INFLUENCE OF FERTILIZER LEVELS ON GROWTH AND YIELD OF QUINOA (*Chenopodium quinoa*)

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INFLUENCE OF FERTILIZER LEVELS ON GROWTH AND YIELD OF QUINOA (*Chenopodium quinoa*)

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CERTIFICATE

This is to certify that the thesis entitled "INFLUENCE OF FERTILIZER LEVELS ON GROWTH AND YIELD OF QUINOA (*Chenopodium quinoa*)" **submitted to the** *Faculty of Agriculture*, **Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of** *MASTER OF SCIENCE (M.S.) IN AGRONOMY,* **embodies the results of a piece of** ***bona fide*** **research work carried out by** *SADIA AFRIN,* **Registration. No.17-08205, under my supervision and guidance. No part of this 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)

Supervisor

Dhaka, Bangladesh

DEDICATED

TO

MY BELOVED MOTHER

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ABSTRACT

An experiment was conducted at the Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka from November, 2017 to January, 2018 to study the performance of two different varieties of quinoa as influenced by different fertilizer levels. The treatments were included two factors in this study as, Factor A: Variety (2) viz. Titicaca (V_1) and Vikinga (V_2) and Factor B: fertilizer levels (7); F_1 (No fertilizer), F_2 (120kg N ha^{-1}), F_3 (50 kg P ha^{-1}), F_4 (50kg K ha^{-1}), F_5 (120-50 kg NP ha^{-1}), F_6 (120-50 kg NK ha^{-1}), F_7 (120-50-50 kg NPK ha^{-1}). The experiment was laid out in RCBD (factorial) design with three replications. Data on different growth parameters, yield attributes and yield were significantly varied for different parameters. The experimental results indicate that seed yield of quinoa was significantly influenced by the application of different fertilizer levels. The higher plant height at harvest (23.34cm), higher inflorescence length (14.77cm), higher straw weight $plant^{-1}$ (2.54g), higher 1000 seed weight (2.55g), higher seed weight (383.66 kg ha^{-1}), higher straw weight (582.65kg ha^{-1}) was found by V_2. The highest seed yield (682.07 kg ha^{-1}) was obtained from V_2F_7 which was statistically similar with V_2F_6 .The lowest seed yield (73.15 kg ha^{-1}) was obtained from V_1F_3 which was statistically similar to V_1F_5 and V_1F_1. Therefore, present study suggest that Vikinga with 120-50-50 NPK Kg ha^{-1} or 120-50 kg NK ha^{-1} is the most compatible in respect of yield advantage and economic gain. The same interaction also showed higher yield for Titicaca also though it was lower compared to that at Vikinga variety.

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LIST OF ACRONYMS

AEZ	Agro-Ecological Zone
%	Percent
$Plot^{-1}$	Per plot
cm	Centimeter
CV%	Percentage of coefficient of variance
DAS	Days After Sowing
et al.	And others
g	Gram
ha^{-1}	Per hectare
HI	Harvest Index
kg	Kilogram
LSD	Least Significant Difference
Mop	Muriate of Potash
N	Nitrogen
no.	Number
NPK	Nitrogen, Phosphorus and Potassium
NS	Non-significant
$Plant^{-1}$	Per plant
SAU	Sher-e-Bangla Agricultural University
t ha^{-1}	Ton per hectare
TSP	Triple Super Phosphate
Wt.	Weight

CHAPTER I

INTRODUCTION

Quinoa (*Chenopodium quinoa* willd) is a yearly herbaceous plant belongs to Amaranthaceae family, but once located in Chenopodiaceae family. Quinoa is a pseudocereal, considered to have originated in the Inca and Tiahuanaco regions of the Andes. For thousands of years it was the main food of the ancient cultures of the Andes. This plant was called by the Incas 'the mother grain' and it was given a sacred status, a gift from their Gods. It was cultivated and worn by the Inca (ruling class) people since 5,000 B.C. Quinoa is revealed as a strength rations by North Americans and Europeans in the 1970's. After the arrival of the Spaniards, its use, consumption and cultivation was almost eliminated and only remained in the farmers' traditions. Its reputation is dramatically increased in recent years because it is gluten-free (helpful for diabetic patients) and high in protein. Bolivia in South America is the largest manufacturer of quinoa with 46 per cent of world manufacture followed by Peru with 42 per cent and United States of America with 6.3 per cent (FAOSTAT, 2013). It is also cultivated in the USA (Colorado and California), South America, China, Europe, Canada, and India. It is also cultivated experimentally in Finland and the UK. Hence FAO nominated 2013 as International year of Quinoa (Bhargava *et al.*, 2006).

As per United Nations Organization for Agriculture and Food, the quinoa grain is the only vegetable food that provides all amino acids fundamental to the life of humans in most favorable quantities and is comparable with milk. The protein content ranges from 7.47 to 22.08 per cent with higher concentration of lycine, isoleucine, methionine, histidine, cystine and glycine. The digest ability of quinoa protein is more than 80 per cent. The exceptionally high levels of amino acids in quinoa enhancing the immune function by aiding in the formation of antibodies, assisting in cell repair, calcium absorption and transport, involvement in the metabolism of fatty acids, and even preventing cancer metastasis. Quinoa is recognized as a pseudocereal with the broadest and most complete nutritional composition known today. The Food and Agriculture Organization of the United Nations (FAO) has considered quinoa to be the "grain of the future".

Quinoa was annual crop, taproot system and penetrating as deep as 1.5 m below the surface, which protects against drought conditions, with broad leaved. The inflorescence in panicle is 15 -70 cm length and rising from the top of the plant and axils of lower leaves, usually standing about 1-2 m. Quinoa seeds was small with diameter about 1-2.5 mm and 1,000 seed weight was1.4-4.3 g according to Shams and Bhargava *et al.*(2006). Quinoa is a quick-rising plant, thickly ragged, triangular to ovate vegetation and is like in look to the universal North American weed (*Chenopodium album* called as lamb's quarter or goosefoot). Every inflorescence produces hundreds of little achiness, approximately 2 mm in width. Quinoa is an achene (a seed-similar to fruit with a firm fur) with diversified colours ranging from white or pale yellow to orange, red, brown and black. The seeds have a coating which contains bitter-tasting saponins, making them unpalatable. Most of the grain sold commercially has been processed to remove this coating. This bitterness has beneficial effects during cultivation, as it deters birds and therefore, the plant requires minimal protection.

The adaptation of certain quinoa varieties is possible even under marginal environments for the production of seeds with high protein and mineral content (Karyotis *et al.* 2003). Quinoa's aptitude to produce high-protein grains under ecologically extreme conditions makes it important for the diversification of agriculture as in high-altitude regions of the Himalayas and North Indian Plains (Bhargava *et al.*, 2005). Quinoa is reported to be one of the few crop plants grown in the salt level of southern Bolivia and northern Chile.

In adding up to higher than dietary factors, the quinoa grain is supple, gluten free, gets cooked rapidly and has an enjoyable flavor. Quinoa flour works well as a starch extender when combined with wheat flour or grain, or corn meal in making biscuits, bread and processed food. The seeds are also used for brewing beer and for because of its high nutritional value and medicinal use, animal feed. In poultry-feeding trials, chicks fed with a ration containing cooked quinoa made equal gains to those receiving maize and skimmed milk. Quinoa leaves can be eaten as a leafy vegetable, just like spinach. It is obsessive in broad diversity of forms i.e., grains, flakes, pasta, bread, biscuits, beverages, meals etc.

There are no experimental data was available to understand the quinoa responses to different fertilizers application rate on growth and yield. And to gain better understanding of quinoa production as a new crop in Bangladesh. The selection of cultivated area, climatic analogue with the original area was necessary. New cultivated area should be similar to origin. Thus, the experiment was aimed to evaluate the growth and yield responses of quinoa under difference of NPK fertilizers rates in Bangladesh climate condition with the subsequent objectives.

i. to study the response of quinoa varieties in different fertilizers
ii. to find out the suitable combination of variety and fertilizer dose
iii. to know the possibility of growing quinoa as a new crop in Bangladesh

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CHAPTER-II

REVIEW OF LITERATURE

Quinoa presents high commercial value and excellent nutritional quality. Its composition has attracted the attention of scientific community for its high nutritional value, being rich in proteins, lipids, fibers, vitamins, and minerals, with an extraordinary balance of essential amino acids. It is also gluten-free, a characteristic that enables its use by celiac patients. In spite of all these attributes, there is lack of sufficient research works on this pseudo-cereal due to little knowledge of its benefits. However, some research related to the effects of different fertilizer levels on quinoa have so far been done at abroad which have been reviewed in this chapter under the following heads. When ample information on quinoa related to different fertilizers were not available, relevant literatures on crops associated to family Amaranthaceae were also cited.

2.1 Performance of quinoa at different fertilizer levels

2.1.1 Growth parameters

2.1.1.1 Plant height

Geren (2015) found that the highest plant height (101.1 cm) was obtained from 175 kg N ha^{-1} application in 2014, whereas the lowest was 43.8 cm for 0 kg N ha^{-1} application in 2013. Year effect was also significant and average quinoa height of second year (76.2 cm) was higher than the first year (66.1 cm) due to the total precipitation of the second year which was clearly higher than first year. He also informed that the plant height of quinoa increased noticeably by increasing nitrogen fertilizer rate up to 175 kg N ha^{-1} in both seasons.

Many researchers informed that the plant height of quinoa increases with the increasing nitrogen level are mainly due to the role of nitrogen in stimulating metabolic activity which contribute to the increase in metabolites amount and consequently lead to internodes elongation and increase plant height with the increasing nitrogen rate (Jacobsen *et al.*, 1994, Erley *et al.*, 2005; Shams, 2012).

Jacobsen *et al.* (1994) expressed that plant height of quinoa increased with increasing N fertilization rate from 40 to 160 kg N ha^{-1}.

Shams (2012) found clearly that plant height in quinoa increased gradually with increasing nitrogen levels up to 360 kg N ha^{-1}

Fawy *et al*. (2015) reported that 240 kg N ha^{-1}, 37 kg P ha-1 and 150 kg K ha^{-1} (P as ordinary superphosphate of 68 g P kg-1 and K as potassium sulphate of 420 g K kg^{-1}) fertilizers as soil application increases about 33% for plant height (cm) he also found that the combination of 48 mg organic manure ha^{-1}+ 240 kg N ha^{-1} with spraying with humic acid solution of 600 mg L^{-1}+ ascorbic acid solution of 1000 mg L-1 gave the highest positive response of plant height (cm) of 118. Quinoa yielded between 1790 and 3495 kg grain ha^{-1} and responded strongly to N fertilization. NUtE averaged 22.2 kg ha^{-1} and did not decrease with increasing N rates.

2.1.1.2 Biomass production

Thanapornpoonpong (2004) reported that in a greenhouse study, quinoa has shown a positive reaction to nitrogen and specifically, biomass, harvest index and protein content were positively correlated with nitro-gen fertilization.

Ioanna *et al.* (2013) informed that biomass nitrogen content was significantly affected by different fertilization treatments.

2.1.1.3. Number of branches plant^{-1}

Fawy *et al*. (2015) found that the combination of 48 mg organic manure ha^{-1}+ 240 kg N ha^{-1} with spraying with humic acid solution of 600 mg L^{-1}+ ascorbic acid solution of 1000 mg L^{-1} gave the highest positive response of number of branches per plant of 26.4.

2.1.2. Yield parameters

2.1.2.1 Test weight (1000 seed weight)

N fertilizer as soil application increased yield parameters of quinoa plant, the second rate of N fertilizer recorded the highest increase of yield components than control treatment, where these increases reached about 33, 43, 44 and 50% for plant height (cm), number of branches, weight of 1000-seed (g) and weight of seeds plant^{-1} (g), respectively. This result is due to that N has many functions in plant; this fact is described according to Weisany *et al.* (2013).

The highest average thousand grain weight of quinoa (3.36 g) was measured in control plot, whereas the lowest (3.08 g) was in 175 kg N ha^{-1} treatment. Year effect was also significant on this treatment and average value of the first year (3.25 g) was higher than the second year (3.16 g).

Basra *et al*. (2014) stated that thousand grain weight of quinoa (2.1 g) was not affected by nitrogen fertilization from 0 to 120 kg ha^{-1}.

Thanapornpoonpong (2004) found that thousand grain weight of 1.77 g was the highest after application of 0.8 g N pot^{-1}, with increasing nitrogen level to 1.2 g N per pot it was decreased to 1.58 g.

Gomaa (2013) informed that nitrogen fertilizers application with nitrobin increased the average thousand grain weight from 0 (3.3 g) to 119 (4.9 g) kg N ha^{-1}.

2.1.2.2 Grain per plant

Geren (2015) did a two year field experiment on quinoa in Turkey and found that the nitrogen x year interaction was highly significant on the grain yield per plant. The highest grain yield (11.2 g plant^{-1}) was obtained from 150 kg N ha^{-1} level in the second year, whereas the lowest yield (2.4 g plant^{-1}) was recorded in control plots in the first year. Year effect was also significant and average grain yield per plant of second year (7.6 g) was higher than the first year (6.8 g) most probably due to the average monthly temperatures in the study site which was consistent with the 20-year average, providing better humidity and precipitation for the maturation of crops in 2014 compared to 2013.

Shams (2012) informed that grain yield plant^{-1} in quinoa increased gradually (1gto 10 g plant-1) with increasing nitrogen levels up to 360 kg N ha-1.The possible reasons may be the difference in agro-ecological conditions and quinoa genotypes regard in gmaturation period.

2.1.2.3 Seed yield

In a field trial conducted in Wadi El - Natroon region, Beheira Governorate, Egypt during 2008/2009 and 2009/2010 winter seasons, Shams (2011) studied different rates of nitrogen fertilization (0, 90, 180, 270, and 360 Kg N ha^{-1}) for improvement of growth and yield in sandy soils. High nitrogen fertilizer rate significantly increased yield during both the seasons. However, nitrogen use efficiency has reduced with increased rate of nitrogen application**.**

In a pot experiment with two quinoa lines (Quinoa-52 and Quinoa-37) and two commercial varieties (Titicaca and Puno) Lavini *et al.* (2014) studied the effect of five rates of nitrogen application (0, 50, 100,150, and 200 mg kg^{-1}of soil). The results showed that both the lines responded similarly to the application of nitrogen and yield has improved significantly with increased nitrogen rate.

Jacobsen *et al*. (1994) reported that yield response of quinoa at 40 kg N ha^{-1} was 24.1% lower than at 160 kg N ha^{-1}.

According to Erley *et al*. (2005), the grain yield of quinoa (cv. Faro and Cochabamba) almost doubled from 1790 kg ha-1 under the unfertilized treatment to 3495 kg ha-1 under 120 kg N ha^{-1}.

Razzaghi *et al*. (2011) reported that the soil N fertilizer is applied at 120 kg N ha^{-1}, nitrogen uptake by quinoa is134 kg N ha^{-1}in sandy clay loam and 77 kg N ha^{-1} in sandy soil, leading to differing quinoa seeds yield of 3300 kg ha^{-1}and 2300 kg ha^{-1}, respectively.

