 3 and Appendix VII). At 55 DAS, the highest number of branches (13.70) was recorded in T_7 (complete management) that was statistically similar with T_6 (no pesticides). The next highest number of branches (9.75) was counted in T_4 (no thinning) which was statistically dissimilar with others. On the contrary, the lowest number of branches plant^{-1} (3.57) was found in T_1 (No management) which was statistically dissimilar to others. The second lowest number of branches plant^{-1} (9.75) was counted in T_3 which was statistically similar with T_2 (no weeding) and T_4 (no thinning).

At 70 DAS, the highest number of branches plant^{-1} (18.07) was also recorded in T_2 which was statistically similar with others except T_1 and T_5. The second highest number of branches (17.67) was found in T_7 (complete management) that was statistically different with T_5 (14 cm). While the minimum number of branches (8.47) was reported in T_1 (no management) which was statistically different from other treatments. The second minimum number of branches (13.60) was counted in T_3 which was similar with T_5 and T_6. At harvest, the highest number of branches was observed in T_7 (19.60) which was statistically similar with others except T_5 and T_1. The second highest number of branches (19.53) was recorded in T_2 that was statistically non-significant with T_4 (19.17),T_6 (17.80) and T_3 (16.47). Whereas the lowest number of branches (10.53) was found in T_1 which was statistically dissimilar with others. From the above results, it may conclude that with complete management gave higher number of branches compared to no agronomic managements.

Table 3. Effect of agronomic managements on number of branches plant^{-1} of quinoa at different studied durations

Treatments	Number of branches plant^{-1} at		
	55 DAS	70 DAS	Harvest
T_1	3.57d	8.47c	10.53c
T_2	7.70c	18.07a	19.53a
T_3	8.30c	13.60b	16.47ab
T_4	9.75b	17.27a	19.17ab
T_5	7.00c	14.00b	15.93b
T_6	13.00a	15.87ab	17.80a
T_7	13.70a	17.67a	19.60a
$LSD_{(0.05)}$	2.011	3.518	3.418
CV(%)	12.56	13.19	11.29

T_1: Control (no management), T_2: No weeding but all other managements, T_3: No fertilizer but all other managements, T_4: No thinning but all other managements, T_5: No irrigation but all other managements, T_6: No pesticides but all other managements andT_7: Complete management

4.4. Dry weight plant^{-1}

The total dry matter content of plant was significantly influenced by different agronomic management practices at different growth stages (Table 4 and Appendix IX). At 30 DAS, the highest dry matter weight plant^{-1} (0.13g) was measured in T_2 which was statistically similar with T_6(0.11g), T_7 (0.10g) and T_4 (0.09 g). The next maximum dry matter weight was found in T_3 (0.08 g) and T_5 (0.08g) that was statistically similar with others. On the other hand, the minimum dry weight (0.05 g) was weighed in T_1 that was statistically similar with T_3 (0.08g) and T_5 (0.08 g).

Table 4. Effect of agronomic managements on dry weight plant^{-1} of quinoa at different studied durations

Treatments	Dry weight (g) plant^{-1} at		
	30 DAS	60 DAS	Harvest
T_1	0.05c	0.50d	0.14e
T_2	0.13a	2.59b	1.16bc
T_3	0.08bc	2.59b	0.42d
T_4	0.09ab	2.34c	0.49d
T_5	0.08bc	0.82d	0.22e
T_6	0.11ab	2.18c	1.10c
T_7	0.10abc	3.25a	1.39a
$LSD_{(0.05)}$	0.046	0.219	0.138
CV(%)	28.84	5.17	11.01

T_1: Control (no management), T_2: No weeding but all other managements, T_3: No fertilizer but all other managements, T_4: No thinning but all other managements, T_5: No irrigation but all other managements, T_6: No pesticides but all other managements and T_7: Complete management

At 60 DAS, the highest dry weight (3.25 g) was recorded in T_7 which was statistically significant from others. The second highest dry weight was measured in T_2 (2.59 g) and T_3(2.59g) that was statistically dissimilar from others. The third highest (2.34 g) dry weight was weighted in T_4 that was statistically similar to T_6 (2.18 g).Whereas the lowest dry weight (0.50 g) was recorded in T_1 which was statistically non- significant with T_5 (0.82g).

At harvest, the highest dry matter production was also observed in T_7 (1.39 g) that was statistically significant from others. The second highest dry weight (1.16 g) was weighted in T_2 that was statistically significant from others. The T_6treatment decreased dry matter production by 16.91% respectively compared to M_7 due to no pest management. While the lowest dry matter production was observed in T_1 (0.14 g) which was statistically insignificant with T_5 (0.22 g). The next lowest dry weight (0.49 g) was recorded in T_4 that was statistically dissimilar to others except T4 (no thinning).

4.5. Fresh weight plant^{-1}

The total fresh weight of plant was significantly influenced by different agronomic management practices at different growth stages (Table 5 and Appendix VIII). At 30 DAS, the highest fresh weight (2.87g) was measured in T_2 which was statistically similar with others except T_1 (1.15g). The second maximum fresh weight was found in T_6 (2.65g) and followed by T_7 (2.61g) that was statistically similar with others. On the other hand, the lowest dry weight (1.15 g) was weighed in T_1 that was statistically similar with T_3 (1.92g) and T_4 (2.19g) and T_5(1.93g). The T_5 treatment showed 32.75% lower fresh weight production compared to T_2 due to no irrigation.

At 60 DAS, the highest fresh weight (13.76 g) was recorded in T_7 which was statistically significant from others. The second highest fresh weight was measured in T_2 (11.79 g) and T_3 (11.37g) that was statistically dissimilar from others. The next highest (9.93 g) fresh weight was weighted in T_6 that was statistically dissimilar from others. Whereas the lowest fresh weight (3.60 g) was recorded in T_1 which was statistically non-significant with T_5 (4.24g). The T_5 treatment showed 69.18% lower fresh weight production compared to T_7 due to no irrigation. The second lowest fresh weight (8.36g) observed in T_4 which was statistically different from others.

Table 5. Effect of agronomic managements on fresh weight plant^{-1} of quinoa at different studied durations

Treatment	Fresh weight (g)plant^{-1} at		
	30 DAS	60 DAS	Harvest
T_1	1.15b	3.60e	1.77d
T_2	2.87a	11.79b	6.96a
T_3	1.92ab	11.37b	4.99bc
T_4	2.19ab	8.36d	4.60c
T_5	1.93ab	4.24e	2.48d
T_6	2.65a	9.93c	5.77b
T_7	2.61a	13.76a	7.08a
$LSD_{(0.05)}$	1.126	1.094	1.083
CV(%)	28.92	6.82	12.65

T_1: Control (no management), T_2: No weeding but all other managements, T_3: No fertilizer but all other managements, T_4: No thinning but all other managements, T_5: No irrigation but all other managements, T_6: No pesticides but all other managements and T_7: Complete management

At harvest, the highest fresh weight production was also observed in T_7 (7.08 g) that was statistically non significant with T_2 (6.96 g). The next highest fresh weight (6.96 g) was weighted in T_6 that was statistically similar with T_3 (4.99 g).The T_6 and T_5 treatments decreased dry matter production by 16.91% and 25.58%, respectively compared to T_7 due to no pest management and no fertilizing. While the lowest fresh weight production was observed in T_1 (1.77 g) which was statistically insignificant with T_5 (2.48 g). The next lowest fresh weight (4.60 g) was recorded in T_4 that was statistically similar with T_3 (4.99 g). The T_3 and T_4 produced 29.52% and 35.03% lower fresh weight compared to T_7 due to no fertilizer and thinning, respectively.

4.6 Root length plant^{-1}

A statistically significant effect of agronomic managements was observed on root length at different growth stages of quinoa (Table 6 and Appendix X). At 30 DAS, the highest root length (3.87 cm) was recorded in T_6 (no pesticides) that was statistically similar with others except T_1 (2.51). On the contrary, the lowest root length (2.51) was found in T_1 (no management) which was statistically similar with others except T_6.

At 60 DAS, the highest root length (8.27) was also recorded in T_2 which was statistically similar with others except T_1 and T_5. While the minimum root length (4.82) was reported in T_1 (no management) which was statistically different from other treatments except T_5 (5.28) (no irrigation). At harvest, the highest root length was observed in T_3 (7.82) which was statistically similar with others except T_5 and T_1. Whereas the lowest root (4.39) was found in T_1 which was statistically dissimilar with other except T_5. From the above discussion, it may conclude that with complete management gave higher root length compared to no agronomic managements.

Table 6. Effect of agronomic managements on root length plant^{-1} of quinoa at different studied durations

Treatment	Root length (cm) plant^{-1} at		
	30DAS	60DAS	Harvest
T_1	2.51b	4.82b	4.39b
T_2	3.32ab	8.27a	7.44a
T_3	3.33ab	8.17a	7.82a
T_4	2.89ab	7.70a	7.24a
T_5	3.34ab	5.28b	5.01b
T_6	3.87a	7.29a	6.97a
T_7	3.15ab	7.52a	7.05a
$LSD_{(0.05)}$	1.145	1.666	1.816
CV(%)	20.11	13.37	15.55

T_1: Control (no management), T_2: No weeding but all other managements, T_3: No fertilizer but all other managements, T_4: No thinning but all other managements, T_5: No irrigation but all other managements, T_6: No pesticides but all other managements and T_7: Complete management

4.7 Shoot length plant^{-1}

Different agronomic managements showed statistically significant variation on shoot length at 30, 60 DAS and at harvest (Table 7 and Appendix XI). At 30 DAS, maximum shoot length were recorded in T_2 (15.54 cm) which was statistically similar with others except T_1 and T_3. On the other hand, the minimum shoot length plant^{-1} (11.21 cm) were counted in T_1 (No management) that was statistically similar with T_3 and T_5.

At 60 DAS, the highest shoot length (41.48 cm) was recorded in T_4 (no thinning) which was statistically similar with others except T_3 and T_5. The next highest shoot length was measured in T_3 (33.10 cm) that was statistically dissimilar from others this was followed by T_5 (19.20 cm) which also statistically dissimilar from others. Whereas the lowest shoot length (15.59 cm) was recorded in T_1 which was statistically significant with others. The T_5 treatment showed 53.71% the lower shoot length production compared to T_4 due to no irrigation. At harvest, the maximum shoot length (48.27 cm) was reported in T_2 (no weeding) which was statistically non-significant with T_7 (complete management) and T_6 (no pesticide). The next maximum shoot length (44.64 cm) was recorded in T_4 (no thinning) that was also statistically different from others. The next highest shoot length (36.83 cm) was recorded from T_3 (no fertilizer) which was statistically different from others. On the contrary, the minimum shoot length (18.83 cm) was also counted in T_1 (no management) that was statistically different to others. The second minimum shoot length (24.07 cm) was reported in T_5 (no irrigation) which was statistically dissimilar with others.