Hirich (2014) informed that the yield was highest in the 50% of full irrigation treatment with 240 kg ha^{-1} of nitrogen. CWP increased with higher supply of nitrogen and the degree of water stress, the value being highest in the most stressed treatment (25% of full irrigation) and 240 kg ha^{-1}of nitrogen and lowest with the full irrigation without nitrogen supply.

In studies conducted by Gomaa (2013) in Egypt, quinoa plants were fertilized with ammonium nitrate (34% N) at 0, 120, 238, 357 kg ha^{-1} in combination with nitrobin (biofertilizer) or calcium super phosphate (15.5% P2O5) at 0, 120, 238, 357 kg ha^{-1} in combination of phosphor in (biofertilizer). The plants performed the best in the treatment receiving 238 kg ha^{-1}ofammonium nitrate in combination with nitrobin.

Shams (2012) studied the response of quinoa to five nitrogen fertilization levels of 0, 90, 180, 270 and 360 kg ha^{-1}. The author found clearly that grain and biological yields increased gradually with increasing nitrogen levels up to the highest level.

Gomaa (2013) informed that the growth traits, seed yield and seed quality of quinoa plant can be improved by the application of inorganic and biofertilizers (nitrobin or phosphorin).

Geren (2015) found that the highest grain yield (3308 kg ha^{-1}) was found in the second year at 150 kg N ha^{-1} level, whereas the lowest yield (867 kg ha^{-1}) was in the first year at control plot. The highest grain yield (3308 kg ha^{-1}) was found in the second year at 150 kg N ha^{-1} level, whereas the lowest yield (867 kg ha^{-1}) was in the first year at control plot.

Kakabouki *et al*. (2014) reported that nitrogen fertilization increased also the grain yield of quinoa under different tillage system.

2.1.2.4 Harvest index

Lizica and Bjarne (2014) revealed that, among four quinoa varieties (Jason Red, Jacobsen 2, Mixed Jacobsen and Jorgen), harvest index of the cultivar Jacobsen 2 (57.03%) recorded significantly higher harvest index than mixed Jacobsen (48.2%), Jason Red (50.3%), Jorgen (44.5%) under temperate climatic conditions of Romania.

Geren (2015) reported that the harvest index of quinoa increased by increasing nitrogen treatments till 150 kg N ha-1level but later on decreased.

Erley *et al*. (2005) stated that harvest index of quinoa (31%) was not affected by nitrogen fertilization from 0 to 120 kg ha^{-1}.

Basra *et al.* (2014) informed that harvest index increased by increasing nitrogen treatments from 0 to 100 kg N ha^{-1} level but later decreased at 120 kg N ha^{-1} level.

The increases in harvest index of quinoa with increasing nitrogen levels are mainly due to the role of N in stimulating metabolic activity which contributed to the increase in metabolites amount most of which is used building yield and its components (Shams, 2012).

Geren (2015) conducted a experiment and observed that harvest index presented tremendous variability and ranged from 12.3% to 48.5% and being affected by nitrogen levels. Rojas *et al.* (2003) who reported harvest index in quinoa in the range from 6% to 87%.

2.1.3. Quality parameters

2.1.3.1 Protein content (%) and oil content (%) in grain and plant

Gomaa (2013) reported that the application of nitrogen and phosphorus increased crude protein and nutrients content in quinoa seeds.

Darwinkel and Stølen (1997) reported the requirements of 70 kg P_2O_5 ha^{-1} for quinoa prior to seed filling and noted that existing levels of 29 kg phosphorus in many agricultural soils are likely sufficient. They also noted a fairly large requirement for potassium, with uptake of 400 kg K ha^{-1}, and recommend application of 100-200 kg K_2O ha^{-1}.

Azarpour *et al.* (2014) stated that foliar application of ascorbic acid combined with application of N increased yield and nutrient contents in quinoa.

Bilalis *et al.* (2014) reported that 2000 kg cow manure ha^{-1} by 100 kg N ha^{-1} fertilizer gave the highest protein yield of 2481 kg protein ha^{-1}.

In an experiment Geren (2015) found that Nitrogen level of 150 kg ha^{-1} was proved to be the best level for nitrogen supplementation of soil for grain yield (2.95 tha-1) and crude protein content (16%) of quinoa under Mediterranean ecological conditions of Bornova.

Kakabouki *et al.* (2014) stated that there were significant differences in quinoa crude protein (CP) content among fertilizer treatments (2000 kg ha^{-1} cow manure, 100 and 200 kg N ha^{-1}) and all fertilization treatments resulted in values higher than those of the control and, the highest CP content (27%) in quinoa was observed for 200 kg N ha^{-1} application.

The higher protein content at higher nitrogen levels was mainly due to the structural role of nitrogen in building up amino acids (Finck, 1982; Bhargava *et al.*, 2006).

The progressive increase in protein contents of quinoa seed with the increasing nitrogen rates were also reported by many research workers (Jacobsen *et al.*, 1994; Erley *et al.*, 2005; Shams, 2012).

Erley *et al.* (2005) informed that average CP content of quinoa cultivars (Faro and Cochabamba) increased gradually (12.3% to 14.6%, respectively) with the increasing nitrogen levels from 0 kg N to 120 kg N ha^{-1}.

Miranda *et al*. (2013) reported an average CP content of 18.8% using cold resistance quinoa cultivars (Regalona Baer and Villarrica).

Kakabouki *et al*. (2014) also stated that increasing nitrogen level increased CP content of quinoa from 7% to 27% under different tillage system.

The major fact that determines the grain protein content is nitrogen availability, and quinoa is highly responsive to nitrogen fertilizer (Basra et al., 2014) and higher CP content, in a crop with high yield, can be obtained just by application of higher nitrogen quantities.

2.1.4 Geometry and climatic parameters

Bilalis *et al*. (2012) revealed that nitrogen content in cow manure (2000 kg ha^{-1}), compost (250 kg ha^{-1}) and control under minimum tillage was (0.173, 0.164 and 0.156 %) respective recorded higher than conventional tillage (0.156, 0.149 and 0.137 %) respectively in clay loam soil at Greece.

Ioanna *et. al*. (2018) conducted a three year experiment and found that the nitrogen uptake and utilization efficiency were only influenced by fertilization. The higher biomass nitrogen content (4.08-4.33%), biomass nitrogen yield (371-386 kg N ha^{-1}), seed nitrogen content (2.59-2.78%), seed nitrogen yield (62.58-65.42 kg N ha^{-1}) and total plant nitrogen uptake (437.20-454.93 kg N ha^{-1}) were found in 200 kg N ha^{-1}.

CHAPTER III

MATERIAL AND METHODS

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

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted during the period from November, 2017 to January, 2018.

3.1.2 Experimental location

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

3.1.3 Characteristics of soil

The general soil type of the experimental field was Deep Red Brown Terrace soil and the soil belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ-28). A composite sample of the experimental field was made by collecting soil from several spots of the field at a depth of 0-15 cm before beginning of the experiment. The composed soil was air-dried, grind and passed through 2 mm sieve and analyzed at Soil Resources Development

Institute (SRDI), Farmgate, Dhaka for some important physical and chemical properties. The soil was consuming a texture of silty clay with pH and organic matter 5.6 and 0.78%, respectively. The results presented that the soil composed of 26% sand, 45% silt and 29% clay; details have been presented in Appendix II.

3.1.4 Climatic condition

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

3.2 Experimental details

3.2.1 Treatments of the experiment

The experiment comprised of two factors

Factor A: variety (2)

i) Titicaca - V_1

ii) Vikinga - V_2

Factor B: fertilizers levels (8)

i. No fertilizer - F_1
ii. 120 kg N ha^{-1} - F_2
iii. 50 kg P ha^{-1} - F_3
iv. 50 kg K ha^{-1} F_4
v. 120-50 kg NP ha^{-1}- F_5
vi. 120 – 50 kg NK ha^{-1}- F_6
vii. 120 – 50 – 50 kg NPK ha^{-1} - F_7

There were total 14 (7×2) treatment combinations as follows,

V_1F_1, V_1F_2, V_1F_3, V_1F_4, V_1F_5, V_1F_6, V_1F_7, V_2F_1, V_2F_2 V_2F_3, V_2F_4, V_2F_5, V_2F_6 V_2F_7

3.2.2 Planting material

Quinoa varieties Titicaca and Vikinga were used as planting material for the study. The seeds of Titicaca and Vikinga were collected by the supervisor personally.

3.2.3 Land preparation

The experimental field was first opened on 3th November, 2017 with the help of a power tiller and prepared by three successive ploughings and cross-ploughings. Each plough was followed by laddering to have a desirable fine tilth. The visible larger clods were hammered to break into small pieces. All kinds of weeds and residues of previous crop were removed from the field. Sowing of quinoa seed was made on 3 November 2017 according to design immediately after final land preparation. Individual plots were cleaned and finally leveled with the help of wooden plank.

3.2.4 Fertilizer application

Urea, Triple super phosphate (TSP) and Muriate of potash (MoP) were used in the experimental soil as a source of nitrogen (N), phosphorous (P) and potassium (K), respectively. Urea was applied 120 kg N ha^{-1} in the soil as per treatment of the experiment. TSP was applied at the rate of 50 kg P ha^{-1}. MoP was applied at the rate of 50 K kg ha^{-1}. All of the fertilizers of TSP and MoP along with one third urea were applied in final land preparation. Rest urea was applied as top dressing at 30 and 45 DAS.

3.2.5 Experimental design and layout

The experiment was conducted considering seven treatments and laid out in a Randomized Complete Block Design (RCBD). Each treatment was replicated three times. Field trials were conducted during the winter season in the research field of Agronomy Department, Sher-e-Bangla Agricultural University Campus. The whole experimental area was 12.8 m x 17.5 m The distance between plots and blocks were 0.5 m and 1.0m respectively. Area of each plot was 1.4 m x 2.5 m = 3.5 m^2.

3.3 Growing of crops

3.3.1 Sowing of seeds in the field

The seeds of Quinoa were sown on November 3, 2017 in solid rows in the furrows having a depth of 2-3 cm and row to row distance was 40 cm.

3.3.2 Intercultural operations

3.3.2.1 Mulching

A natural mulching was done with breaking down the top soil on 14 November, 2017 which was 11 days after sowing.

3.3.2.2 Thinning

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

3.3.2.3 Irrigation, drainage and weeding

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

3.3.2.4 Plant protection measures

Sevien was applied at 5.11.2017 and 10.11.2017 to protect from ants.

3.4 Crop sampling and data collection

Five plants from each treatment were randomly selected and marked with sample card. Number of leaves plant^{-1} , Plant height, number of branches plant^{-1}, length of inflorescence plant$^{-1,}$ seed weight plant $^{-1}$, thousand seed weight, straw weight plant^{-1} were recorded at different DAS and at harvest following standard procedure.

3.5 Harvest and post harvesting operations

Harvesting was done when 90% of the grain became green to yellow and red in color and it was carried out 27 January, 2018. The matured crops were collected by hand picking from each plot. The collected crops were sun dried, threshed and weighted to a constant moisture level. The seeds were separated, cleaned and dried in the sun for 3 to 5 consecutive days for achieving safe moisture of seed.

3.6 Threshing

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

3.7 Drying, cleaning and weighing

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

3.8 Data collection

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

A. Crop growth characters

a) Leaf number at 30 DAS, 45 DAS and 60 DAS
b) Plant height (cm) at 30 DAS, 45DAS and 60 DAS and harvest
c) Length of inflorescence plant^{-1}
d) Number of branches plant^{-1}

B. Yield and other crop characters

a) Straw weight (g plant^{-1})
b) Seed weight (g plant^{-1})
c) 1000-seed weight (g)
d) Seed yield (kg ha^{-1})
e) Straw yield (kg ha^{-1})

f) Biological yield (Kg ha^{-1})

g) Harvest Index (%)

3.9 Procedure of data collection

3.9.1 Crop growth characters

i. Leaf number

The leaf number of plant was recorded at 30 DAS, 45 DAS, 60 DAS. Data were recorded from randomly selected 5 plants from each plot and average plant height plant^{-1} was documented as per treatment.

ii. Plant height

The height of plant was recorded in centimeter (cm) at 30 DAS, 45 DAS, 60 DAS and at harvest. Data were recorded from randomly selected 5 plants from each plot and average plant height plant^{-1} was documented as per treatment. The height was measured from the ground level to the tip of the leaf of main shoot.

iii. Inflorescence length plant^{-1}

Length of inflorescence of five selected plants from each plot was measured at harvest. The length of inflorescence plant^{-1} was measured from five randomly sampled plants. It was completed by measuring total number of inflorescence of all sampled plants then the average data were recorded.

iv. Number of branches plant^{-1}

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

3.10. Yield and other crop characters

i. Straw weight (g plant^{-1})

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

ii. Seed weight (g plant^{-1})

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

iii. 1000-seed weight (g)

The 1000 seeds were counted manually, which were taken from the seeds sample of each plot separately during 1st harvest, then weighed in an electrical balance and data were recorded in gram. Similar procedure was followed for measuring 500 seed weight at last harvest.

iv. Seed yield (kg ha^{-1})

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

v. Straw yield (kg ha^{-1})

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

vi. Biological yield (kg ha^{-1})

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

Biological yield (kg ha^{-1}) = seed weight (kg ha^{-1}) + straw weight (kg ha^{-1})

vii. Harvest index

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

$$\text{Harvest index} = \frac{\text{Grain or seed yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

3.11 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program Statistix 10 and the mean differences were adjudged by Least Significance Difference (LSD) test at 5% level of significance.