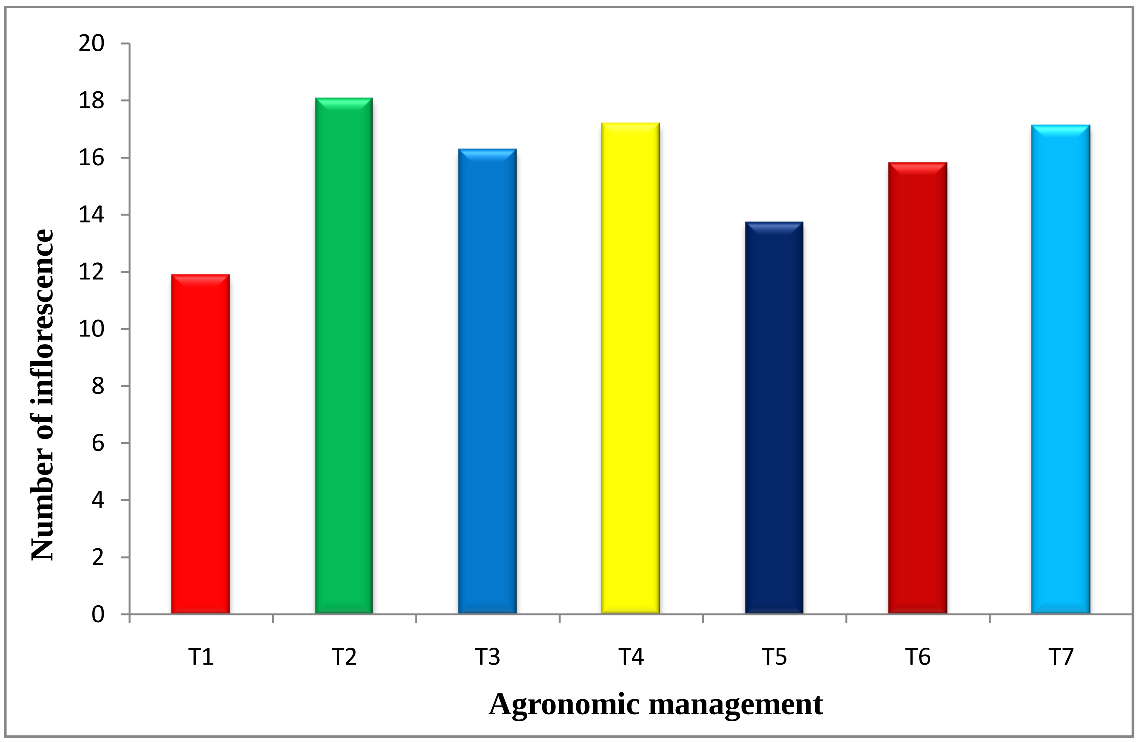
Table 7. Effect of agronomic managements on shoot length plant^{-1}of quinoa at different studied durations

Treatment	Shoot length (cm) plant^{-1} at		
	30 DAS	**60 DAS**	**Harvest**
T_1	11.21c	15.59d	18.83e
T_2	15.54a	41.31a	48.27a
T_3	12.43bc	33.10b	36.83c
T_4	14.05ab	41.48a	44.64b
T_5	13.38abc	19.20c	24.07d
T_6	14.91a	40.99a	46.68ab
T_7	13.81ab	41.28a	46.28ab
$LSD_{(0.05)}$	2.464	1.811	3.552
CV(%)	10.17	3.06	5.26

T_1: Control (no management), T_2: No weeding but all other managements, T_3: No fertilizer but all other managements, T_4: No thinning but all other managements, T_5: No irrigation but all other managements, T_6: No pesticides but all other managements and T_7: Complete management

4.8 Number of effective inflorescence plant^{-1}

Different agronomic managements showed non-significant differences on number of effective inflorescence plants^{-1}at different growth stages (Figure 1 and Appendix XII). At harvest, the numerically maximum number of effective inflorescence was recorded in T_2 (18.07) which was statistically insignificant with others. Numerically the second maximum value was observed in T_4 (17.20) that was statistically insignificant with others. While the minimum number of inflorescence (11.87) was measured in T_1 which was statistically similar with others.

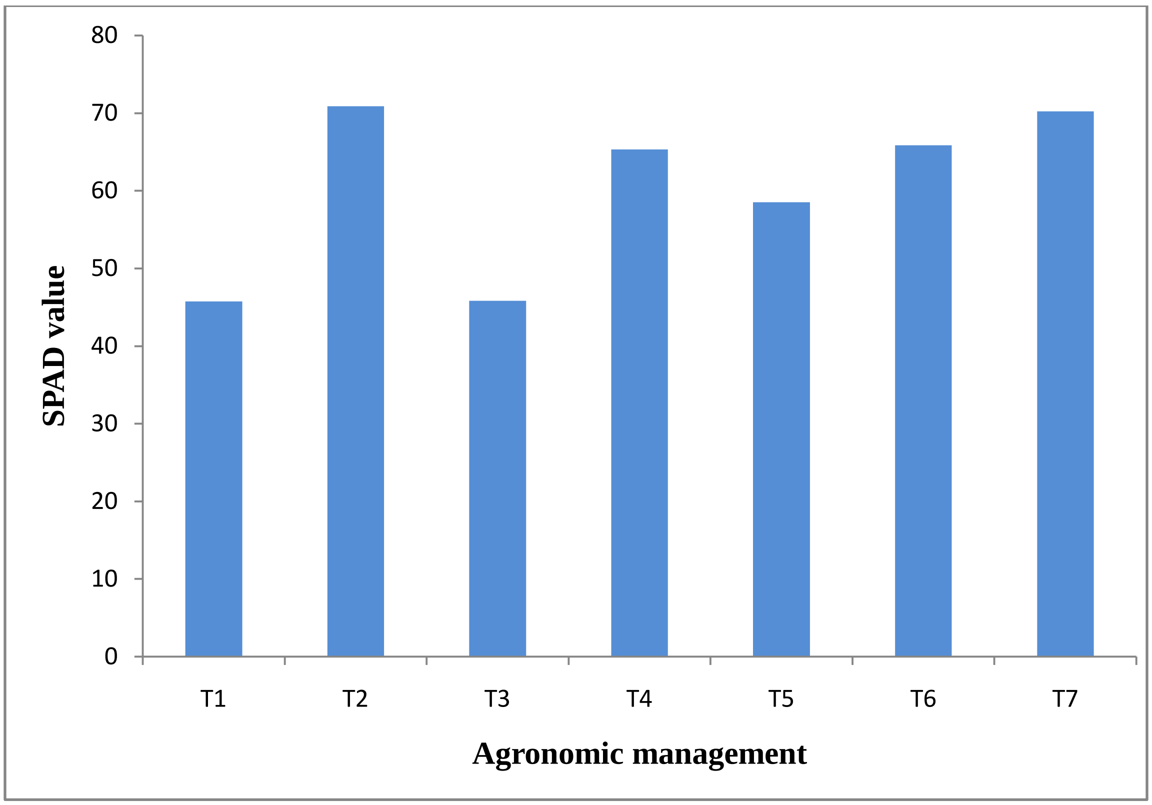


T_1: Control (no management), T_2: No weeding but all other managements, T_3: No fertilizer but all other managements, T_4: No thinning but all other managements, T_5: No irrigation but all other managements, T_6: No pesticides but all other managements and T_7: Complete management

Figure 1. Number of effective Inflorescence plant^{-1}of quinoa as influenced by agronomic managements.

4.9 SPAD value

Different agronomic managements showed significant differences on SPAD value of chlorophyll content in leaf at different growth stages (Figure 2 and Appendix XII). At 40 DAS, the highest SPAD value was recorded in T_2 (70.89) which was statistically insignificant with T_7. The second highest value was observed in T_6 (65.87) that was statistically insignificant with T_4 (65.33), T_5 (58.52). Hakim *et al*. (2013) mentioned that the chlorophyll content (SPAD value) was decreased with increasing the duration of weed interference period. While the lowest SPAD value was measured in T_1 which was statistically dissimilar to others. The lowest SPAD value (45.75) and (45.82) was recorded in T_1 and T_3, respectively and they were statistically significant with others.

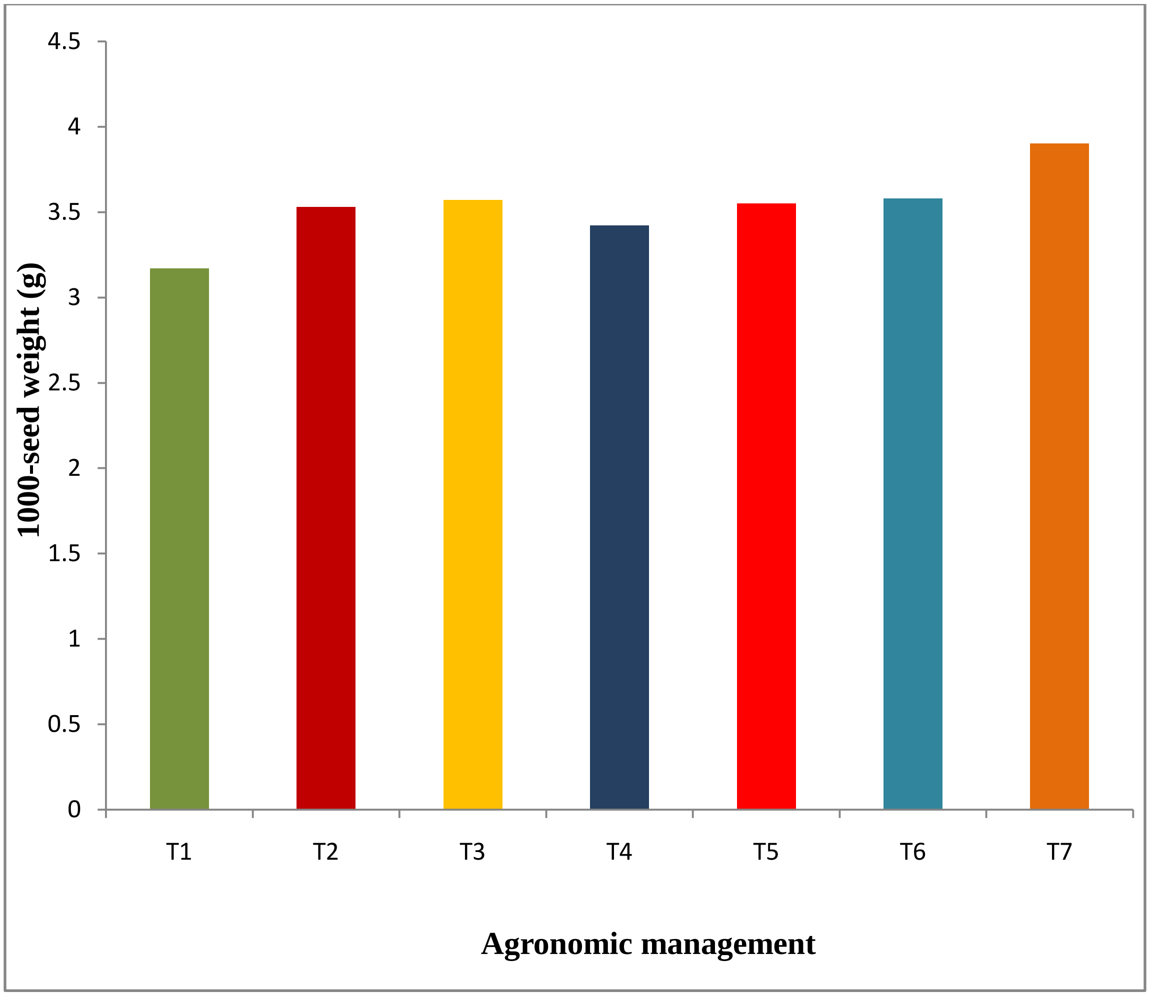


T_1: Control (no management), T_2: No weeding but all other managements, T_3: No fertilizer but all other managements, T_4: No thinning but all other managements, T_5: No irrigation but all other managements, T_6: No pesticides but all other managements and T_7: Complete management

Figure 2. SPAD value of quinoa as influenced by agronomic managements ($LSD_{(0.05)}$= 10.758) .

4.10 1000-seed weight

Weight of 1000-grain was varied statistically by the effects of different agronomic managements and it was ranged from 3.90 g to 3.17 g (Figure 3 and Appendix XIII). The highest 1000-seed weight (3.90 g) was measured in T_7 (complete management) which was statistically significant with others. The second highest 1000-seed weight was weighted from T_6 (3.58 g) that was also statistically insignificant with others except T_1 and T_4 .Dissimilar result was reported by Begum *et al.* (2017) who observed that weight of 1000-seed was varied significantly by infestation of pests. Kaur *et al.* (2018) found that weed free field was performed higher 1000-seed weight and enhanced the yield up to 43.1% over weedy check. The third maximum 1000-seed weight (3.42 g) was recorded in T_4 that was statistically similar with others except T_1 and T_7. Whereas, the lowest 1000-seed weight was recorded from T_1 (3.17 g) which was statistically dissimilar from other treatments except T_4.



T_1: Control (no management), T_2: No weeding but all other managements, T_3: No fertilizer but all other managements, T_4: No thinning but all other managements, T_5: No irrigation but all other managements, T_6: No pesticides but all other managements and T_7: Complete management

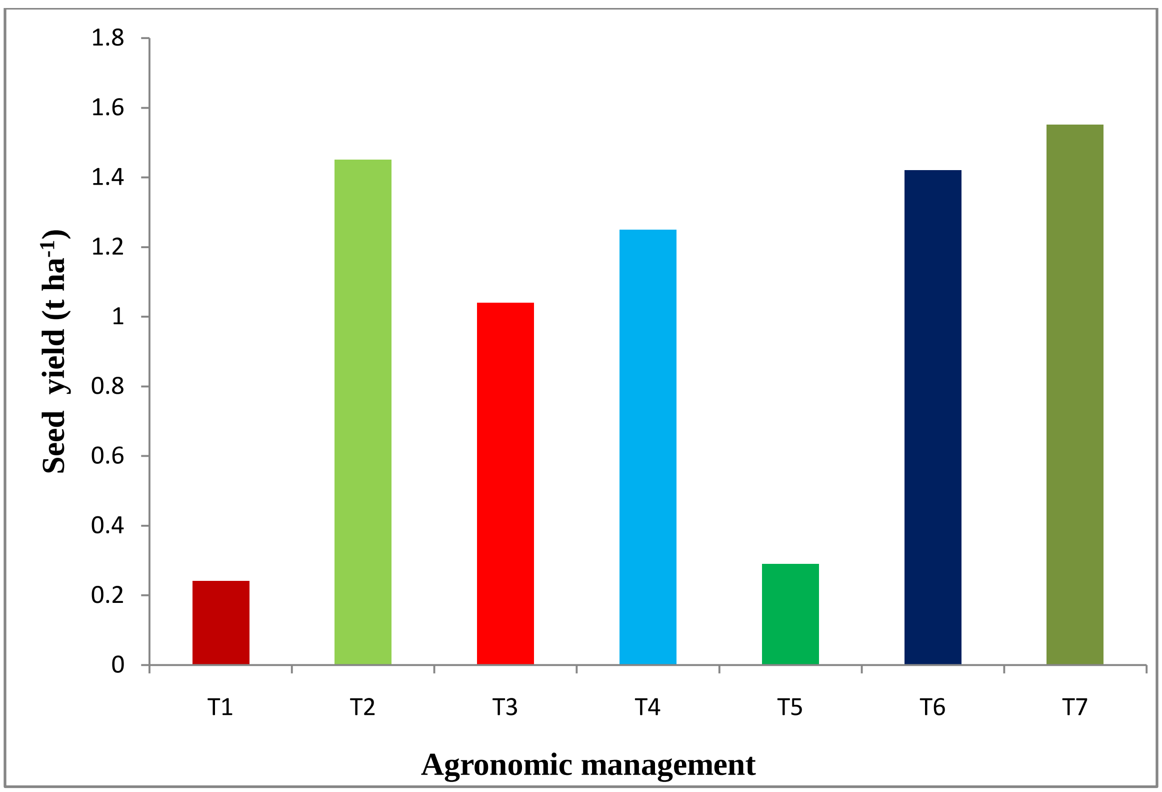
Figure 3. 1000 seed weight of quinoa as influenced by agronomic managements ($LSD_{(0.05)}$= 0.305) .

4.11 Seed yield

Different agronomic managements showed a statistically significant differences on grain yield of quinoa and it was ranged from 0.25 t ha^{-1} to 1.55 t ha^{-1} (Figure 5 and Appendix XIII). The highest seed yield (1.55 t ha^{-1}) was obtained from T_7 plot which was statistically similar with T_2 (1.45 t ha^{-1}) and T_6 (1.42t ha^{-1}). The next highest seed yield was observed in T_4 (1.25 t ha^{-1}) and it was statistically similar with T_6 (1.42t ha^{-1}). But the outcomes were contrary to the concept of Yang *et al*. (2019) and Dai *et al*.

(2014). They found that increasing planting density from 135 to 405 plants m^{-2} has been shown to significantly increase grain yield.

The T_6 treatment was decreased seed yield by 8.39% compared to T_7 because of no pest management. Duyn (2005) reported that yield reductions of 10 to 20% are typical in infested commercial fields of quinoa by pests. The next highest grain yield (1.04 t ha^{-1}) was measured from T_3 treatment which was statistically significant with others and it reduced yield by 32.90% compared to T_7 treatment by the influence of no fertilizer management.Whereas, the lowest grain yield (0.24t ha^{-1}) was found in T_1 which was statistically similar with T_5 (0.29 t ha^{-1}). The T_5 treatment showed lowest seed yield except T_1 due to no irrigation. The result agreed with the findings of Uddin *et al.* (2016). They reported that about 30% of quinoa production was lost due to lack of irrigation water. Chouhan *et al*. (2015) also observed that a slightly reduction of 10.8% in the grain yield of quinoa because of severe water deficit during the growing stages.

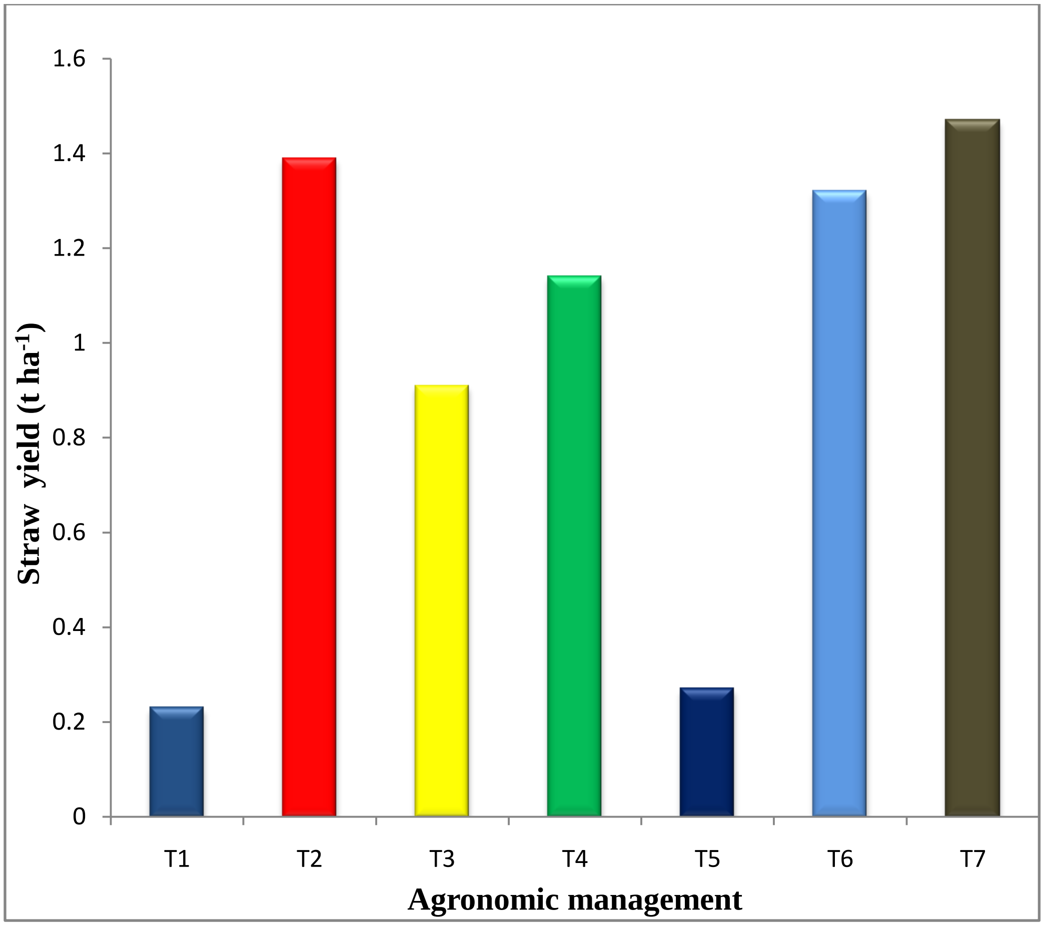


T_1: Control (no management), T_2: No weeding but all other managements, T_3: No fertilizer but all other managements, T_4: No thinning but all other managements, T_5: No irrigation but all other managements, T_6: No pesticides but all other managements and T_7: Complete management

Figure 4. Seed yield of quinoa as influenced by agronomic managements ($LSD_{(0.05)}$= 0.199) .

4.12 Straw yield

Agronomic management practices showed a statistically significant variation on straw yield of quinoa and it was ranged from 0.23 t ha^{-1} to 1.47 t ha^{-1} (Fig. 6 and Appendix XIII). The highest straw yield was obtained from T_7 (1.47 t ha^{-1}) followed by T_2 (1.39 t ha^{-1}) but they showed similarity statistically. The T_6 treatment showed 3.40% lower straw yield compared to T_7 because of no pest management. Similar result was also found by Larsson (2005) who revealed that grain and straw weight losses was about 5-7% in mildly damaged grain by pest. The next highest straw yield (1.14 t ha^{-1}) was recorded in T_4which was statistically different from others. The T_4 treatment performed 22.44% lower straw yield compared to T_7 due to no thinning. But the outcome was contrary to the findings of Begum *et al*. (2017) and Roy (2007). They announced that higher number of plants $meter^{-2}$was performed higher straw yield. And next highest straw yield was recorded in T_3 (0.91 t ha^{-1}) that was statistically different from other treatments and it decreased straw yield by 38.09% compared to T_7 due to no fertilizer managements. The lowest straw yield was observed in T_1 (0.23 t ha^{-1}) that statistically similar with T_5 (0.27t ha^{-1}). This result coincided with the findings of Kaur *et al.* (2018), Singh (2014) and Sultana *et al.* (2012) who observed that lower grain and straw yield was produced with weedy check.