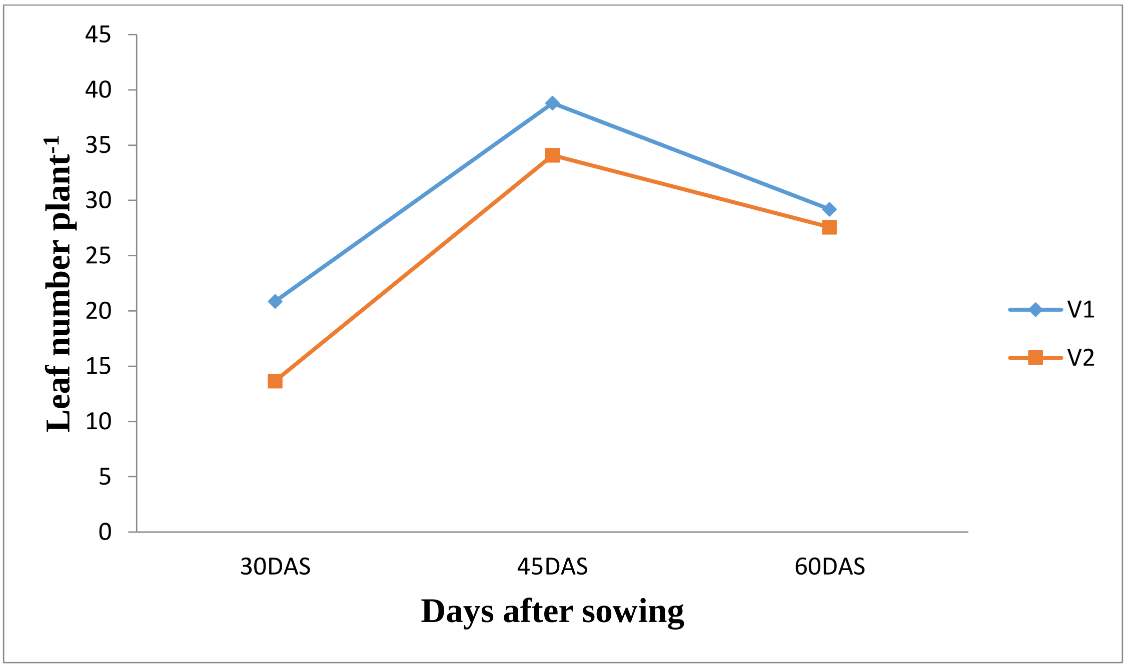
CHAPTER IV

RESULTS AND DISCUSSION

4.1. Leaf number plant^{-1}

4.1.1. Effect of variety

Leaf number at 30 DAS, 45 DAS showed significant variation for different varieties but at 60 DAS showed non-significant variation (Appendix VI and Figure 1). The result revealed that at 30 DAS, the higher leaf number plant^{-1} (20.87) was obtained from Titicaca (V_1) and the lower leaf number (13.67) obtained from Vikinga (V_2). At 45 DAS, the higher Leaf number (38.79) was obtained from Titicaca (V_1) and the lower leaf number plant^{-1} obtained from (34.08) Vikinga (V_2). At 60 DAS, the higher leaf number (29.19) was obtained from Titicaca (V_1) and the minimum leaf number obtained from (27.57) Vikinga (V_2). A trend of decreasing leaf number after 45 DAS till harvest was found in this experiment.

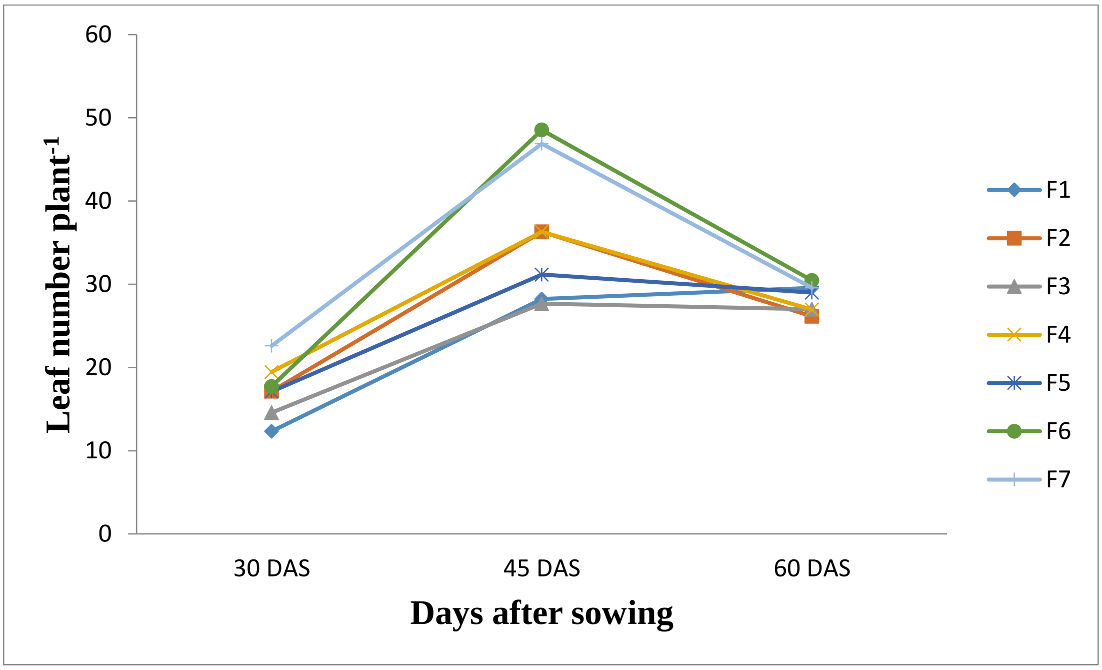


V_1: Titicaca and V_2: Vikinga

Figure 1. Leaf number of quinoa as influenced by variety (LSD$_{(0.05)}$ at 30 DAS and 45 DAS = 4.738, 4.28 respectively)

4.1.2 Effect of fertilizer levels

Leaf number plant^{-1} at 30, 45 DAS was showed significance variation for different fertilizer levels but at 60 DAS showed non-significant variation (Figure 2). The result revealed that at 30 DAS, the highest leaf number plant^{-1} (22.59) was obtained from F_7 (120-50-50 kg NPK ha^{-1}) and the lowest leaf number plant^{-1} obtained from (14.56) at F_3 (50 kg P ha^{-1}). At 45 DAS, the highest leaf number plant^{-1} (48.53) was obtained from F_6 (120-50 kg NK ha^{-1}) and the lowest leaf number obtained from (27.66) F_3 (50 kg P ha^{-1}). At 60 DAS, the highest leaf number plant^{-1} (30.44) was obtained from F_6 (120-50 kg NK ha^{-1}) and the lowest leaf number obtained from (26.13) F_2 (120 kg N ha^{-1}). A trend of decreasing the leaf number after 45DAS was found in this experiment.



F_1 : no fertilizer
F_2 : 120kg N ha^{-1}
F_3 : 50 kg P ha^{-1}
F_4 : 50 kg K ha^{-1}
F_5 : 120 – 50 kg NP ha^{-1}
F_6 : 120 – 50 kg NK ha^{-1}
F_7 : 120 – 50 – 50- kg NPK ha^{-1}

Figure 2: Leaf number of quinoa as influenced by fertilizer levels (LSD$_{(0.05)}$ at 30 DAS and 45 DAS = 8.84 and 7.99 respectively).

4.1.3 Interaction effect of variety and fertilizer levels

Leaf number at 30 DAS and 45 DAS showed significant variation for different varieties with fertilizer levels but at 60 DAS showed non-significant variation (Table 1). The result revealed that at 30 DAS, the highest leaf number plant^{-1} (29.00) was obtained from V_1F_7 Titicaca (V_1) with 120- 50- 50 kg NPK ha^{-1} and the lowest leaf number plant^{-1} obtained from V_2F_1 (10.60) Vikinga (V_2) with no fertilizer. At 45 DAS, the highest leaf number plant^{-1} (53.66) was obtained from V_1F_7 Titicaca (V_1) (120- 50- 50 kg NPK ha^{-1} and the lowest leaf number plant^{-1} (10.10) obtained from V_2F_7 , Vikinga (V_2) with 120- 50- 50 kg NPK ha^{-1} . At 60 DAS, the highest leaf number plant^{-1} (33.80) was obtained from Titicaca (V_1) with treatment five (120 – 50 kg NP ha^{-1} and the lowest leaf number plant^{-1} (24.19) obtained from V_2F_5 Vikinga (V_2) with 120 – 50 kg NP ha^{-1}. Among the two cultivars, Titicaca cultivar had the highest leaf number.

Table 1. Interaction effect of variety and fertilizer levels on leaf number/plant of quinoa at different growth stages.

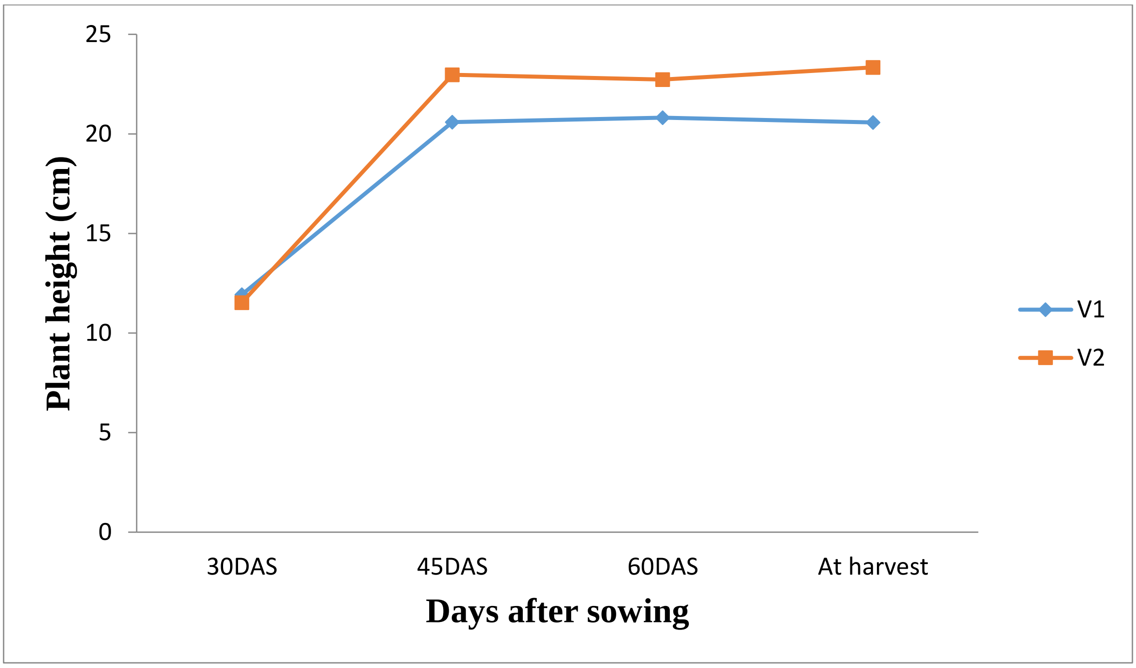
	Leaf number plant^{-1}		
Treatment	30 DAS	45DAS	60DAS
V_1F_1	14.06c	30.50ef	32.46
V_1F_2	19.00abc	34.66def	26.66
V_1F_3	16.86abc	30.86ef	27.86
V_1F_4	27.40ab	43.66abcd	26.73
V_1F_5	21.60abc	31.66ef	33.80
V_1F_6	18.00abc	46.53abc	28.13
V_1F_7	29.20a	53.66a	28.66
V_2F_1	10.60c	25.93f	26.66
V_2F_2	12.26bc	37.93cde	25.60
V_2F_3	12.26c	24.46f	26.15
V_2F_4	11.53c	28.93ef	27.16
V_2F_5	12.60c	30.86ef	24.19
V_2F_6	13.46abc	50.53ab	32.75
V_2F_7	15.99bc	10.10bcde	30.46
LSD $_{(0.05)}$	9.34	11.30	12.51
CV (%)	43.17	18.49	26.27

F_2 : 120kg N ha^{-1}
F_3 : 50 kg P ha^{-1}
F_4 : 50 kg K ha^{-1}
F_5 : 120 – 50 kg NP ha^{-1}
F_7 : 120 – 50 – 50- kg NPK ha^{-1}
V_1: Titicaca
V_2 : Vikinga

4. 2 Plant height (cm)

4.2.1 Effect of variety:

Different varieties of quinoa showed non significance variation in their plant height at 30DAS, 45 DAS, 60DAS and harvest. The result revealed that at 30 DAS, the higher plant height (11.93 cm) was obtained from Titicaca (V_1) and the lower plant height (11.52 cm) obtained from Vikinga (V_2) and both the varieties are statistically similar. At 45 DAS, the higher plant height (22.96 cm) was obtained from Vikinga (V_2) and the lower plant height obtained from (20.58 cm) Titicaca (V_1). At 60 DAS, the higher plant height (22.73 cm) was obtained from Vikinga (V_2) and the lower plant height (20.81cm) obtained from Titicaca (V_1). At harvest, the higher plant height (23.34 cm) was obtained from Vikinga (V_2) and the lower plant height (20.56 cm) obtained from Titicaca (V_1).

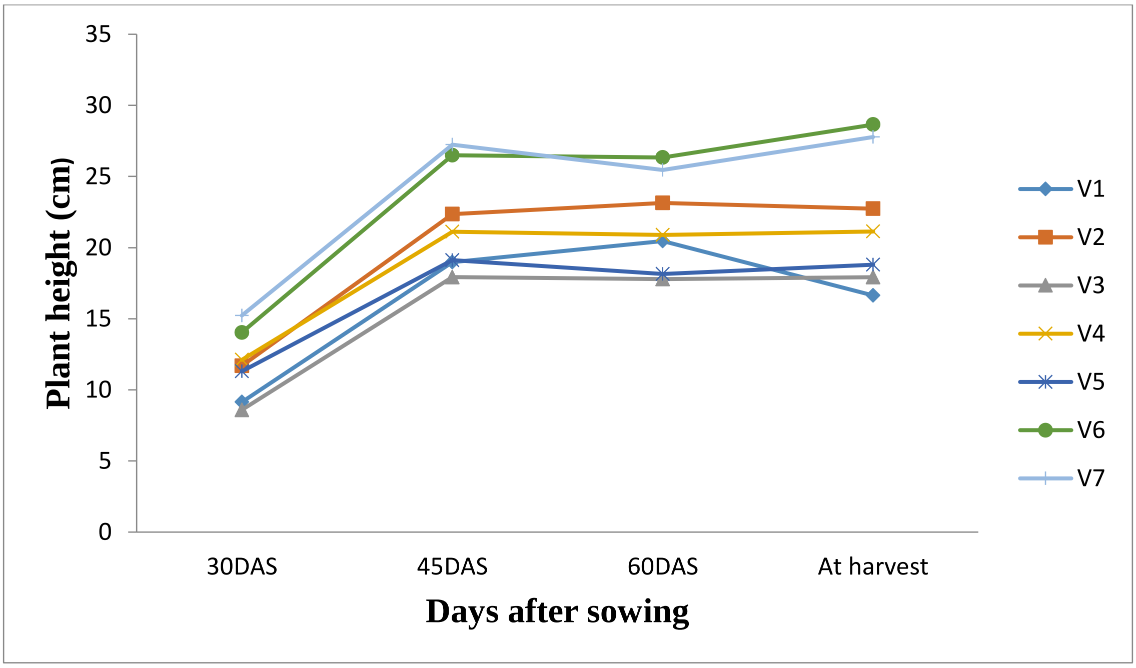


V_1: Titicaca and V_2: Vikinga

Figure 3. Plant height of quinoa as influenced by variety

4.2.2 Effect of fertilizer levels

Plant height at 30 DAS, 45 DAS, 60 DAS and harvest showed significant variation for different fertilizer levels (Figure 4 and Appendix v). The result showed that at 30 DAS, the highest plant height (15.22cm) was obtained from F_7 (120-50-50 kg NPK ha^{-1}) and the lowest plant height (8.593 cm) obtained from at F_3 (50 kg P ha^{-1}). At 45 DAS, the highest plant height (27.24 cm) was obtained from F_7 (120-50-50 kg NPK ha^{-1}) that was statistically similar with F_6 and the lowest plant height (19.12 cm) obtained from F_5 (120-50 kg NP ha^{-1}). At 60 DAS, the highest plant height (26.33 cm) was obtained from F_6 (120-50 kg NK ha^{-1}) and the lowest plant height (17.79 cm) obtained from at F_3 (50 kg P ha^{-1}). At harvest, the highest plant height (28.64 cm) was obtained from F_6 (120-50 kg NK ha^{-1}) and the lowest plant height (17.92 cm) obtained from F_3 (50 kg P ha^{-1}).

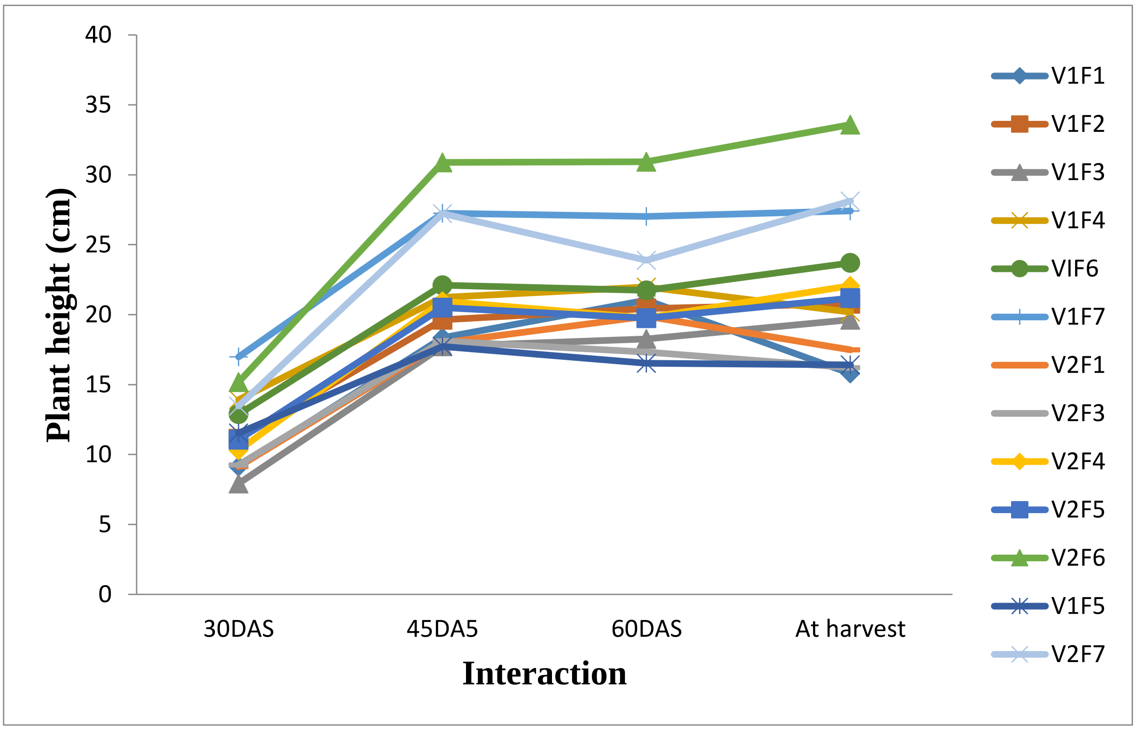


F_1 : no fertilizer
F_2 : 120kg N ha^{-1}
F_3 : 50 kg P ha^{-1}
F_4 : 50 kg K ha^{-1}
F_5 : 120 – 50 kg NP ha^{-1}
F_6 : 120 – 50 kg NK ha^{-1}
F_7 : 120 – 50 – 50- kg NPK ha^{-1}

Figure 4: Plant height of quinoa as influenced by fertilizer levels ($LSD_{(0.05)}$ at 30 DAS, 45 DAS and at harvest = 10.10, 8.74 and 8.22 respectively)

4.2.3 Interaction effect of variety and fertilizer levels

Plant height of quinoa was significantly influenced by varieties with different fertilizer levels (Figure 5). At 30 DAS there were significant differences in plant height but it showed increasing trend with advancement of time up to 60 DAS and then in some treatments slightly decreased up to harvest. This might happen because of breakdown of top portion of the plant. At harvest the tallest plant height (33.59 cm) was obtained from V_2F_6 and lowest plant height (15.80 cm) was obtained from V_1F_1.



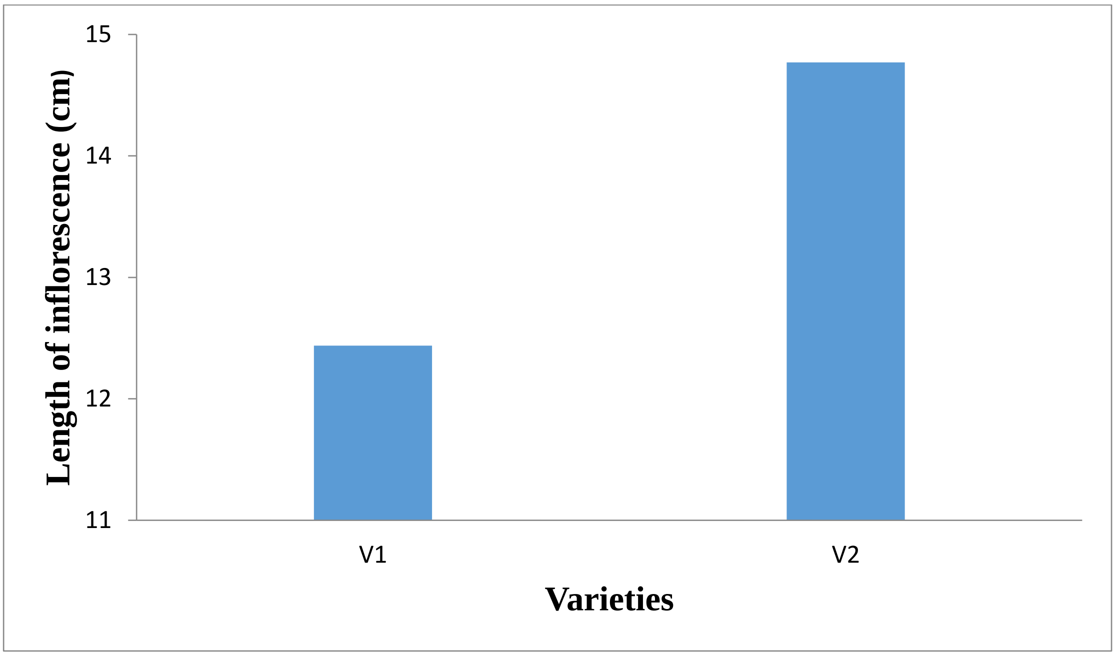
F_1 : no fertilizer
F_2 : 120kg N ha^{-1}
F_3 : 50 kg P ha^{-1}
F_4 : 50 kg K ha^{-1}
F_5 : 120 – 50 kg NP ha^{-1}
F_6 : 120 – 50 kg NK ha^{-1}
F_7 : 120 – 50 – 50- kg NPK ha^{-1}
V_1: Titicaca
V_2 : Vikinga

Figure 5: Interaction effect of variety and fertilizer levels on plant height of quinoa at different growth stages

4.3 Length of inflorescence plant^{-1}

4.3.1 Effect of variety:

Inflorescence length of individual plant at harvest showed significant variation for different varieties (Figure 6). The result showed that at harvest, the higher Inflorescence length of plant^{-1} (14.76 cm) was obtained from Vikinga (V_2) and the lower inflorescence length of individual plant obtained from (12.43 cm) Titicaca (V_1).



V_1: Titicaca and V_2: Vikinga

Figure 6. Length of inflorescence of quinoa as influenced by variety

4.3.2 Effect of different fertilizer levels

Plant height at harvest showed significant variation for different fertilizer levels. The result showed that the highest inflorescence length (18.56 cm) was obtained from F_6 (120-50 kg NK ha^{-1}) that was statistically similar with F_7 (120-50-50 kg NPK ha^{-1}) and the lowest inflorescence length (10.02 cm) obtained from at F_3 (50kg P ha^{-1}) that was statistically similar with F_1 (No fertilizer), F_5 (120-50 kg NP ha^{-1}).

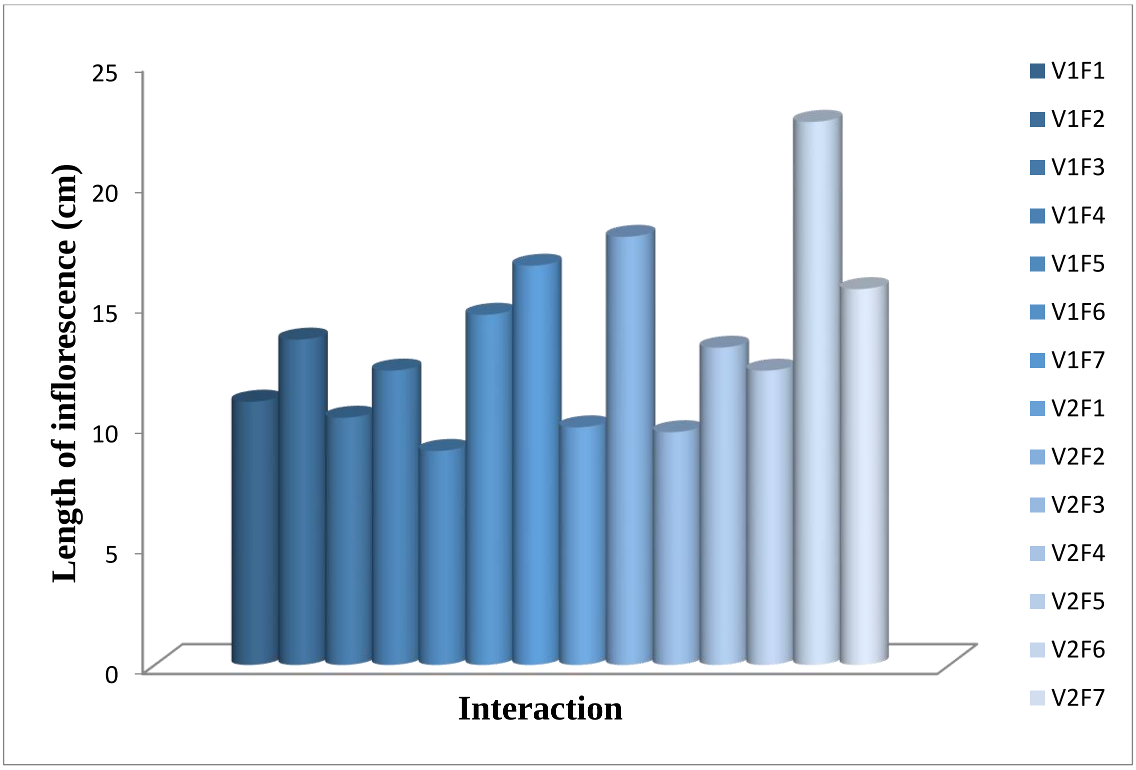
Table 2. Effect of fertilizer levels on Inflorescence length $plant^{-1}$

Fertilizer levels	Inflorescence length (cm)
F_1	10.15 c
F_2	15.69 ab
F_3	10.02 c
F_4	12.92 bc
F_5	10.61 c
F_6	18.56 a
F_7	17.24 a
LSD $_{(0.05)}$	3.09

F_1 : no fertilizer
F_2 : 120kg N ha^{-1}
F_3 : 50 kg P ha^{-1}
F_4 : 50 kg K ha^{-1}
F_5 : 120 – 50 kg NP ha^{-1}
F_6 : 120 – 50 kg NK ha^{-1}
F_7 : 120 – 50 – 50- kg NPK ha^{-1}

4.3.3. Interaction effect of variety and fertilizer levels

Significant variations were found for inflorescence length at harvest (Figure 7). The highest inflorescence length was found in variety two (Vikinga) when it was interacted with F_6 (120 – 50 kg NK ha^{-1}) which was statistically similar with others. The shortest inflorescence was found in F_5 (120 – 50 kg NP ha^{-1}) with variety one (Titicaca) which was also statistically similar with others.



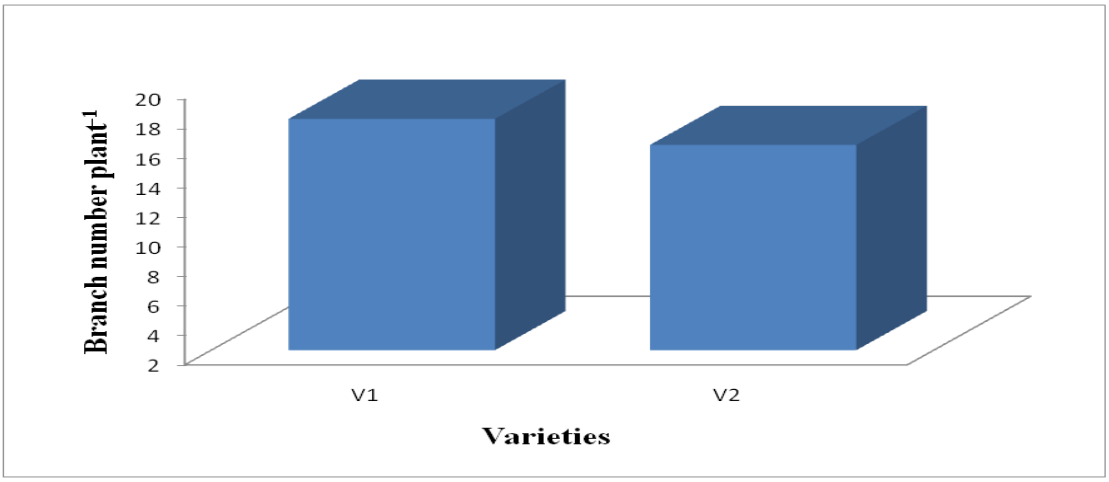
F_1 : no fertilizer
F_2 : 120kg N ha^{-1}
F_3 : 50 kg P ha^{-1}
F_4 : 50 kg K ha^{-1}
F_5 : 120 – 50 kg NP ha^{-1}
F_6 : 120 – 50 kg NK ha-1
F_7 : 120 – 50 – 50- kg NPK ha^{-1}
V_1: Titicaca
V_2 : Vikinga

Figure 7: Interaction effect of variety and fertilizer levels on inflorescence length on of quinoa (LSD$_{(0.05)}$ 4.374)

4.4 Number of branches plant^{-1}

4.4.1 Effect of variety

Branch number plant^{-1} at harvest showed non-significant variation for different varieties (Figure 8). The result revealed that, the higher branch number (17.67) was obtained from Titicaca (V_1) (Figure 8). And the lower branch number obtained from (15.90) at Vikinga (V_2).