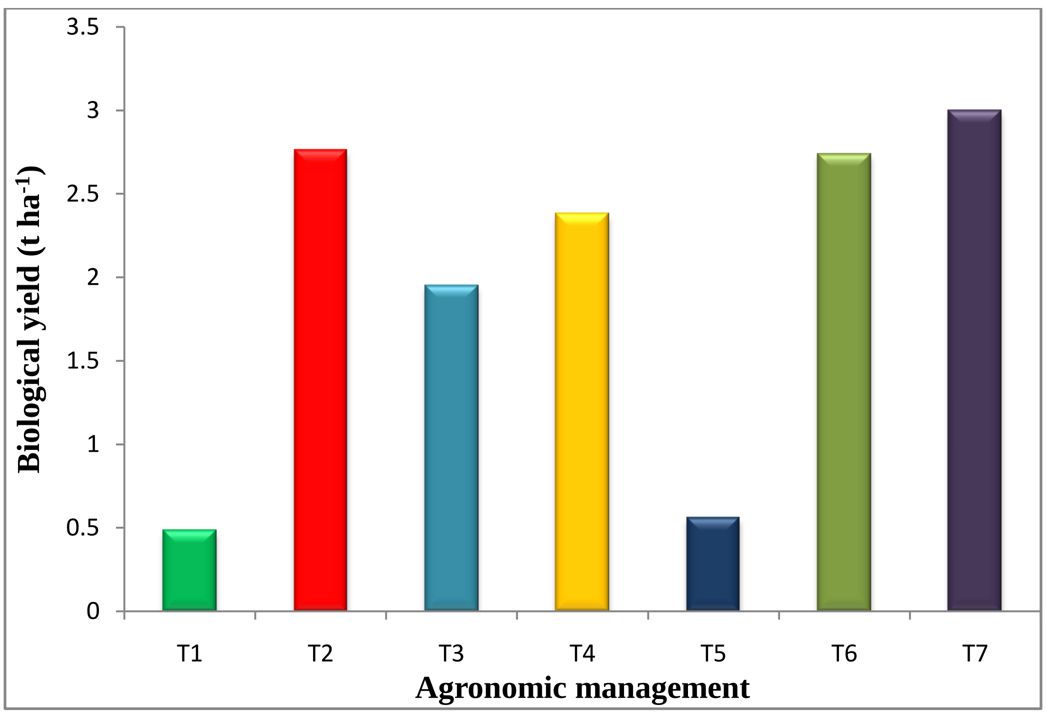


T_1: Control (no management), T_2: No weeding but all other managements, T_3: No fertilizer but all other managements, T_4: No thinning but all other managements, T_5: No irrigation but all other managements, T_6: No pesticides but all other managements and T_7: Complete management

Figure 5. Straw yield of quinoa as influenced by agronomic managements ($LSD_{(0.05)}$= 0.208)

4.13 Biological yield

Statistically significant variation was observed on biological yield by the influence of different types of agronomic management (Figure 7 and Appendix XIII). The biological yield was varied from 0.48 t ha^{-1} to 3.00 t ha^{-1}. The highest biological yield (3.00 t ha^{-1}) was obtained from T_7 which was statistically similar with T_6 (2.74 t ha^{-1}) and T_2 (2.76 t ha^{-1}). The next highest biological yield was recorded from T_4 (2.38 t ha^{-1}) that was statistically similar with T_6 (2.74 t ha^{-1}) and T_2 (2.76 t ha^{-1}). The treatment T_4 decreased biological yield by 20.66% compared to T_7 because of no thinning operation. This was contradictory to the findings of Begum *et al.* (2017) and Roy (2007), who opined that biological yield was increased with maximum plant density. The next highest biological yield (1.95 t ha^{-1}) was noted from T_3 which showed statistically dissimilarity with othersand it was decreased biological yield by 35.00% compared to T_7 for the reason of no fertilizer application. Kumar *et al.* (2018), Khan *et al.* (2014) and Gul *et al*. (2011) also found similar findings. No weed management reduced 8.00% biological yield as compared to complete management of M_7. Sujoy *et al.* (2006) also found similar outcomes. They found that biological yield was decreased with the increasing of weed infestation and period. While the lowest biological yield (0.48 t ha^{-1}) was recorded in T_1 which was statistically similar with T_5 (0.56 t ha^{-1}). The treatment T_5 (no irrigation but all other management) reduced biological yield drastically compared to other treatments except T_1. Islam *et al.* (2018), Islam *et al*. (2015), Kabir *et al.* (2009) and Gupta *et al*. (2001) found similar results and showed that biological yield increased significantly with irrigation.

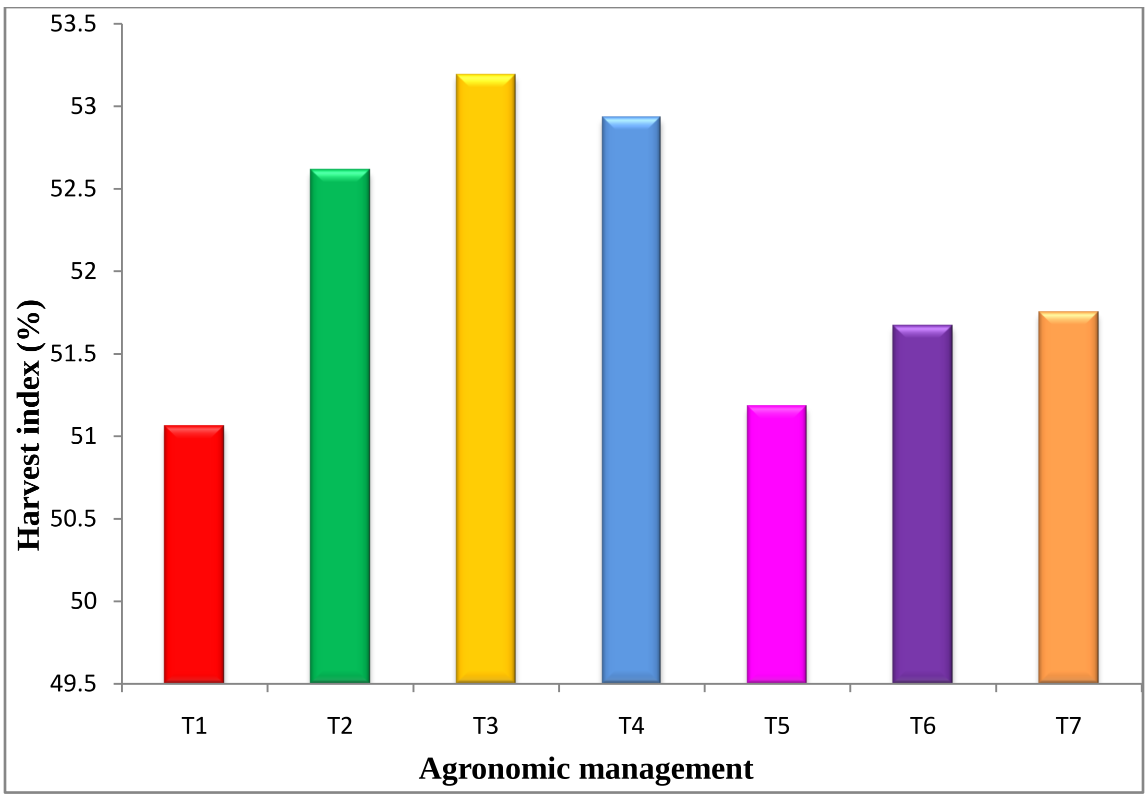


T_1: Control (no management), T_2: No weeding but all other managements, T_3: No fertilizer but all other managements, T_4: No thinning but all other managements, T_5: No irrigation but all other managements, T_6: No pesticides but all other managements and T_7: Complete management

Figure 6. Biological yield of quinoa as influenced by agronomic managements ($LSD_{(0.05)}$= 0.400)

4.14 Harvest index

Different agronomic managements showed statistically significant variations on harvest index and it was ranged from 51.06% to 53.19% (Figure 8 and Appendix XIII). The highest harvest index (53.19%) was obtained from T_3 treatment they were statistically similar with others except T_1 (51.06%)and T_5 (51.18%).The T_4 treatment performed higher harvest index after T_3 but this finding was contrary to results of Mustari *et al.* (2014), Sultana (2009), Hossain (2008) and Sujoy *et al.* (2006). They found maximum harvest index in fully weed managed field. The next maximum harvest index (51.18%) was recorded in T_5 which was statistically significant with others except T_3. The T_5 treatment showed 3.93% lower harvest index compared to T_3 treatment because of no irrigation operation. Similar findings were also found by Islam *et al*. (2018), Islam *et al*. (2015) and Ngwako and Mashiqa (2013).



T_1: Control (no management), T_2: No weeding but all other managements, T_3: No fertilizer but all other managements, T_4: No thinning but all other managements, T_5: No irrigation but all other managements, T_6: No pesticides but all other managements and T_7: Complete management

Figure 7. Harvest index of quinoa as influenced by agronomic managements ($LSD_{(0.05)}$= 1.898) .

On the contrary, the minimum harvest index (51.06%) was noted from T_1 that was statistically similar with others except $T_{3.}$ it decreased harvest index by 4.17% compared to T_3 for the reason of no management.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the research field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November, 2020 to March, 2021 to study the effects of different agronomic managements on growth and yield of quinoa. The experiment comprised of one factor. Factor A: Agronomic managements: 7 levels; No management (control)- T_1; No weeding but all other managements- $T_{2;}$ No fertilizer but all other managements- T_3;No thinning but all other managements- $T_{4;}$ No irrigation but all other managements- T_5; No pesticides but all other managements- T_6 and Complement management (recommended)- T_7. The experiment was laid out in RCBD design with three replications having agronomic managements in plots. Significant variation was recorded for data different growth and yield contributing characters and yield of quinoa.

Plant height was measured at 25, 40, 55, 70 DAS and harvest. By the influence of agronomic managements, the tallest plant (7.73, 21.53, 47.96, 50.62and 54.02 cm) was found in T_6 and T_2 while the shortest plant (6.26, 10.09, 13.98, 18.32 and 21.24 cm) in T_1 at 25, 40, 55 and 70 DAS and harvest, respectively.

Number of leaves plant^{-1} was counted at 25, 40, 55, 70 DAS and harvest. By the effects of agronomic managements, the highest number of leaves (11.0, 16.8, 21.13, 32.00 and 17.53) were observed in T_4, T_2, T_7 whereas the lowest (9.33, 10.73, 11.40, 14.20 and 9.27) in T_1, at 25, 40, 55, 70 DAS and harvest respectively.

Number of branch plant^{-1} was counted at 50, 70 DAS and harvest. By the effects of agronomic managements, the highest number of branch is (13.7, 17.67 and 19.60) were observed in T_7 whereas the lowest (3.57, 8.47 and 10.53) in T_1, at 50, 70 DAS and harvest respectively.

Fresh weight of plant was weighed at 30, 60 and harvest. By the effects of agronomic managements, the maximum fresh weight (2.87 g), (13.76g) and (7.08g) was recorded from T_7, while the minimum dry weight (1.15 g), (3.60 g) and (1.77 g) from T_1 at different stages.

Dry weight of plant was weighed at 30, 60 DAS and harvest. By the effects of agronomic managements, the maximum dry weight (0.13 g), (3.25 g) and (1.39 g) was recorded from T_7 and T_2, while the minimum dry weight (0.05 g), (0.50 g) and (0.14 g) from T_1 at different stages.

Root length of plant was measured at 30, 60 DAS and harvest. By the effects of agronomic managements, the maximum root length (3.87, 8.27 and 7.44 cm) was recorded from T_6 and T_2, while the minimum root length (2.51, 4.82 and 4.39 cm) from T_1 at different stages.

Shoot length of plant was measured at 30, 60 DAS and harvest. By the effects of agronomic managements, the maximum sooth length (15.5, 41.48 and 48.27 cm) was recorded from T_2 and T_4, while the minimum sooth length (11.21, 15.59 and 18.83 cm) from T_1 at different stages.

Number of effective inflorescence plant^{-1} was counted at harvest. By the effects of agronomic managements, the maximum number of effective inflorescence (17.20) was recorded from T_4, while the minimum number of inflorescence (11.87) from T_1 at harvest.

SPAD value was measured at 50 DAS. By the effects of agronomic managements, the maximum SPAD value (70.89) was obtained from T_2, while the minimum (45.72) from T_1 at different growth stages.1000-seed weight was weighted at harvest. By the effects of agronomic managements, the maximum 1000-grain weight (3.90 g) was noted from T_7 while the minimum (3.17 g) from T_1.

Seed yield was weighted at harvest. By the effects of agronomic managements, the highest seed yield (1.55 t ha^{-1}) was found in T_7 while the lowest (0.24 t ha^{-1}) in T_1.Straw yield was weighted at harvest. The maximum straw yield (1.47 t ha^{-1}) was recorded in T_7 whereas the minimum (0.23 t ha^{-1}) in T_1 by the effects of agronomic managements

By the effects of agronomic managements, the highest biological yield (3.00 t ha^{-1}) was found in T_7 whereas the lowest (0.48 t ha^{-1}) in T_1. By the effects of agronomic managements, the maximum harvest index (53.19%) was found in T_3 while the minimum (51.06%) in T_1.

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

- ✓ The complete agronomic management showed maximum growth and yield of quinoa. No management reduced (84.52%) yield of quinoa that followed by no irrigation (81.29%), no fertilizer (32.90%), no thinning (13.35%), no weeding (6.45%), and no pesticide (5.41%) application compared to complete management.
- ✓ Irrigation considered as the most important yield limiting factor of quinoa that followed by fertilizer.

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

- ✓ Similar studies need to be conducted in different Agro-Ecological Zones (AEZ) of Bangladesh.
- ✓ More experiments may be carried out with other varieties and agronomic managements.

REFERENCES

Abdullah, A.M., Ono, E., Rodriguez, J.P., and Abdelaziz, H. (2020). Cultivation of Quinoa (*Chenopodium quinoa*) in Desert Ecoregion. *Emerg. in Alter.* Crops. 145-161.

Akhter, N., Rahman, M., Hasanuzzaman, M. and Nahar, K. (2009). Plant characters and seed yield of garden pea under different light intensity. *American-Eurasian J. Agron.* **2**(3):152-155.

Ali reza, R. and Emanuele (2020). How Do Intensification Practices Affect Weed Management and Yield in Quinoa (*Chenopodium quinoa* Willd.). **46**: 44121.

Ali, A., Choudhry, M.A., Malik, M.A., Ahmad, R. and Saifullah. (2011). Effect of various doses of nitrogen on the growth and yield of two wheat cultivar. *Pakistan J. Biol. Sci*. **3**(6): 1004-1005.

Ali, M.A.and Amin, S. (2007). Effect of irrigation frequencies on yield and yield attributes of wheat cultivar (*Triticum aestivum*) ‘Shatabdi’. Faisalabad, Pakistan: *Medwell Online. J. Food-Tech.* **2**(3): 145-147.

Alissie, E. and Onore, G. (1988). Ciclo biologico de *Copitarsia* sp. 2, Noctuido asociado a *Chenopodium quinoa* y lista de otros insectos perjudiciales. In: Memorias de VI Congreso internacional sobre cultivos Andinos, Quito, Ecuador, 95-98.

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.

Aroni, G. (2000). Manejo y produccion actual de quinua en Bolivia.

Asiimwe, P., Naranjo, S.E.and Ellsworth, P.C. (2014).Effects of irrigation levels on interactions among *Lygus hesperus* (Hemiptera: Miridae), insecticides, and predators in cotton.*Environ. Entomol*. **43**:263–273.

Atikullah, M.N. (2014). Effect of irrigation levels on growth, yield attributes and yield of wheat. *J. Biosci. Agric. Res*. **2**: 83-89.

Bàrberi, P., Cozzani, M. and Bonari, E. (2002). Size and composition of the weed seedbank under different management systems for continuous maize cropping. *Weed Res*. **38**: 319-334.

Bazile, D., Bertero, H.D.and Nieto, C.(2015). State of the Art Report on Quinoa Around the World in 2013. FAO and CIRAD. ;

Begum, F., Islam, M.N., Aminuzzaman, F.M. and Islam, M.R. (2017). Impact of seed infection level and plant density on the quality yield of wheat cv. Shatabdi. *Int. J. Expt. Agric.* **7**(3): 19-33.

Blanco, A. (1994). Umbral econo´mico de kcona kcona Eurysacca melanocampta (Lepidoptera, Gelechiidae) en quinua (*Chenopodium quinoa* Willd.). Ingeniero Agro´nomo, Thesis for Ingeniero Agronomo, UNA, Puno, Peru.

Blanco, M.C. (1982). Evaluacio´n de danos de Scrobipalpula sp. y Perisoma sp. en el cultivo de quinua en la zona del Cusco. In: III Congreso Internacional de Cultivos Andinos, La Paz, Bolivia, 133–135

Bosque Sanchez, H., Lemeur, R. and Van Damme, P. (2003). Análisis ecofisiológico del cultivo de la quínua (*Chenopodium quinoa* Willd.) en condiciones de estrés de la sequía y la salinidad. *Tropicultura*. **18**: 198-202.

Brevault, T. and Clouvel, P. (2019). Pest management: reconciling farming practices and natural regulations. *Crop Prot*. **115**: 1-6.

Caldero´n, R., Becerra, A. and Marquez, A. (1996). Expectativas del virus granulosis Phthorimaea operculella para el control de otros lepido´pteros. IV Reunio´n

Nacional de la Papa: Compendio de Exposiciones. Cochabamba, Bolivia: IBTA, pp. 107–108.

Chouhan, S.S., Awasthi, M.K. and Nema, R.K. (2015). Studies on water productivity and yields responses of wheat based on drip irrigation systems in clay loam. *Soil Indian J. Sci. Tech*. **8**(7):650-654.

Choukr-Allah, R., Rao, N.K., Hirich, A., Shahid, M., Alshankiti, A. Toderich, K., Gill, S. and Butt, K.U.R. (2016). Quinoa for Marginal Environments: Toward Future Food and Nutritional Security in MENA and Cenral Asia Regions. *Front. Plant* Sci. **7**: 1–11.

Claus,R., Aziz,L.,Peter,E. (2003) Advances in the knowledge of quinoa pests. Food reviews international. **19**(1-2): 61-75

Dai, X.L., Xiao, L.L., Jia, D.Y., Kong, H.B., Wang, Y.C., Li, C.X., Zhang, Y. and He, M.R. (2014). Increased plant density of winter wheat can enhance nitrogen uptake from deep soil. *Plant Soil*. **384**(1-2):141-152.

Delgado, A.I., Palacios, J.H. and Betancourt, G.C. (2009). Evaluation of 16 genotypes of sweet quinoa (Chenopodium quinoa Willd.) in the municipality lles, Narino (Colombia). **27**: 159-167.

Deng,Y., Juan-ling, W., Anwar, S., Zhao,L. and Li-guana, Z. (2021). Phenology, lodging and yield traits of *Chenopodium quinoa* under the effect of planting density and row spacings. *Fresnius Env. Bulletin*. **30**: 11757-11767.

Dent, D. (1995). Integrated pest Management. London: Chapman & Hall.

Duyn, J.V. (2005). Managing Insect Pests. **In**: Organically Certified Wheat. *North Carolina Cooperative Extn. Service*. p. 56.

EI-Gamal, B.A. and Hamed, M.A. (2020). Impact of organic and bio fertilizers on soil health and production of quinoa and soybean. *J. Agric. Res.* **9**: 828-847.

Eisa, S.S., Eid, M.A., Hussin, S.A., Ali, S.H. and EI-samad. (2017). *Chenopodium quinoa* Willd. A new cash crop halophyte for saline regions of Egypt. *Australian J. Crop Sci.* **11**: 343-351.

El youssfi, L., Choukr-Allah, R., Zaafrani, M., Mediouni, T., Ba Samba, M. and Hirich, A.(2012). Effect of domestic treated wastewater use on three varieties of Quinoa (*Chenopodium quinoa*) under semi arid conditions. *World Acad. Sci. Eng. Techn.* **68**: 306–309.

English, M. (1990). Deficit irrigation. I. Analytical framework. J. *Irrig. Drain E*. ASCE, **116**: 399-412.

Fghire, R., Anaya, F., Ali, O.I., Benlhabib, O., Ragab, R. and Wahbi, S. (2015). Physiological and photosynthetic response of quinoa to drought stress. *Chil. J. Agric. Res.* **75**: 174–183.

Galwey, N.W. (1993). The potential of quinoa as a multipurpose crop for agricultural diversification: a review. *Ind. Crops Prod.* **1**:101 – 106.

Garcia, G.A., Dreccer, M.F., Miralles, D.J. and Ser-rago, R.A. (2015). High night temperatures dur-inggrainnumberdeterminationreducewheat and barley grain yield: a field study. *Glob Chang Biol.* **21**(11): 4153-64.

Garcia, M., Raes, D. and Jacobsen, S.E. (2003). Evapotranspiration analysis and irrigation requirements of quinoa (*Chenopodium quinoa*) in the Bolivian highlands. *Agric. Water Mng.* **60**: 119-134.

Gawlik-Dziki, U.,Dziki, D.,Swieca, M. and Urszula, R.R. (2015). Bread enriched with *Chenopodium quinoa* leaves powder – The procedures for assessing the fortification efficiency. *LWT- F. Sci. Techno.* **62**: 1226-1234.