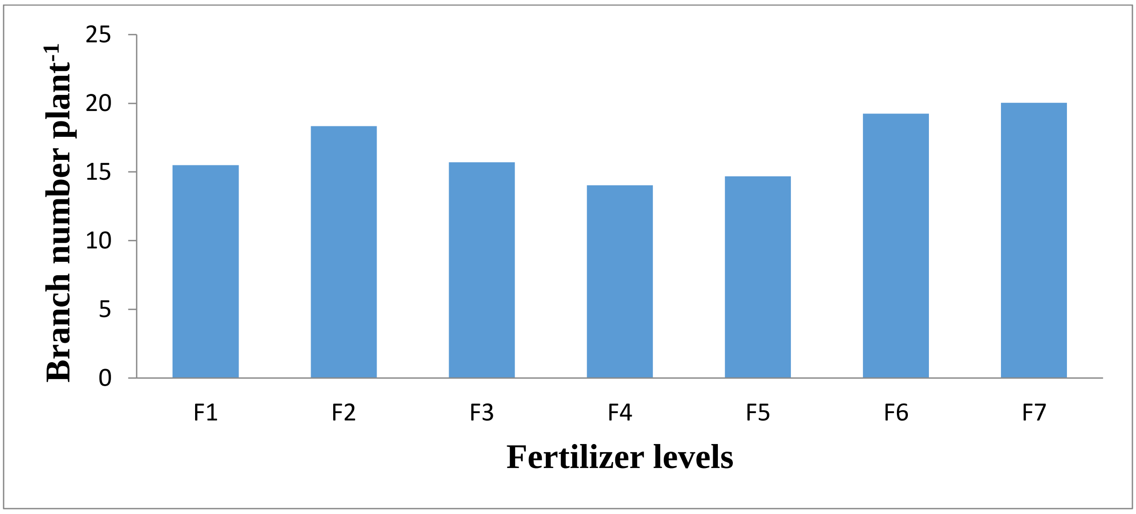


V_1: Titicaca and V_2: Vikinga

Figure 8. Branch number of quinoa as influenced by variety

4.4.2. Effect of different fertilizer levels:

Branch number plant^{-1} at harvest showed significant variation for different fertilizer levels (Figure 9). The result revealed that the highest branch number plant^{-1} (20.0) was obtained from F_7 (120-50-50 kg NPK ha^{-1}) and the lowest branch number (14.033) obtained from at F_4 (50 kg K ha^{-1}). Fawy *et at*. (2015) reported that branch number plant^{-1} from highest doses of nitrogen.

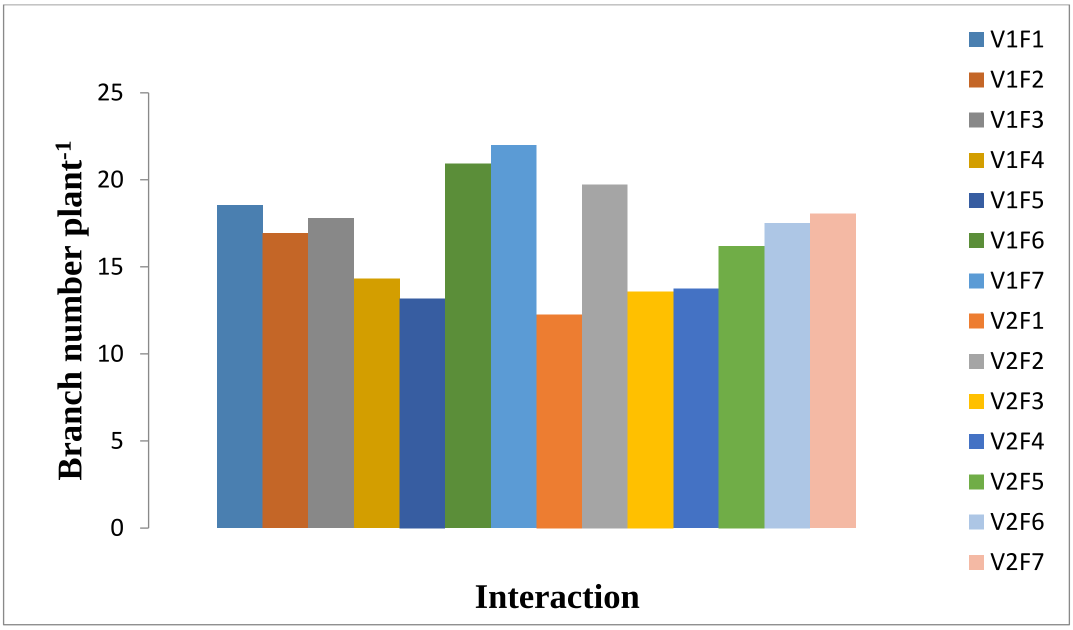


F_1 : no fertilizer
F_2 : 120kg N/ha
F_3 : 50 kg P/ha
F_4 : 50 kg K/ha
F_5 : 120 – 50 kg NP/ha
F_6 : 120 – 50 kg NK/ha
F_7 : 120 – 50 – 50- kg NPK/ha

Figure 9: Branch number of quinoa as influenced by fertilizer levels ($LSD_{(0.05)}$ at harvest = 2.704)

4.4.3 Interaction effect of variety and fertilizer levels

Significant variations were found for branches plant^{-1} at harvest (Figure 10 and Appendix V). The highest number of branches plant^{-1} (22.00) was obtained from the Titicaca variety which was interacted with 120 – 50 – 50 kg NPK ha^{-1} (F_7) that statistically similar with V_1F_6. The lowest number of branches plant^{-1} (12.26) was found from V_2F_1 that statistically at par with V_1F_5.



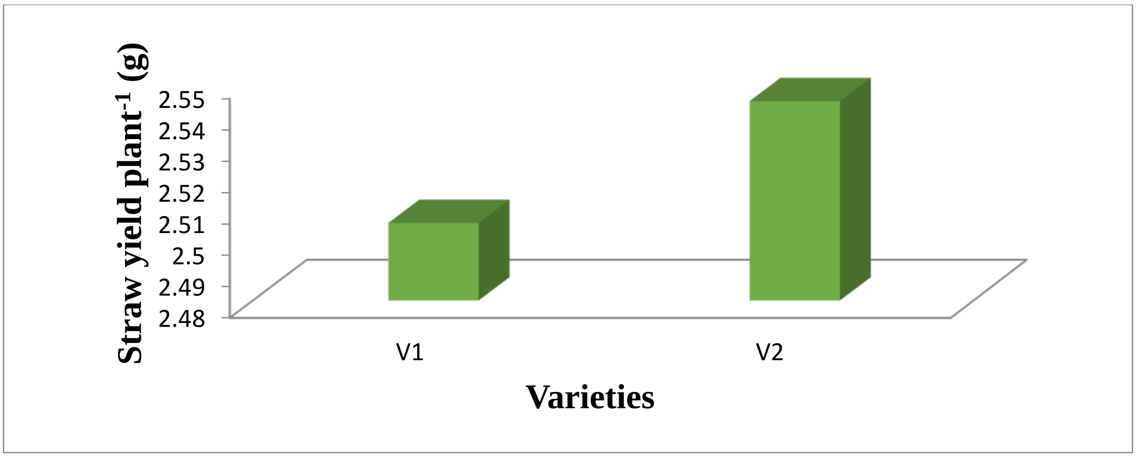
F_1 : no fertilizer
F_2 : 120kg N ha^{-1}
F_3 : 50 kg P ha^{-1}
F_4 : 50 kg K ha^{-1}
F_5 : 120 – 50 kg NP ha^{-1}
F_6 : 120 – 50 kg NK ha^{-1}
F_7 : 120 – 50 – 50- kg NPK ha^{-1}
V_1: Titicaca
V_2 : Vikinga

Figure 10. Interaction effect of variety and fertilizer levels on branch number of quinoa (LSD $_{(.05)}$ = 3.824)

4.5 Straw weight plant^{-1} (g)

4. 5.1. Effect of variety

Straw weight plant^{-1} at harvest showed non-significant variation for different varieties. The result revealed that, the higher straw weight (2.543 g) was obtained from Vikinga (V_2). And the lower straw weight obtained from (2.50 g) Titicaca (V_1). (Figure 11)

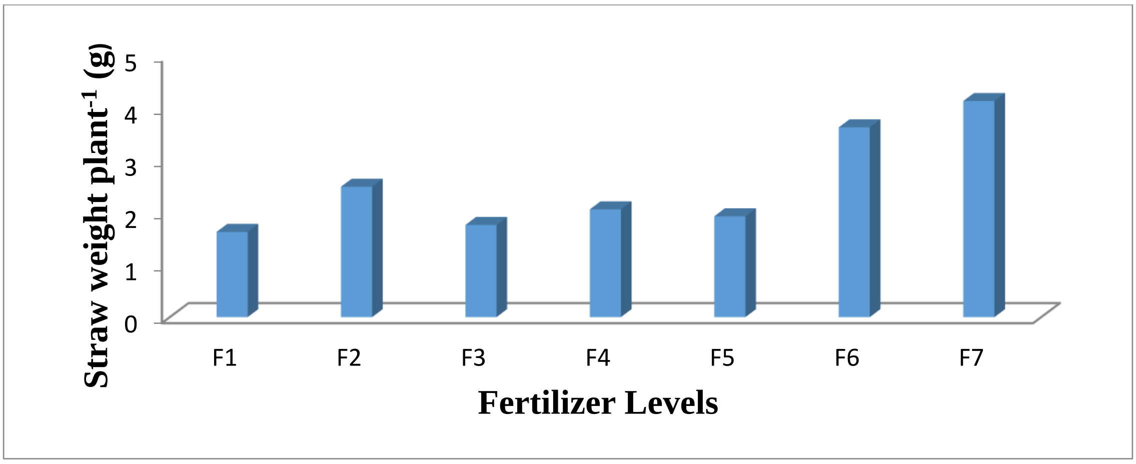


V_1: Titicaca and V_2: Vikinga

Figure 11. Straw weight plant^{-1} of quinoa as influenced by variety

4.5.2 Effect of different fertilizer levels

Straw weight plant^{-1} at harvest showed significant variation for different fertilizer levels (Figure 12). The result showed that the highest straw weight (4.13 g) was from F_7 (120-50-50 kg NPK ha^{-1}) and the lowest straw weight (1.63 g) obtained from F_1 (No fertilizer) that was statistically similar with F_2 (120kg N ha^{-1}), F_3 (50kg P ha^{-1}), F_4 (50kg K ha^{-1}), F_5 (120-50 kg NP ha^{-1}), F_6 (120-50 kg NK ha^{-1}).

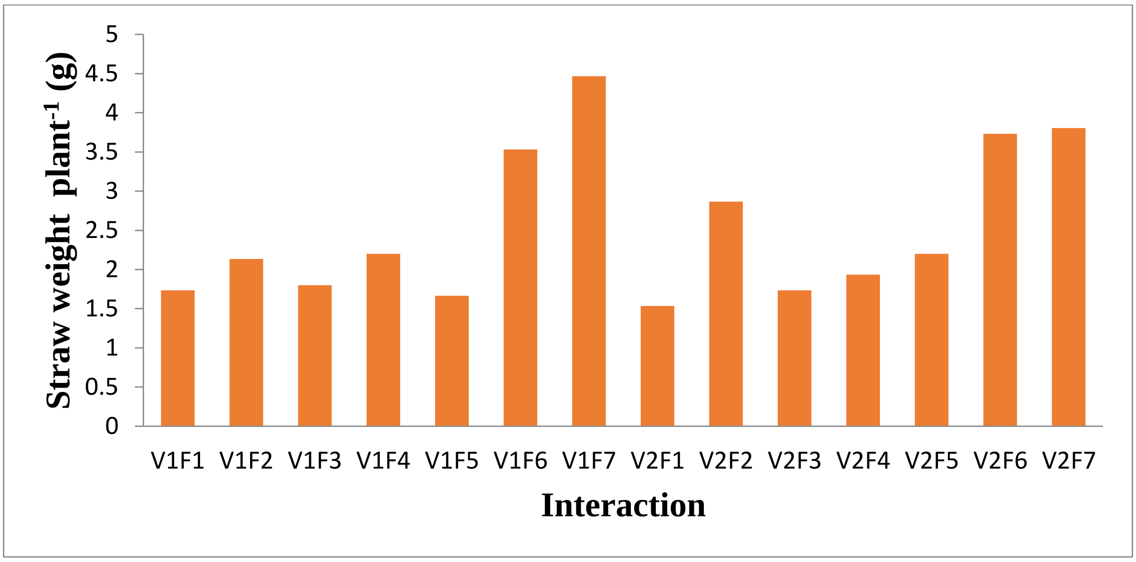


F_1 : no fertilizer
F_2 : 120kg N ha^{-1}
F_3 : 50 kg P ha^{-1}
F_4 : 50 kg K ha^{-1}
F_5 : 120 – 50 kg NP ha^{-1}
F_6 : 120 – 50 kg NK ha^{-1}
F_7 : 120 – 50 – 50- kg NPK ha^{-1}
V_1: Titicaca
V_2 : Vikinga

Figure 12: Straw weight plant^{-1} of quinoa as influenced by fertilizer levels (LSD$_{(0.05)}$ = 7.762).

4.5.3 Interaction effect of variety and fertilizer levels

Significant variations were found for straw weight plant^{-1} at harvest (Figure 13 and Appendix Vi). The highest straw weight plant^{-1} (4.46 g) was obtained from the Titicaca variety which was interacted with 120 – 50 – 50 kg NPK ha^{-1} (F_7). The lowest straw weight plant^{-1} (1.53 g) was found from V_2F_1.



F_1 : no fertilizer
F_2 : 120kg N ha^{-1}
F_3 : 50 kg P ha^{-1}
F_4 : 50 kg K ha^{-1}
F_5 : 120 – 50 kg NP ha^{-1}
F_6 : 120 – 50 kg NK ha^{-1}
F_7 : 120 – 50 – 50- kg NPK ha^{-1}
V_1: Titicaca
V_2 : Vikinga

Figure 13. Interaction effect of variety and fertilizer levels on Straw weight plant^{-1} of quinoa

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

4.6.1 Effect of Variety

Seed weight of plant^{-1} at harvest showed non-significant variation for different varieties (Table 3). The result showed that at harvest, the higher seed weight of plant^{-1} (3.50 g) was obtained from Titicaca (V_1) and the lower seed weight of plant^{-1} (3.35 g) obtained from Vikinga (V_2).

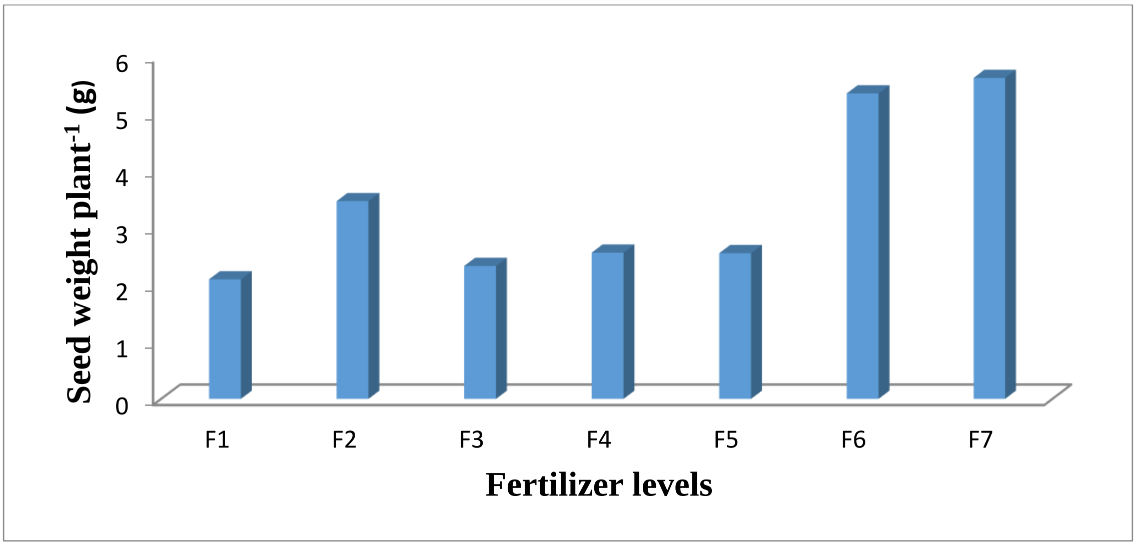
Table 3: Effect of varieties on seed weight (g plant^{-1}) of quinoa

Variety	Seed weight (g plant^{-1})
V_1	3.50
V_2	3.35
LSD $_{(0.05)}$	NS

V_1: Titicaca and V_2: Vikinga

4.6.2 Effect of different fertilizer levels

Seed weight (g plant^{-1}) at harvest showed significant variation for different fertilizer levels (Figure 13). The result showed that the highest seed weight (5.62 g) was obtained from F_7 (120-50-50 kg NPK ha^{-1}) that was statistically similar with F_6 (120-50 kg NK ha^{-1}) and the lowest straw weight (2.10 g) obtained from at F_1 (No fertilizer).



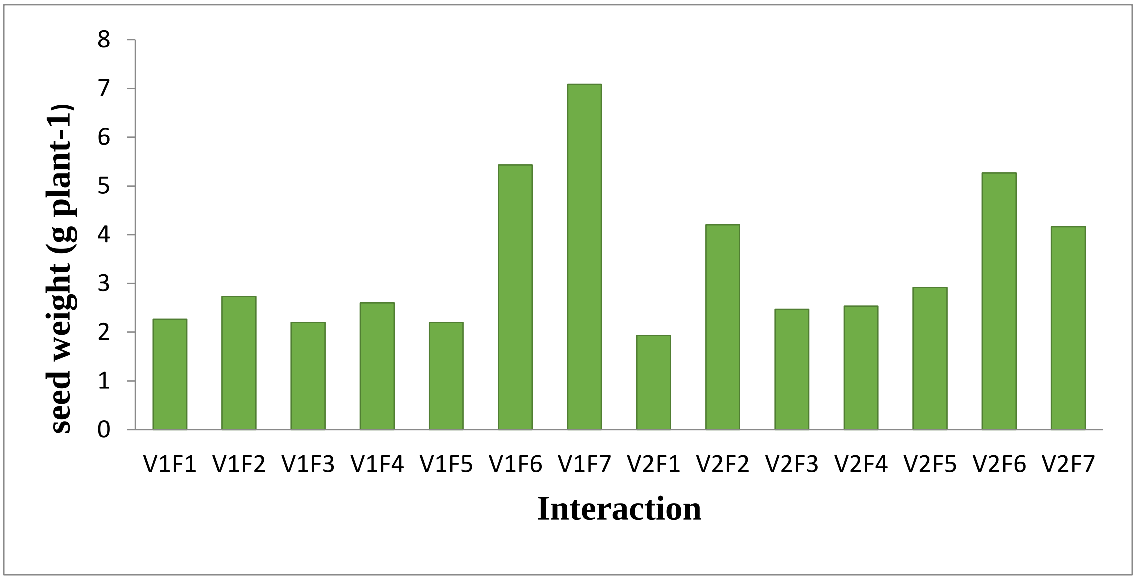
F_1 : no fertilizer
F_2 : 120kg N ha^{-1}
F_3 : 50 kg P ha^{-1}
F_4 : 50 kg K ha^{-1}
F_5 : 120 – 50 kg NP ha^{-1}
F_6 : 120 – 50 kg NK ha^{-1}
F_7 : 120 – 50 – 50- kg NPK ha^{-1}
V_1: Titicaca
V_2 : Vikinga

Figure 14: Seed weight plant^{-1} of quinoa as influenced by fertilizer levels (LSD$_{(0.05}$ = 1.62)

4.6.3 Interaction effect of variety and fertilizer levels

Interaction between variety and fertilizer levels showed significant differences on seed weight plant^{-1} (Appendix Vi and Figure15). The highest seed weight plant^{-1} (7.08 g) was observed in V_1F_7 (Titicaca with 120 – 50 – 50 kg NPK ha^{-1}) which was not statistically similar with other interaction.

The lowest seed weight plant^{-1} (2.20 g) obtained from V_1F_3 that was statistically similar with V_1F_5.



F_1 : no fertilizer
F_2 : 120kg N ha^{-1}
F_3 : 50 kg P ha^{-1}
F_4 : 50 kg K ha^{-1}
F_5 : 120 – 50 kg NP ha^{-1}
F_6 : 120 – 50 kg NK ha^{-1}
F_7 : 120 – 50 – 50- kg NPK ha^{-1}
V_1: Titicaca
V_2 : Vikinga

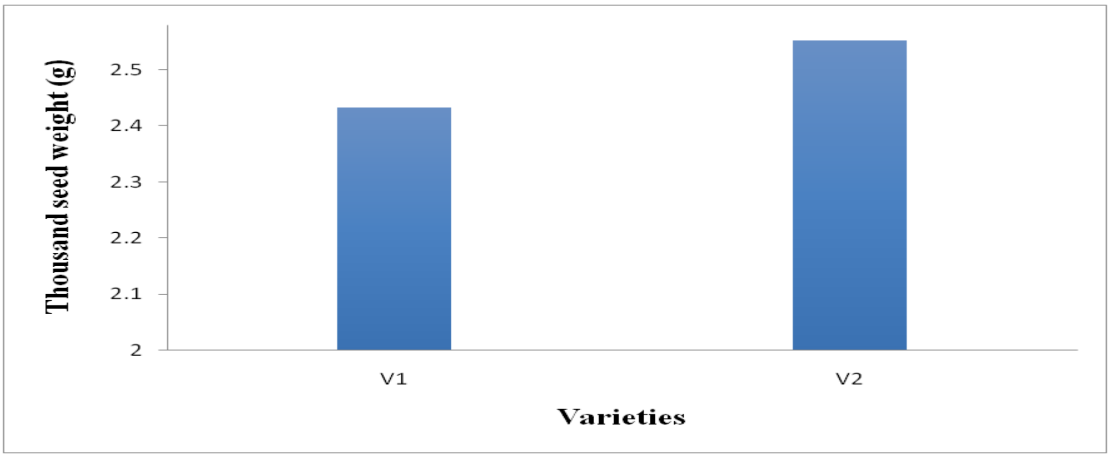
Figure 15. Interaction effect of variety and fertilizer levels on seed weight plant^{-1} of quinoa. (LSD$_{.05\%}$ = 2.35)

4.7 Thousand seed weight

4.7.1 Effect of variety:

The 1000 seed weight of quinoa at harvest showed non-significant variation for different varieties (Figure 16).

The result showed that at harvest, the higher 1000-seed weight (2.55 g) was obtained from Vikinga (V_2) and the lower 1000-seed weight obtained from (2.43 g) Titicaca (V_1).



V_1: Titicaca and V_2: Vikinga

Figure 16. Thousand seed weight of quinoa as influenced by variety

4.7.2 Effect of different fertilizer levels

Thousand seed weight at harvest showed significant variation for different different fertilizer levels (Table 4). The result revealed that at harvest, the highest thousand seed weight (2.84 g) was obtained from F_7 (120-50-50 kg NPK ha^{-1})and the lowest thousand seed weight (2.24 g) obtained from F_2 (120kg N ha^{-1}) which is statistically similar with F_1, F_3 and F_4.

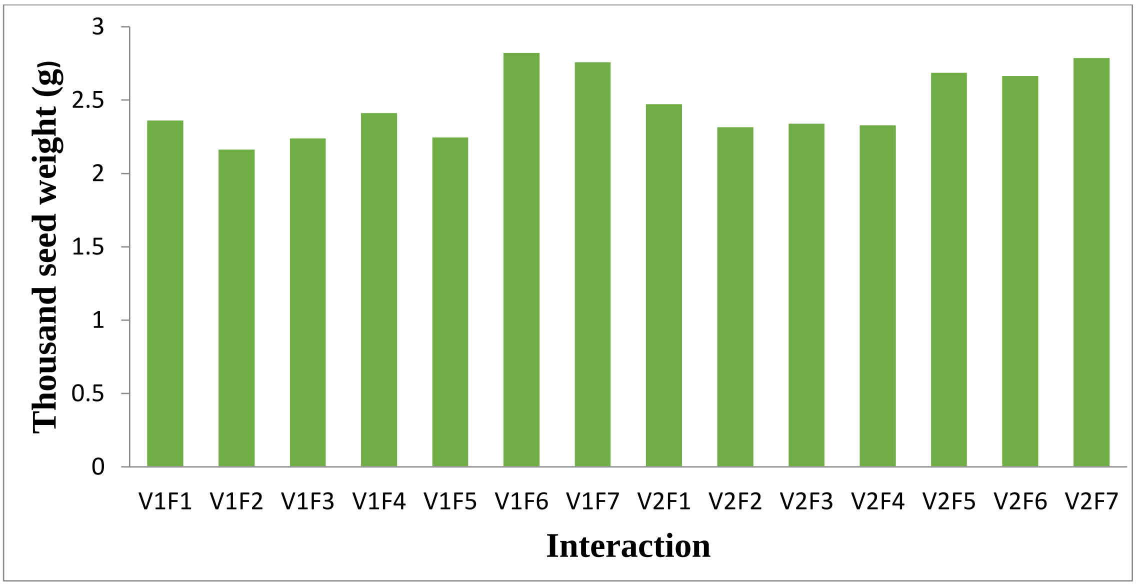
Table 4: Effect of fertilizer levels on 1000 seed weight (g) $plant^{-1}$ of quinoa at harvest.

Fertilizer levels	1000seed weight (g)
F_1	2.4217 c
F_2	2.2433 c
F_3	2.2933 c
F_4	2.3750 c
F_5	2.4700 bc
F_6	2.8049 ab
F_7	2.8428 a
LSD $_{(0.05)}$	0.0328

F_1 : no fertilizer
F_2 : 120kg N ha^{-1}
F_3 : 50 kg P ha^{-1}
F_4 : 50 kg K ha^{-1}
F_5 : 120 – 50 kg NP ha^{-1}
F_6 : 120 – 50 kg NK ha^{-1}
F_7 : 120 – 50 – 50- kg NPK ha^{-1}
V_1: Titicaca
V_2 : Vikinga

4.7.3 Interaction effect of variety and fertilizer levels

Interaction between variety and fertilizer levels showed significant differences on 1000-seed weight of quinoa at harvest (Appendix VI and Figure 17). The highest 1000-seed weight was found in V_1F_6 (Titicaca with 120 – 50 kg NK ha^{-1}) which was not statistically similar with others. The lowest 1000-seed weight was observed in V_1F_2 (Titicaca with 120kg N ha^{-1}) which was not statistically similar with others.



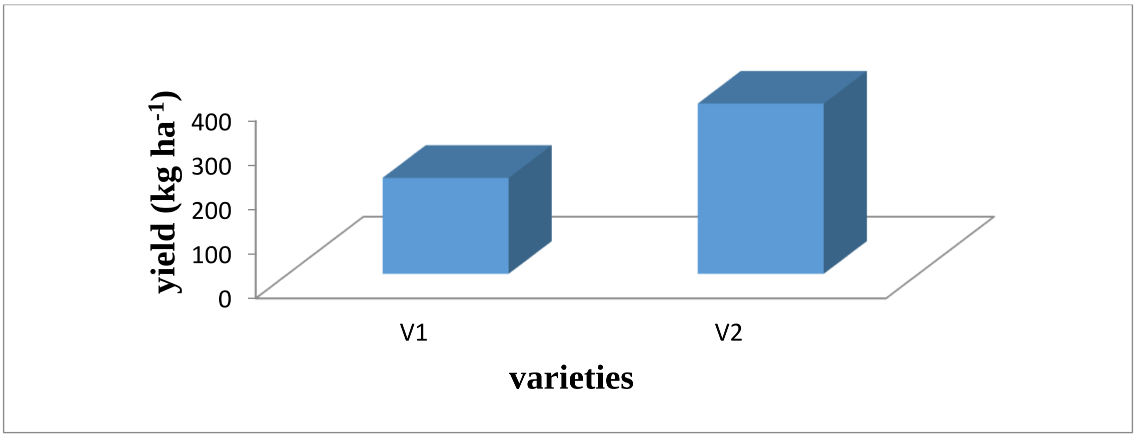
F_1 : no fertilizer
F_2 : 120kg N ha^{-1}
F_3 : 50 kg P ha^{-1}
F_4 : 50 kg K ha^{-1}
F_5 : 120 – 50 kg NP ha^{-1}
F_6 : 120 – 50 kg NK ha^{-1}
F_7 : 120 – 50 – 50- kg NPK ha^{-1}
V_1: Titicaca
V_2 : Vikinga

Figure 17. Interaction effect of variety and fertilizer levels on thousand grain weight of quinoa (LSD $_{(0.05)}$ = 0.464)

4.8 Seed yield (kg ha^{-1})

4.8.1 Effect of variety:

Seed yield (kg ha^{-1}) at harvest showed significant variation for different varieties (Figure 18). The result showed that at harvest, the higher grain yield (383.66 kg ha^{-1}) was obtained from Vikinga (V_2) and the lower grain yield obtained from (216.30 kg ha^{-1}) Titicaca (V_1).



V_1: Titicaca and V_2: Vikinga

Figure 18. Seed yield (kg ha^{-1}) of quinoa as influenced by variety ($LSD_{(0.05)}$ = 73.556)

4.8.2 Effect of different fertilizer levels

Seed yield (kg ha^{-1}) at harvest showed significant variation for different fertilizer levels (Table 5). The result revealed that at harvest, the highest seed weight of plant^{-1} (6.44 g) was obtained from F_6 and the lowest seed weight of plant^{-1}obtained from F_3.