Geerts, S., Raes, D., Garcia, M., Condori, O., Mamani, J., Miranda, R., Cusicanqui, J., Taboada, C., Yucra, E. and Vacher, J. (2008). Could deficit irrigation be a sustainable practice for quinoa (*Chenopodium quinoa*Willd.) in the Southern Bolivian Altiplano? *Agric. Water Mng.* **95**: 909–917.

Geerts, S., Raes, D., Garcia, M., Del Castillo, C. and Buytaert, W. (2006). Agro-climatic suitability mapping for crop production in the Bolivian Altiplano: A case study for quinoa. *Agric. Forest Meteorol*. **139**: 399-412.

Geerts, S., Raes, D., Garcia, M., Vacher, J., Mamanib, R., Mendoza, J. and Taboada, C. (2008). Introducing deficit irrigation to stabilize yields of quinoa (*Chenopodium quinoa* Willd.). *Europ. J. Agron*. **28**: 427-436.

Geiger, F., Bengtsson, J., Berendse, F., Emmerson, M., Morales, M.B., Liira, J. and Winqvist, C. (2010). Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. *Basic Appl. Ecol*. **11**: 97-105.

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

Gimplinger, D.M., Schulte Auf' m Erley, G., Dobos, G. and Kaul, H.P.(2008). Optimum crop densities for potentialyield and harvestable yield of grain amaranth are conflicting. *Eur. J. Agron.* **28**: 119–125.

Gopinath, K., Saha, S., Mina,B., Pande, H., Kundu, S. and Gupta, H.(2008). Influence of organic amendments on growth, yield and quality of wheat and on soil properties during transition to organic production. *Nutr. Cycl. Agroecosys.* **82**: 51– 60.

Gul, H., Said, A., Saeed, B., Ahmad, I. and Ali, I.K. (2011). Response of yield and yield components of wheat towards foliar spray of nitrogen, potassium and zinc. *ARPNJ. Agric. Biol. Sci.* **6**(2): 23-25.

Gupta, P.K., Gautam, R.C. and Ramesh, C.R. (2001). Effect of water stress on different stages of wheat cultivation. *Plant Nutri. Fert. Sci*. **7**(2): 33-37.

Hakim, M.A., Juraimi, A.S., Musa, M.H., Ismail, M.R., Moshiur, R.M. and Selamat, A. (2013). Impacts of weed competition on plant characters and the critical period of weed control in rice under saline environment. *Agric. J. Crop Sci*. **7**(8):1141-1151.

Hartley, I.P., HopkinsD.W., Sommerkorn,M. and Wookey,P.A. (2010). The response of organic matter mineralisation to nutrient and substrate additions in sub-arctic soils. *Soil Biol. Biochem.* **42**: 92–100.

Hirich, A., Choukr-Allah, R., Jelloul, A. and Jacobsen, S.E. (2014). Quinoa (*Chenopodium quinoa* Willd.) seedling, water uptake and yield responses to irrigation water salinity. *Acta Hortic.* **1054**: 145–152.

Hirich, A., Jelloul, A., Choukr-Allah, R. and Jacobsen, S.E.(2014). Saline water irrigation of Quinoa and Chickpea: seedling rate, stomatal conductance and yield responses. J. *Agron. Crop. Sci.* **200**: 378–389.

Hossain, M.A. (2008). Performance of herbicide on weed suppression towards growth and yield of wheat. MS Thesis, SAU, Dhaka,Bangladesh.

Ibrahim, M., Hassan,A., Iqbal,M.and Valeem,E.E. (2008). Response of wheat growth and yield to various levels of compost and organic manure. *Pak. J. Bot.* **40**: 2135–2141.

Ioanna, K., Karkanis, A., Hela, D. and Travlos, I.S. (2015). Weed flora and seed yield in quinoa crop (*Chenopodium quinoa*Willd.) as affected by tillage systems and fertilization practices. *Int. J. Pest Mng.* **61**: 228-234.

Islam, S.T., Haque, M.Z., Hasan, M.M., Khan,A.B.M.M.M. and Shanta, U.K. (2018). Effect of different irrigation levels on the performance of wheat. *Prog. Agric.* **29**(2): 99-106.

Islam, S., Islam, M.S., Uddin,M.J., Mehraj, H. and Uddin, A.F.M.J. (2015). Growth and yield response of wheat to irrigation at different growing stages. *Int. J. Agron. Agric. Res.* **6**(1): 70-76.

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

Jacobsen, S.E. and Christiansen, J.L. (2016). Some agronomic strategies for organic Quinoa (*Chenopodium quinoa* Willd.). *J. Agron. Crop Sci.* **202**: 454-463.

Jacobsen,S.E., Jørgensen, I. and Stølen, O. (1994). Cultivation of quinoa (*Chenopodium quinoa*) under temperate climatic conditions in Denmark, *J. Agric. Sci.* **122**: 47-52.

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

Jensen, C.R., Jacobsen, S.E., Andersen, M.N. and Núńez, S.D. (2000). Leaf gas exchange and water relation characteristics of field quinoa (*Chenopodium quinoa* Willd.) during soil drying. *Eur. J. Agron*. **13**: 11-25.

Jesus, E., Delatorre-Herrera, J. and Rodriguez, J.P. (2021). Quinoa (*Chenopodium quinoa*Willd.) seed yield and efficiency in soils deficient of Nitrogen in the Bolivian Altiplano: An Analytical Review. *Plants*. **11**: 2479 .

Jorge, M., Albert, P., Susana, F. and Maria D., L. (2019).Critical period of weed interference on total polyphenol content in quinoa. *ChilliJ. Agric. Res.* **79**.

Kabir, N.A.M.E., Khan, A.R., Islam, M.A. and Haque, M.R. (2009). Effect of seed rate and irrigation level on the performance of wheat cv. Gourab. *J. Bangladesh Agril. Univ*. **7**(1):47-52.

Kaur, E., Sharma, R. and Singh, N.D. (2018). Efficacy of pre-emergence and post-emergence herbicides on weed control and yield in wheat. *Int. J. Curr. Microbiol. Appl. Sci.* **7**(2):883-887.

Khan,A.A., Inamullah and Jan, M.T. (2014). Impact of various nitrogen and potassium levels and application methods on grain yield and yield attributes of wheat. *Sarhad J. Agric.* **30**(1): 35-46.

Klikocka, H., Cybulska, M., Barczak, B., Narolski, B., Szostak, B., Kobialka, A., Nowak, A. and Wojcik, E. (2016). The effect of sulfur and nitrogen fertilization on grain yield and technological quality of spring wheat. *Plant Soil Environ*. **62**(5): 230-236.

Koyro, H.W. and Eisa, S.S. (2008). Effect of salinity on composition, viability and germination of seeds of *Chenopodium quinoa* Willd. *Plant Soil*. **302**: 79-90.

Kumar, S., Bishnoi,S.D.K., Kumar, N. and Dhillion, A. (2018). Effect of integrated nutrient management on yield and yield attributes and economics of wheat (*Triticum aestivum* L.) under saline and non-saline irrigation water. *Int. J. Curr. Microbiol. Appl. Sci.* **7**(5): 618-628.

Larsson, H. (2005). Economic damage by *Limothrips denticornis* in rye, triticale and winter barley. *J. Appl. Entom.* **129**: 386-392.

Louis, N., Amidou, G., Abdou, G. and Jacob, S. (2020). Biplot analysis of test environments of quinoa (*Chenopodium quinoa* Willd.) in Burkina Faso. *African J.Plant Sci.* **14**: 358-371.

Mahmud, M.H. (2017). Growth and yield of *Aus* rice as affected by agronomic managements. MS Thesis, Dept. of Agronomy, SAU, Dhaka, Bangladesh.

Matiacevich, S.B., Castellión, M.L., Maldonado, S.B. and Buera, M.P. (2006). Water-dependent thermal transitions in quinoa embryos. *Thermochimica Acta*. **448**: 117–122.

Meng, C.B., Wang, F.X., Engel, B.A., Yang, K.J. and Zhang, Y.L. (2019). Is cattle manure application with plastic-filmmulch a good choice for potato production? *Agron.* **9**: 534.

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**: 135–145.

Moses, F.A., Gardner, M., Jessica, R. and Murphy, K.M. (2019). Assessing the potential adoption of quinoa for human consumption in central Malawi. *Front. Sust. Food Sys.* **3**: 52.

Mujica, A. (1993). Cultivo de Quinoa. Lima: INIA.

Mujica, A., Jacobsen, S-E., Bertero, D. and Gonzalez, J. (2000). Un recorrido por el nor oeste Argentina buscando quinua. In: Jacobsen, S.-E., Portillo, Z., eds. Primer Taller Internacional sobre Quinua - Recursos Gene´ticos y Sistemas de Produccio´n, 10–14 May, 1999. 1999. Peru: UNALM, In press.

Mustari, S., Bari, M.N., Islam, M.R. and Karim, A.J.M.S. (2014).Evaluation of selected herbicidesonweedcontrolefficiency andyieldof wheat. *J. Sci. Foundation.* **12**(2): 27-33.

Ngwako, S. and Mashiqa, P.K. (2013). The effect of irrigation on the growth and yield of winter wheat (*Triticum aestivum* L.) cultivars. *Int. J. Agric. Crop Sci*. **5**(9): 976-982.

Orellano, H. and Tillmann, H.J. (1984). La quinua en Yanamarca, prov. de Jauja. Boletı´n de Lima. **35**:55–64.

Ouedraogo, E., Mando, A. and Zombre,N. (2001). Use of compost to improve soil properties and crop productivity under low input agricultural system in West Africa. *Agr. Ecosys. Environ*. **84**: 259–266.

Pa´sko, P., Barto ´n, H., Zagrodzki, P., Gorinstein, S., Fołta, M. and Zachwieja, Z. (2009). Anthocyanins, total polyphenols and antioxidant activity in amaranth and quinoa seeds and sprouts during their growth. *Food Chem*. **115**: 994–998.

Page, A.L., Miller, R.H. and Keeney, D.R. (Eds.). (1982). Methods of Soil Analysis: Part 2, Chemical and Microbiological Properties. Gronomy Series No 9. American Society of Agronomy, Madison, WI.

Panayiota, P., Kakabouki, I. and Dimitra, D.B. (2014). Effects of fertilization on yield and quality of biomass of quinoa (*Chenopodium quinoa*Willd.) and green amaranth (*Amaranthus retroflexus* L.). Bulletin UASVM Horticulture. **71**: 287-292.

Parr, J., Papendick,R., Hornick,S. and Colacicco,D. (1989). Use of organic amendments for increasing the productivity of arid lands. *Arid Land Res. Mng*. **3**: 149–170.

Pathan, S., Eivazi, F., Valliyodan, B., Paul, K., Ndunguru, G. and Clark, K. (2019). Nutritional Composition of the Green Leaves of Quinoa (*Chenopodium quinoa* Willd.). *J. Food Res*. **8**: 55.

Pedigo, L.P. and Rise, M.E. (2009). Entomology and pest management. Waveland Press, Inc., Long Grove, IL.

Rachid, F., Said, W., Fatima, A., Oudou, I.A., Ouafae, B. and Ragab, R. (2015). Response of quinoa to different water management strategies: Field experiments and Saltmed model application results. *Irrig. Drain*. **64**:232–238.

Razzaghi, F., Ahmadi, S.H., Jacobsen, S.E., Jensen, C.R. and Andersen, M.N.(2012a). Effects of salinity and soil-drying on radiation use efficiency, water productivity and yield of quinoa (*Chenopodium quinoa* Willd*.). J. Agro. Crop Sci*. **198**: 173–184.

Razzaghi, F., Plauborg, F., Jacobsen, S., Jensen, C.R. and Andersen, M.N. (2020). Effect of nitrogen and water availability of three soil types on yield, radiation use efficiency and evapotranspiration in field-grown quinoa. *Agric. Water Mngt*. **109**: 20-29.

Rezzouk, F.Z., Shahid, M.A., Zhou, B. and Elouafi, I.A. (2020). Agronomic performance of irrigated quinoa in desert areas: Comparing different approaches for early assessment of salinity stress**.** *Agric. Water Mngt.* **240**: 106205.

Risi, J. and Galwey, N.W. (1991). Effects of sowing date and sowing rate on plant development and grain yield ofquinoa (*Chenopodium quinoa*) in a temperate environment. *J. Agr. Sci.* **117**: 325–332.

Roy, J. (2007). Effect of sowing depth and population density on yield attributes and yield of wheat.MS Thesis, Dept. of Agronomy, SAU, Dhaka, Bangladesh.

Safdar, M., Tanveer, A., Khaliq, A. and Maqbool, R. (2016). Critical competition period of parthenium weed (*Parthenium hysterophorus* L.) in maize. *Crop Protec.* **80**:101-107.

Schulte Auf' m Erley, G., Kaul, H.P., Kruse, M. and Aufhammer, W.(2005). Yield and nitrogen utilization efficiency ofthe pseudocereals amaranth, quinoa, and buckwheat under differing nitrogen fertilization. *Eur. J. Agron.* **22**: 95–100.

Singh, M., Kumar, R., Kumar, S. and Kumar, V. (2016). Critical period for weed control in field pea. *Legume Res.* **39**(1):86-90.

Singh, R. (2014). Evaluation of different herbicides with NPK on growth and yield of wheat (*Triticum aestivum* L.) in field trial of Aligarh soil, *Int. J. Sci. Res*. **3**(9):110-147.

Spehar, C.R. and Rocha, J.E.D.S. (2009). Effect of sowing density on plant growth and development of quinoa,genotype 4.5, in the Brazilian Savannah highlands. *Biosci.J*. **25**:53–58.

Sujoy, D., Sarkar, A.K., Bhattacharya, S.P. and Abhijit, S. (2006). Effect of various weed management practices in wheat.*Environ.Ecol.* **24**(3): 620-622.

Sultana, M.R., Alim, M.A., Hossain, M.B., Karmaker, S. and Islam, M.S. (2012). Effect of variety and weed management practices on yield and yield attributes of wheat. *J.Environ. Sci.Nat.Res.* **5**(2): 91-96.

Sultana, S. (2009). Influence of nitrogen level and weeding on the performance of wheat. MS Thesis, Dept. of Agronomy, SAU, Dhaka, Bangladesh.

Suresh, N.,Paramesh,R.,Siddaraju,R., RaviShankar, P. and Mudalagiriyappa. (2019). Studiesongrowthparametersinquinoa(*Chenopodiumquinoa*Willd.). *Int. J. Chem. Stud*. **8**(1):393-397.

Talebnejad, R. and Sepaskhan, A.R. (2015). Effect of deficit irrigation and different saline groundwater depths on yield and water productivity of quinoa. *Agric.Water Mngt*. **159**: 225-238.

Talebnejad, R. and Sepaskhan, A.R. (2015). Effect of different saline groundwater depth and irrigation water salinities on yield and water use of quinoa in lysimeter. *Agric.Water Mngt*. **148**: 177-188.

Tang, Y. and Tsao, R. (2017). Phytochemicals in quinoa and amaranth grains and their antioxidant, anti-inflammatory, and potential health beneficial effects. A review. *Mol. Nutr. Food Res*. **61**: 1–16.

Tapia, M. (1997). Cultivos Andinos Subexplotados y su Aporte a la Alimentos, 30. Santiago, Chile: Oficina Regional de la FAO para America Latina y el Caribe.

Uddin, N., Islam, M.A. and Baten, M.A. (2016). Heavy metal determination of brinjal cultivated in Soil with wastes. *Prog. Agric*. **27**(4):453- 465.

Valencia-Chamorro, S.A. (2003). Quinoa. In: Caballero B.: Encyclopedia of Food Science and Nutrition. Vol. **8**. Academic Press, Amsterdam: 4895–4902.

Van Gaelen, H., Tsegay, A., Delbecque, N., Shretha, N., Garcia, M., Fajardo, H., Miranda, R., Vanuyrecht, E., Abrha, B.and Raes, D. (2015) A semi-quantitative approach for modelling crop response to soil fertility:Evaluation of the AquaCrop procedure. *J. Agric. SC*. **153**: 1218–1233.

Vilche, C., Gely, M. and Santalla, E. (1978). Physical properties of quinoa seeds. *Biosys. Eng*. **86**: 59–65

Villanueva, S. Determinacio´n del "Umbral econo´mico" y "nivel critico" de "Kcona kcona" (Scrobipalpula sp.) en quinua (*Chenopodium quinua* Willd.) Thesis, Puno (Peru) UNA, Thesis for Ingeniero Agronomo, UNA, Puno, Peru.

Walter Valdivia-Cea, Luis Bustamante, Jorge Jara, Susana Fischer and Rosemarie. (2021). Effect of soil water availability on physiological parameters, yield, and seed quality in four quinoa genotypes (*Chenopodium quinoa* Willd.). *Agron.* **11**.

Wang, D., Kang, Y.H. and Wan, S.Q. (2007). Effect of soil matric potential on tomato yield and water use under drip irrigation condition. *Agric. Water Mngt.* **87**: 180–186.

Wang, F.X., Wu, X.X., Shock, C.C., Chu, L.Y., Gu, X.X. and Xue, X. (2011). Effects of drip irrigation regimes on potato tuber yield and quality under plastic mulch in arid northwestern China. *Field Crops Res.* **122**: 78–84.

Yang, D., Cai, T., Luo, Y. and Wang, Z. (2019). Optimizing plant density and nitrogen application to manipulate tiller growth and increase grain yield and nitrogen-use efficiency in winter wheat. *PeerJ*. **7**: 64-84.

Yang, K.J., Wang, F.X., Shock, C.C., Kang, S.Z., Huo, Z.L., Song, N. and Ma, D. (2017). Potato performance as influenced by the proportion of wetted soil volume and nitrogen under drip irrigation with plastic mulch. *Agric. Water Mngt*. **179**: 260–270.

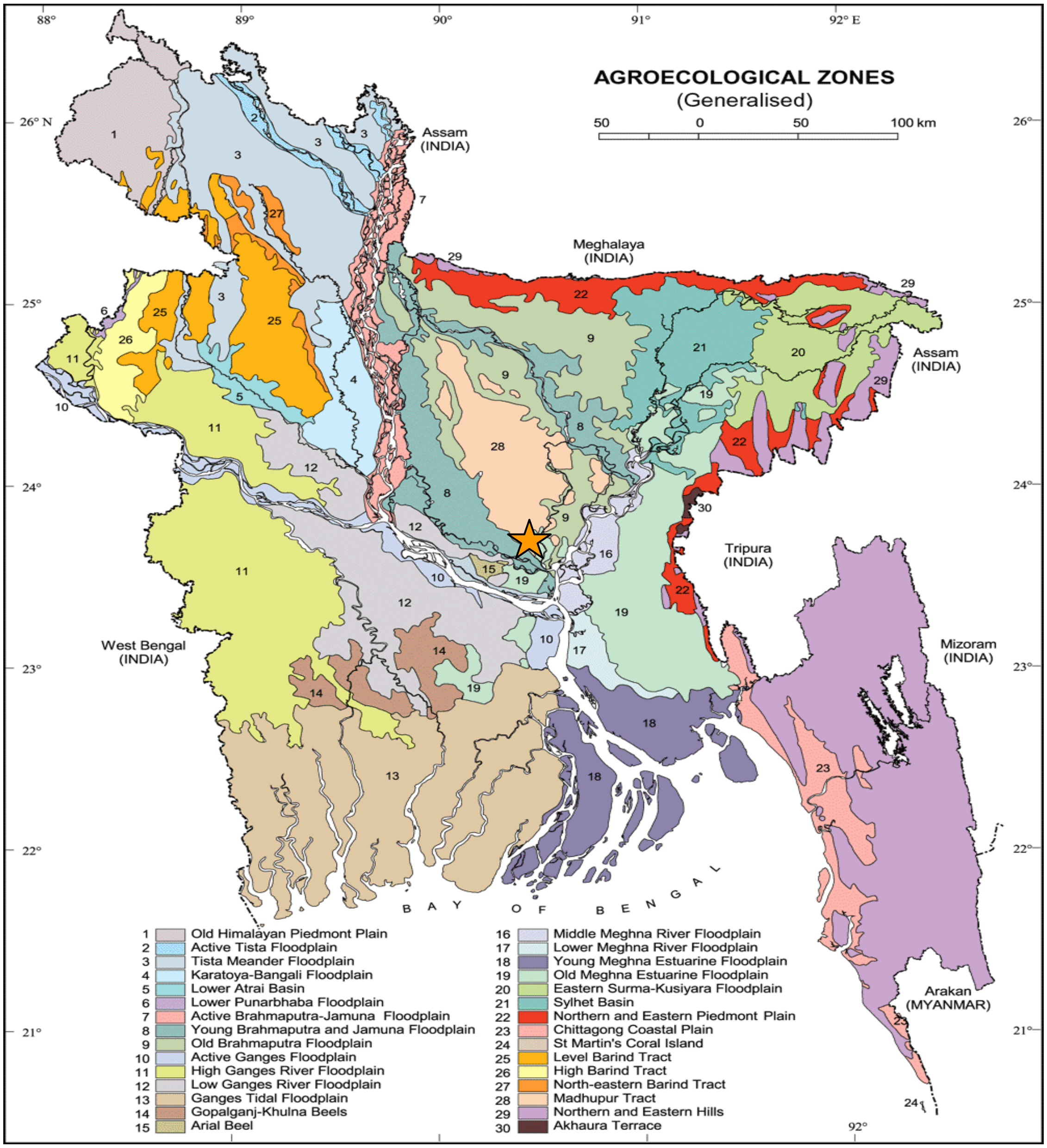
Youssef, M.A. and Ibrahim, M. (2021). Co-application of organic manure and bio-fertilizer to improve soil fertility and production of quinoa and proceeding Jew's mallow crops. *J. Soil Sci. Plant Nutr*. **21**: 2472-2488.

Zanabria, E. and Banegas, M. (1997). Entomologı´a Economica Sostenible. Puno: UNAP.

Zedan, M., Sobh, M. and Ewis, A. (2021). Quinoa-yield and its component as affected by N fertilization, bio-fertilizer and micronutrients fertilization in calcareous soil. *J. Product.Dev*. **26**: 865-885.