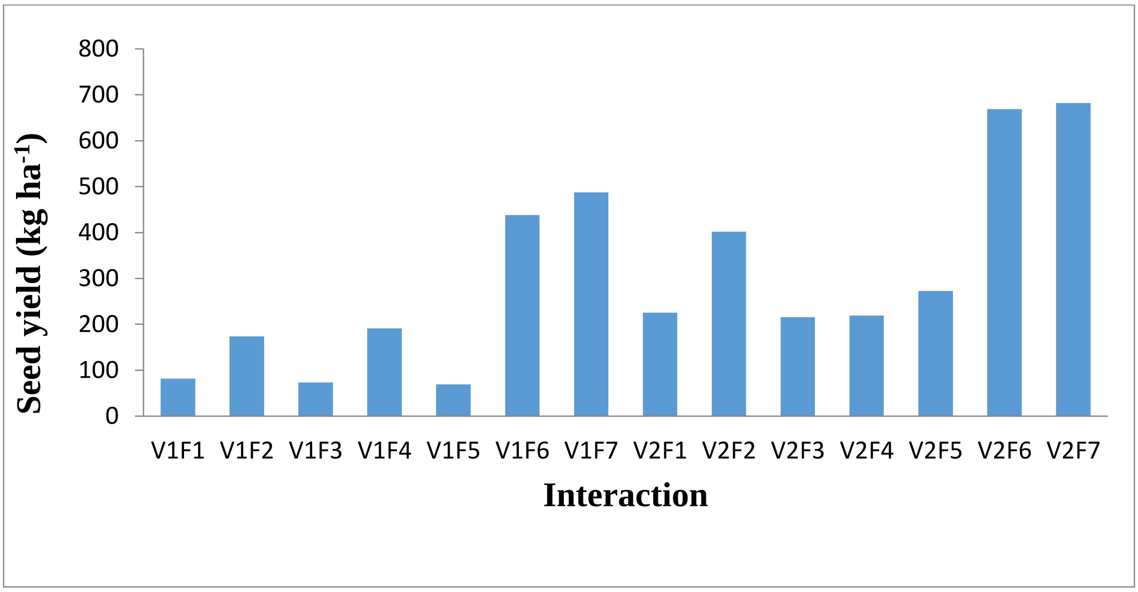
Table 5: Effect of fertilizer levels on seed weight (kg ha^{-1}) of quinoa at harvest

Fertilizer levels	Seed yield (kg ha^{-1})
F_1	153.32 bc
F_2	287.85 b
F_3	144.40 c
F_4	205.20 bc
F_5	171.00 bc
F_6	553.38 a
F_7	515.04 b
$LSD_{(0.05)}$	137.37

F_1 : no fertilizer
F_2 : 120kg N ha^{-1}
F_3 : 50 kg P ha^{-1}
F_4 : 50 kg K ha^{-1}
F_5 : 120 – 50 kg NP ha^{-1}
F_6 : 120 – 50 kg NK ha^{-1}
F_7 : 120 – 50 – 50- kg NPK ha^{-1}
V_1: Titicaca
V_2 : Vikinga

4.8.3 Interaction effect of variety and fertilizer levels

Interaction between variety and fertilizer levels showed significant differences on seed yield (kg ha^{-1}) of quinoa at harvest (Appendix VI and Figure 19). The highest seed yield (682.07 kg ha^{-1}) was found in V_2F_7 which was statistically similar with V_2F_6. The lowest seed yield (73.15 kg ha^{-1}) was observed in V_1F_3 which was statistically similar with V_1F_5 and V_1F_1.



F_1 : no fertilizer
F_2 : 120kg N ha^{-1}
F_3 : 50 kg P ha^{-1}
F_4 : 50 kg K ha^{-1}
F_5 : 120 – 50 kg NP ha^{-1}
F_6 : 120 – 50 kg NK ha^{-1}
F_7 : 120 – 50 – 50- kg NPK ha^{-1}
V_1: Titicaca
V_2 : Vikinga

Figure 19. Interaction effect of variety and fertilizer levels on Seed yield (kg ha^{-1}) of quinoa (CV % = 38.59, LSD $_{(0.05)}$ = 194.26)

4.9 Straw yield (kg ha^{-1})

4. 9.1 Effect of variety

Straw yield kg per hectare showed significant variation for different varieties (Table 6). The result showed that at harvest, the higher straw yield (582.65 kg ha^{-1}) was obtained from Vikinga (V_2) and the minimum straw yield obtained from (298.74 kg ha^{-1}) Titicaca (V_1).

Table 6: Effect of varieties on straw yield (kg ha^{-1}) of quinoa at harvest

Varieties	Straw yield (kg ha^{-1})
V_1	298.74 b
V_2	582.65 a
LSD (0.05)	202.04

V_1: Titicaca and V_2: Vikinga

4. 9.2 Effect of different fertilizer levels

Straw yield (kg ha^{-1}) at harvest showed significant variation for different fertilizer levels (Table 7). The result revealed that at harvest, the highest straw yield (725.04 kg ha^{-1}) was obtained from F_7 (120-50-50 kg NPK ha^{-1}) and the lowest seed weight of $plant^{-1}$obtained from (222.29 kg ha^{-1}) F_3 (50 kg P ha^{-1}) that was statistically similar with F_5 (120-50 kg NP ha^{-1}).

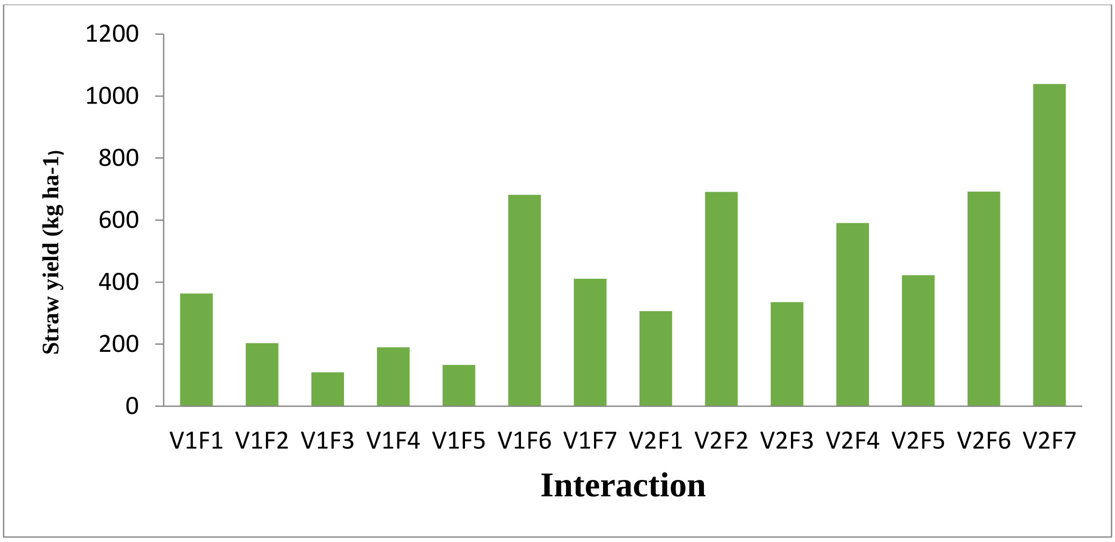
Table 7: Effect of fertilizer levels on straw yield (kg ha^{-1}) of quinoa at harvest

Fertilizer levels	Straw yield (kg ha^{-1})
F_1	335.25 bc
F_2	447.30 abc
F_3	222.29 c
F_4	390.42 abc
F_5	277.97 c
F_6	686.61 ab
F_7	725.04 a
LSD (0.05)	377.39

F_1 : no fertilizer
F_2 : 120kg N ha^{-1}
F_3 : 50 kg P ha^{-1}
F_4 : 50 kg K ha^{-1}
F_5 : 120 – 50 kg NP ha^{-1}
F_6 : 120 – 50 kg NK ha^{-1}
F_7 : 120 – 50 – 50- kg NPK ha^{-1}
V_1: Titicaca
V_2 : Vikinga

4.9.3 Interaction effect of variety and fertilizer levels

There were significant variations observed for biological yield (Figure 20 and Appendix VI). The highest straw yield (1039.4 kg ha^{-1}) was measured from the variety vikinga when incorporated with fertilizer levels seven that was not statistically similar with others. The lowest straw yield (109.2 kg ha^{-1}) was found from the variety 1 (titicaca) which was incorporated with fertilizer level 3 that statistically at par with V1F5 (Figure19).



F_1 : no fertilizer
F_2 : 120kg N ha^{-1}
F_3 : 50 kg P ha^{-1}
F_4 : 50 kg K ha^{-1}
F_5 : 120 – 50 kg NP ha^{-1}
F_6 : 120 – 50 kg NK ha^{-1}
F_7 : 120 – 50 – 50- kg NPK ha^{-1}
V_1: Titicaca
V_2 : Vikinga

Figure 20. Interaction effect of variety and fertilizer levels on straw yield (kg ha^{-1}) of quinoa (CV % = 72.16 , LSD $_{(0.05)}$ = 533.71)

4.10 Biological yield

4.10.1 Effect of variety:

Biological yield kg ha^{-1} showed significant variation for different varieties (Table 8). The result showed that at harvest, the higher straw yield (966.31 kg ha^{-1}) was obtained from Vikinga (V_2) and the lower straw yield obtained from (515.04 kg ha^{-1}) Titicaca (V_1).

Table 8: Effect of varieties on biological yield (kg ha^{-1}) of quinoa.

Varieties	Straw yield
V_1	515.04 b
V_2	966.31 a
LSD $_{(0.05\%)}$	238.76

V_1: Titicaca and V_2: Vikinga

4.10.2 Effect of different fertilizer levels

Biological yield kg per ha at harvest showed significant variation for different fertilizer levels (Table 9). The result revealed that at harvest, the highest straw yield (1309.8 kg ha^{-1}) was obtained from F_7 (120-50-50 kg NPK ha^{-1}) that was statistically similar with F_6 (120-50 kg NK ha^{-1}) and the lowest seed weight of $plant^{-1}$obtained from (366.7 kg ha^{-1}) F_3(50kg P ha^{-1}) that was statistically similar with F_1 (No fertilizer), F_2 (120kg N ha^{-1}), F_3(50kg P ha^{-1}), F_4 (50kg K ha^{-1}), F_5 (120-50 kg NP ha^{-1}).

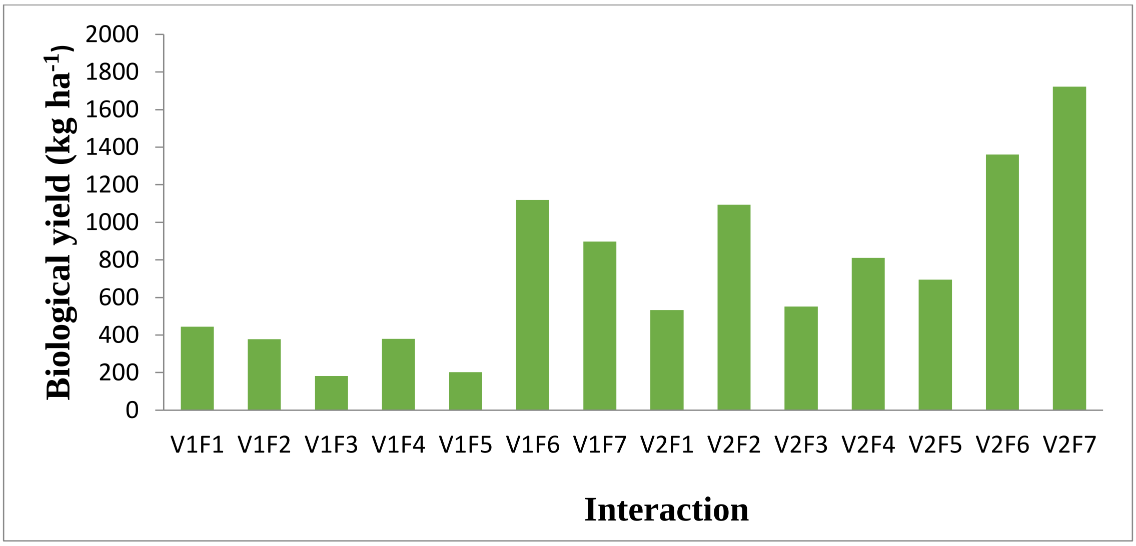
Table 9: Effect of fertilizer levels on biological yield (kg ha^{-1}) of quinoa.

Fartilizer levels	Biological yield (kg ha^{-1})
F_1	488.6 b
F_2	735.1 b
F_3	366.7 b
F_4	595.6 b
F_5	449.0 b
F_6	1240.0 a
F_7	1309.8 a
LSD $_{(0.05)}$	445.89

F_1 : no fertilizer
F_2 : 120kg N ha^{-1}
F_3 : 50 kg P ha^{-1}
F_4 : 50 kg K ha^{-1}
F_5 : 120 – 50 kg NP ha^{-1}
F_6 : 120 – 50 kg NK ha^{-1}
F_7 : 120 – 50 – 50- kg NPK ha^{-1}
V_1: Titicaca
V_2 : Vikinga

4.10.3 Interaction effect of variety and fertilizer levels

The biological yield for the interaction of variety and fertilizer levels found significant where the highest biological yield (1721.5 kg ha^{-1}) was given by V2F7 that followed by V2F6 and V1F6. The lowest biological yield (182.4 kg ha^{-1}) was observed in V1F3 that similar to V1F5 (figure 21).



F_1 : no fertilizer
F_2 : 120kg N ha^{-1}
F_3 : 50 kg P ha^{-1}
F_4 : 50 kg K ha^{-1}
F_5 : 120 – 50 kg NP ha^{-1}
F_6 : 120 – 50 kg NK ha^{-1}
F_7 : 120 – 50 – 50- kg NPK ha^{-1}
V_1: Titicaca
V_2 : Vikinga

Figure 21. Interaction effect of variety and fertilizer levels on Biological yield (kg ha^{-1}) of quinoa.

4.11 Harvest index

4.11.1 Effect of variety:

Harvest index showed non-significant variation for different varieties (Table 10). The result showed that at harvest, the higher harvest index (45.204%) was obtained from Titicaca (V_1) and the lower from (39.77 %) Vikinga (V_2).

Table 10: Effect of varieties on harvest index of quinoa (LSD $_{0.05\%}$ = NS)

Varieties	Harvest Index (%)
V_1	45.204
V_2	39.771
Lsd $_{(0.05)}$	9.85

V_1: Titicaca and V_2: Vikinga

4.11.2 Effect of fertilizer levels

Harvest index at harvest showed significant variation for different fertilizer levels (Table 11). The result revealed that at harvest, the maximum harvest index (51%) was obtained from F_6 (120-50 kg NK ha^{-1}) that and the minimum harvest index obtained from (36.85%) F_1 (No fertilizer) treated plots.