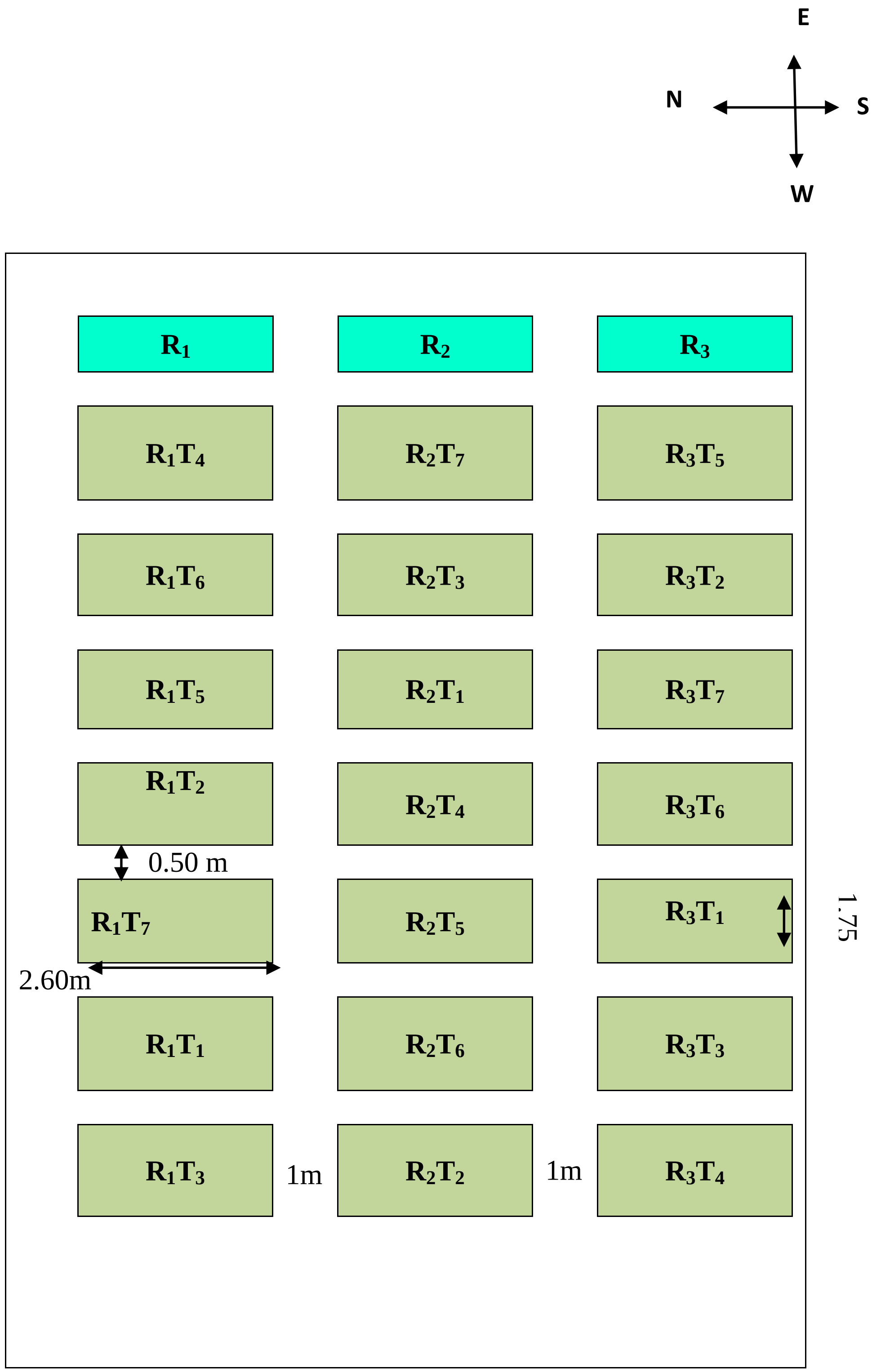
APPENDICES

Appendix I. Map showing the experimental sites under study



☆ **The experimental site under study**

Appendix II. Layout of the experimental field



AppendixIII. 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 record of air temperature, relative humidity and rainfall of the experimental site during the period from December 2020 to March 2021

Year	Month	Air temperature (^{o} C)			Relative humidity (%)	Total Rainfall (mm)
		Minimum	Maximum	Mean		
2020	December	17.00	26.40	21.70	60	9
2021	January	15.30	26.00	20.65	53	2
2021	February	17.40	29.80	23.60	45	10
2021	March	19.40	35.80	27.60	40	11

* 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 agronomic managements

Sources of variation	Degrees of freedom	Mean square value of plant height at				
		25 DAS	40 DAS	55 DAS	70 DAS	Harvest
Replication	2	0.390	8.255	99.259	8.145	3.232
Treatment	6	0.778NS	55.849*	551.738*	505.618*	530.801*
Error	12	1.116	9.110	29.033	5.348	7.503
Total	20					

*Significant at 5% probability level, NS-Not significant

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

Sources of variation	Degrees of freedom	Mean square value of leaves plant^{-1}at				
		25 DAS	40 DAS	55 DAS	70 DAS	Harvest
Replication	2	0.579	4.173	22.656	61.808	5.853
Treatment	6	1.026*	14.342*	36.419*	125.480*	39.051*
Error	12	0.795	0.611	5.728	11.041	2.609
Total	20					

*Significant at 5% probability level

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

Sources of variation	Degrees of freedom	Mean square value of branch plant^{-1} at		
		55 DAS	70 DAS	Harvest
Replication	2	2.951	17.168	12.518
Treatment	6	37.177*	34.024*	30.876*
Error	12	1.277	3.909	3.692
Total	20			

*Significant at 5% probability level

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

Sources of variation	Degrees of freedom	Mean square value of fresh weight plant^{-1} at		
		30 DAS	60 DAS	Harvest
Replication	2	0.546	0.646	0.639
Treatment	6	1.043*	44.565*	12.725*
Error	12	0.400	0.378	0.370
Total	20			

*Significant at 5% probability level

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

Sources of variation	Degrees of freedom	Mean square value of dry weight plant^{-1} at		
		30 DAS	60 DAS	Harvest
Replication	2	0.001	0.009	0.012
Treatment	6	0.002*	3.025*	0.755*
Error	12	0.001	0.015	0.006
Total	20			

*Significant at 5% probability level

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

Sources of variation	Degrees of freedom	Mean square value of root length plant^{-1} at		
		30 DAS	60 DAS	Harvest
Replication	2	0.075	1.261	2.427
Treatment	6	0.533*	5.777*	5.163*
Error	12	0.414	0.877	1.042
Total	20			

*Significant at 5% probability level

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

Sources of variation	Degrees of freedom	Mean square value of shoot length plant^{-1} at		
		30 DAS	60 DAS	Harvest
Replication	2	3.349	0.144	3.309
Treatment	6	6.42*	383.106*	428.173*
Error	12	1.919	1.034	3.986
Total	20			

*Significant at 5% probability level

Appendix XII. Analysis of variance of the data on SPAD value, effective inflorocence plant^{-1} of quinoa as influenced by agronomic managements

Sources of variation	Degrees of freedom	Mean square values of	
		SPAD value at 50 DAS	Effective inflorescence plant^{-1}
Replication	2	14.531	5.522
Treatment	6	344.836*	14.398NS
Error	12	36.569	3.404
Total	20		

*Significant at 5% probability level, NS-Not significant

Appendix XIII. Analysis of variance of the data on yield of quinoa as influenced by agronomic managements.

Sources of variation	Degrees of freedom	Mean square values of					
		Freshg grain yield	Dry grain yield	1000-seed weight	Straw yield	Biological yield	Harvest index
Replication	2	0.002	0.008	0.207	0.002	0.017	1.505
Treatment	6	0.909*	0.909*	0.140*	0.762*	3.335*	2.161*
Error	12	0.004	0.012	0.029	0.014	0.051	1.138
Total	20						

*Significant at 5% probability level

LIST OF PLATES

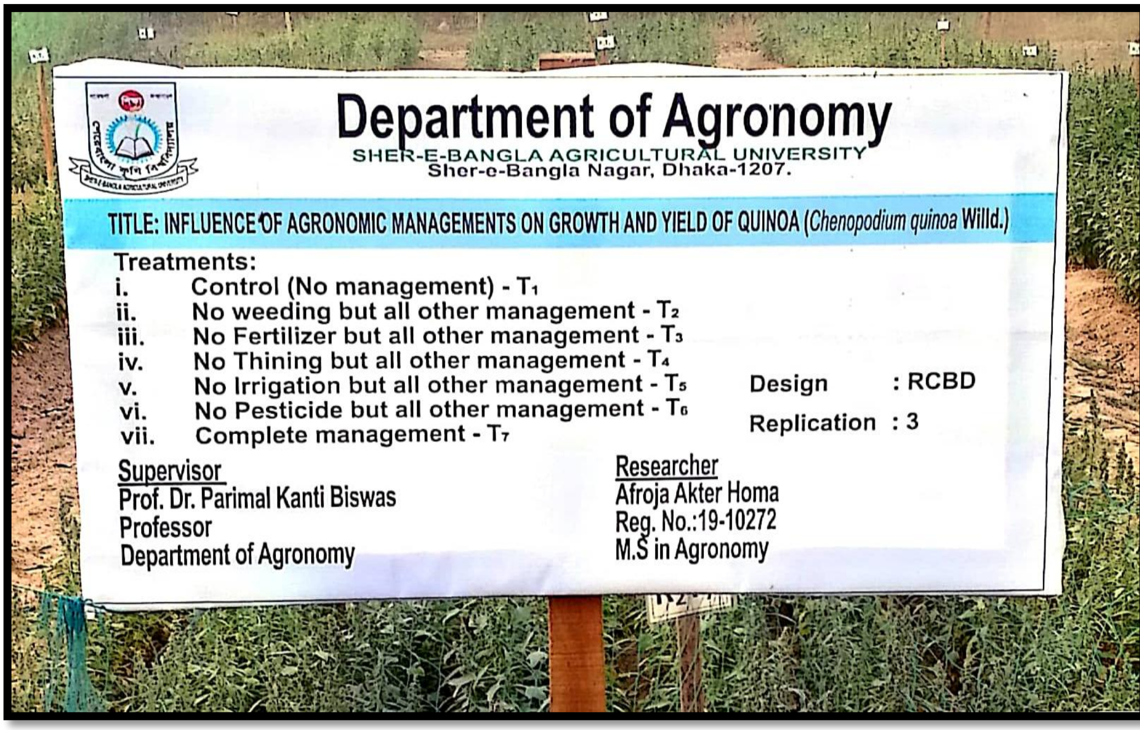


Plate 1. Experimental field after setting up signboard

Plate 2. Field view after completion of tagging and drainage channel

Plate 3. Field view during thinning

Plate 4. Plot view of R_1T_1 (No management)

Plate 5. Plot view of R_1T_5 (No irrigation)

Plate 6. Plot view of R_3T_5 (No irrigation)

Plate 7. Plot view of R_3T_7 (Complete management)