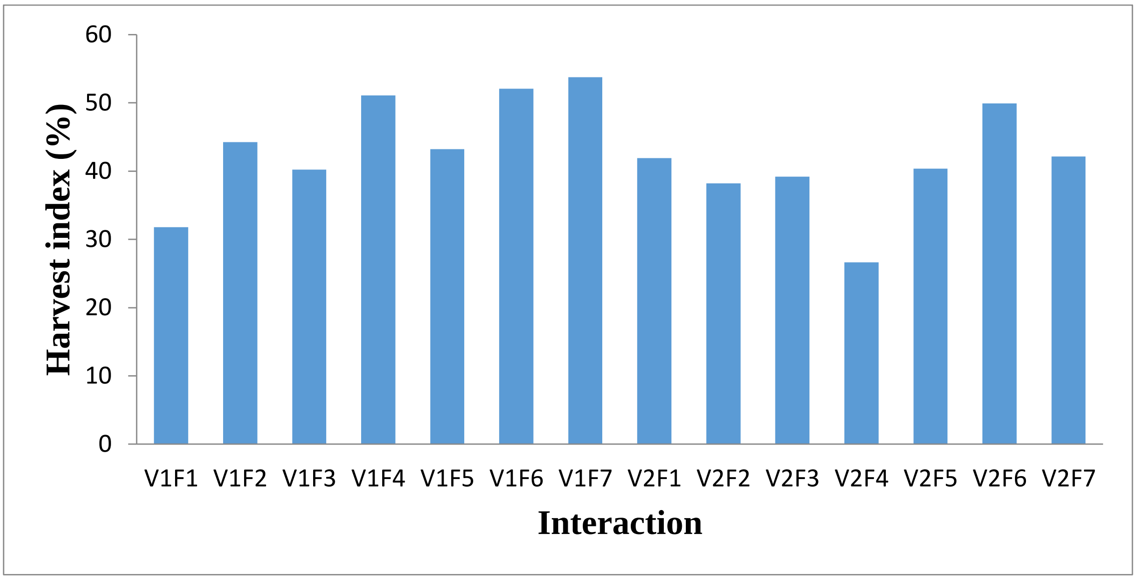
Table 11: Influence of fertilizer levels on harvest index (%) of quinoa

Fertilizer levels	Harvest index (%)
F_1	36.85
F_2	41.21
F_3	39.70
F_4	38.87
F_5	41.79
F_6	51.00
F_7	47.96
LSD $_{(0.05)}$	18.40

F_1 : no fertilizer
F_2 : 120kg N ha^{-1}
F_3 : 50 kg P ha^{-1}
F_4 : 50 kg K ha^{-1}
F_5 : 120 – 50 kg NP ha^{-1}
F_6 : 120 – 50 kg NK ha^{-1}
F_7 : 120 – 50 – 50- kg NPK ha^{-1}
V_1: Titicaca
V_2 : Vikinga

4.11.3 Interaction effect of variety and fertilizer levels

Significant variations were found for harvest index of quinoa (Appendix VII). The maximum harvest index (53.78%) was obtained from interaction of V_1F_7 which was differed with other treatments. The lowest harvest index (26.652%) was found from the fertilizer level F_4 when interacted with V_2 and it was statistically dissimilar with other (Figure 22).



F_1 : no fertilizer
F_2 : 120kg N ha^{-1}
F_3 : 50 kg P ha^{-1}
F_4 : 50 kg K ha^{-1}
F_5 : 120 – 50 kg NP ha^{-1}
F_6 : 120 – 50 kg NK ha^{-1}
F_7 : 120 – 50 – 50- kg NPK ha^{-1}
V_1: Titicaca
V_2 : Vikinga

Figure 22. Interaction effect of variety and fertilizer levels on harvest Index of quinoa (LSD $_{(0.05)}$ = 26.02)

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was conducted at the Agronomy farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the period from November 2017 to January 2018 to study the growth and yield of quinoa (*Chenopodium quinoa)* as influenced by different levels of fertilizer in Rabi season under the Modhupur Tract (AEZ-28). The treatment of the experiment consists of two varieties viz. Titicaca and Vikinga and seven fertilizer levels viz F_1 (No fertilizer), F_2 (120 kg N ha^{-1}), F_3 (50 kg P ha^{-1}), F_4 (50 kg K ha^{-1}), F_5 (120-50 kg NP ha^{-1}), F_6 (120-50 kg NK ha^{-1}), F_7 (120-50-50 kg NPK ha^{-1}). The experiment was laid out in RCBD (factorial) design following the principles of randomization with three replications. Data on different growth parameters, yield contributing characters and yield were recorded and statistically variation was observed for different treatment.

Leaf number of Titicaca was higher (20.88, 38.80 and 29.19cm respectively) at 30,45, 60 DAS than Vikinga. Plant height of Vikinga was higher (24.25, 22.73 and 23.34 cm respectively) at 45, 60 and harvest, but at 30 DAS plant height was lower (11.52) than Titicaca. At harvest, the length of inflorescence $plant^{-1}$ (14.78) was found from V_2 (Vikinga) that was higher than V_1 (Titicaca). At harvest, the higher number of branches $plant^{-1}$ (17.67) was found from V_1 (Titicaca). Straw weight $plant^{-1}$ at harvest (2.54 g) was produced by V_2 (Vikinga) and lower weight (2.504 g) was produced by V_1 (Titicaca) and both were statistically similar. The higher seed weight $plant^{-1}$ (3.50 g) was recorded by V_1 (Titicaca) and the lower seed weight $plant^{-1}$ (3.35 g) was recorded by V_2 (Vikinga) both were statistically similar. The maximum 1000 seed weight (2.5527 g) was recorded by V_2 (Vikinga) and the minimum 1000 seed weight (2.4333 g) was recorded by V_1 (Titicaca) and both were statistically similar. The maximum seed yield (383.66 kg ha^{-1}) was recorded by V_2 (Vikinga) and the minimum seed yield (216.30 kg ha^{-1}) was recorded by V_1 (Titicaca). The higher straw weight (582.65 kg ha^{-1}) was recorded in V_2 (Vikinga) where as the lower straw weight (298.74 kg ha^{-1})

was recorded in V_1 (Titicaca). The higher biological yield (966.31kg ha^{-1}) was recorded in V_2 (Vikinga) whereas the lower straw weight (515.04 kg ha^{-1}) was recorded in V_1 (Titicaca). The highest harvest index (45.204%) was recorded in V_1 (Titicaca), whereas the lower straw weight (39.771%) was recorded in V_2 (Vikinga).

For different fertilizer levels, at 30 DAS leaf number was highest (22.596) in F_7 (120-50-50 kg NPK ha^{-1}), and in 45 and 60 DAS the highest leaf number was (48.53, and 30.44) in F_6 (120-50 kg NK ha^{-1}). At 30 DAS the highest plant height was observed (15.22cm) in F_7 (120-50-50 kg NPK ha^{-1}). At 45, 60 DAS and at harvest plant height was highest (29.49, 23.40and 28.65 cm, respectively) in F_6 (120-50 kg NK ha^{-1}) and lower in 30, 45, 60 DAS (8.59, 17.9 and 20.21 cm, respectively) in F_3 (50kg P ha^{-1}) and at harvest the lowest plant height (16.65) was observed from F_1 (No fertilizer). At harvest, the highest inflorescence length $plant^{-1}$ (18.567) was produce by F_6 (120-50 kg NK ha^{-1}) and lower (10.03) by F_3 (50kg P ha^{-1}). At harvest, the maximum number of branches $plant^{-1}$ (20.03) was found from F_7 (120-50-50 kg NPK ha^{-1}) and the minimum number of branches $plant^{-1}$ (14.03) was found from F_4 (50kg K ha^{-1}). Maximum straw weight $plant^{-1}$ at harvest (4.13 g) was produced by F_7 (120-50-50 kg NPK ha^{-1}) and minimum weight (1.63 g) was produced by F_1 (No fertilizer). The highest seed weight $plant^{-1}$ (5.62 g) was recorded by F_7 (120-50-50 kg NPK ha^{-1}) and the lowest seed weight $plant^{-1}$ (2.10 g) was recorded by F_1 (No fertilizer). The maximum 1000 seed weight (2.84 g) was found from F_7 (120-50-50 kg NPK ha^{-1}) and the minimum 1000 seed weight (2.24 g) was recorded by F_3 (50kg P ha^{-1}). The maximum seed yield (553.38 kg ha^{-1}) was recorded by F_6 (120-50 kg NK ha^{-1}) and the minimum seed yield (144.40 kg ha^{-1}) was recorded by F_3 (50kg P ha^{-1}). The maximum straw yield (725.04 kg ha^{-1}) was recorded by F_7 (120-50-50 kg NPK ha^{-1}) and the minimum straw yield (222.29 kg ha^{-1}) was recorded by F_3 (50kg P ha^{-1}). The higher biological yield (1721.5 kg ha^{-1}) was recorded by F_7 (120-50-50 kg NPK ha^{-1}) and the minimum biological yield (182.4 kg ha^{-1}) was recorded by F_3 (50kg P ha^{-1}). The higher harvest index (51.0 %) was recorded by

F_6 (120-50 kg NK ha^{-1}) and the minimum harvest index (36.85 %) was recorded by F_1 (No fertilizer).

Due to interaction effect of variety and different fertilizer levels, at 30 and 45 DAS the height leaf number (29.20 and 53.66) was recorded in V_1F_7 (Titicaca with 120-50-50 kg NPK ha^{-1}), the lowest leaf number in 30 DAS (11.53, 12.60 and 14.06 respectively) were found in V_2F_4, V_2F_3 and V_1F_1 respectively, they were statistically similar. In 60 DAS the highest leaf number (32.753) was found in V_2F_6 and the lowest leaf number (24.193a) in V_2F_5. The plant height of V_1F_7 was higher (16.98) at 30 DAS, But at 45, 60 DAS and at harvest plant height was higher (34.38, 27.86, 33.59cm) in V_2F_6. At harvest, the higher inflorescence length $plant^{-1}$ (22.55cm) produced by V_2F_6 and the lower (8.953) was found from V_1F_5. The maximum number of branches $plant^{-1}$ (22.0) was found from V_1F_7 and the minimum number of branches $plant^{-1}$ (12.26) was found from V_2F_1. The higher straw weight of $plant^{-1}$ at harvest (4.46 g) was produced by V_1F_7 and minimum number (1.53) was produced by V_2F_1. The highest seed weight $plant^{-1}$ (7.08 g) was recorded by V_1F_7 and lowest weight was (2.20 g) from V_1F_3 and V_1F_5, they were statistically identical. The higher 1000 seed weight (2.82 g) was found from V_1F_6 while at harvest, the lower 1000 seed weight (2.16 g) was found from V_1F_2. The maximum seed weight (682.07 kg ha^{-1}) was recorded by V_2F_7 and the minimum seed weight (73.15 kg ha^{-1}) was recorded by V_1F_3. .Straw weight (1039.4 kg ha^{-1}) was recorded from V_2F_7 and the minimum one (133.4 kg ha^{-1}) was given by V_1F_5. At harvest the maximum biological yield (1721.5 kg ha^{-1}) was obtained from V_2F_7 and the minimum biological yield (182.4 kg ha^{-1}) was obtained from V_1F_3. At harvest the maximum harvest index (53.78%) was obtained from V_2F_7 and the minimum harvest index (26.65%) was obtained from V_2F_4.

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

- The quinoa variety, Vikinga showed higher yield than other variety.
- Out of the the different fertilizer levels 120-50kg NK ha^{-1} showed maximum growth and yield in Quinoa.

- Cultivation of Vikinga with 120-50kg NK or 120-50-50kg NPK ha^{-1} but Titicaca with 120-50-50kg NPK ha^{-1} could be better production package for maximum yield of Quinoa.

Before recommendation of variety and different fertilizer levels to optimize Quinoa production further study is needed in different agro-ecological zones of Bangladesh for regional adaptability.

REFERANCES

Azarpour, E., Bozorgi H.R. and Moraditochaee M. (2014). Effects of ascorbic acid foliar spraying and nitrogen fertilizer management in spring cultivation of quinoa (*Chenopodium quinoa*) in north of Iran. *Biological Forum*, **6**(2): 254-260.

Bilalis, D., Kakabouki I., Karkanis A., Travlos I., Triantafyllidisand V., Hela D. (2012). Seed and saponin production of organic quinoa (*Chenopodium quinoa*Willd.) for different tillage and fertilization. *Not Bot. Horti Agrobot*. *Cluj-Napoca*,**40**: 42–46.

Basra, S.M.A., Iqbal S. and Afzal I. (2014). Evaluating the response of nitrogen application on growth, development and yield of quinoa genotypes. *Int. J. Agric. Biol*. **16**(5): 886-892

Bhargava, A., Shukla, S. and Ohri. D. (2006). *Chenopodium quinoa*-An Indian perspective, *Industrial Crops and Products*, **23**: 73–87.

Bhargava, A., Shukla S. and Ohri, D. (2007). Genetic variability and interrelationship among various morphological and quality traits in quinoa (*Chenopodium quinoa*Willd.), *Field Crops Res.* **101**: 104–116.

Darwinkel, A. and Stølen, O. (1997). Understanding the quinoa crop: guidelines for growing in temperate rejoins of NW Europe.

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

Fawy, H.A. et al. (2015), Effect Of Nitrogen Fertilization And Organic Acids Ongrains Productivity And Biochemical Contents of Quinoa Plant Grown Under Soil Conditions Of Ras Sader-Sinai. *Egyptian J*. **67**(1): 169-183.

Finck, A. (1982). Fertilizer and fertilization “Introduction and practical guide to crop fertilization”. Weinheim; Deerfield Beach, Florida; Basel: Verlag Chemie. ISBN 3-527-25891-4 (Weinheim).

FAOSTAT (2013).Quinoa area and production in the World .http://www.fao.org

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

Geren, H. (2015). Effects of different nitrogen levels on the grain yield and some yield components of quinoa (*Chenopodium quinoa*Willd.)

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

Ioanna P et al. (2013), Influence of fertilization and soil tillage on nitrogen uptake and utilization efficiency of quinoa crop (Chenopodium quinoa Willd.), *J. Soil Sci Plant Nutri*. **8** (1): 220-235.

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

Jacobsen, S.E. (2003). The world potential for Quinoa (*Chenopodium quinoa* willd.). *Food Revi.* **19**: 167-177.

Koyro, H.W. and Eisa, S. (2007). Effect of salnaty on composition viability and germination of seeds of *Chenopodium quinoa* wild. *Plast soil* **302** (1): 79-90.

Kakabouki, I., Bilalis, D., Karkanis, A., Zervas, G., Tsiplakou, E. and Hela, D. (2014). Effects of fertilization and tillage system on growth and crude protein content of quinoa (*Chenopodium quinoa*Willd.): An alternative forage crop, *Emir. J. Food Agric.*, **26**(1): 18-24.

Lavini, A., Pulvento, C., Andria, R., Riccardi, M., Choukr-Allah, R., Belhabib, O., Yazar, A., Incekaya, C., Metin Sezen, S., Qadir, M. and Jacobsen, S.E. (2014). Quinoa's potential in the mediterranean region. *J. Agro.Crop Sci*., **200**:344–360.

Razzaghi, F., Ahmadi, S.H., Jensen, C.R., Jacobsen, S.E. and Andersen, M.N. (2011). The salt tolerance of quinoa measured under field conditions. *Int. Com. Irri. and Drain*., pp. 149-153.

Rojas,W., Barriga, P. and Figueroa, H (2003). Multivariate analysis of genetic diversity of Bolivian quinoa germplasm. *Food Rev. Int*. **19**:9–23.

Shams,A.S. (2012). Response of quinoa to nitrogen fertilizer rates under sandy soil conditions, Proc. 13th International Conf. Agron., Fac. of Agric., Benha Univ., Egypt, 9-10 September 2012, pp:195-205.

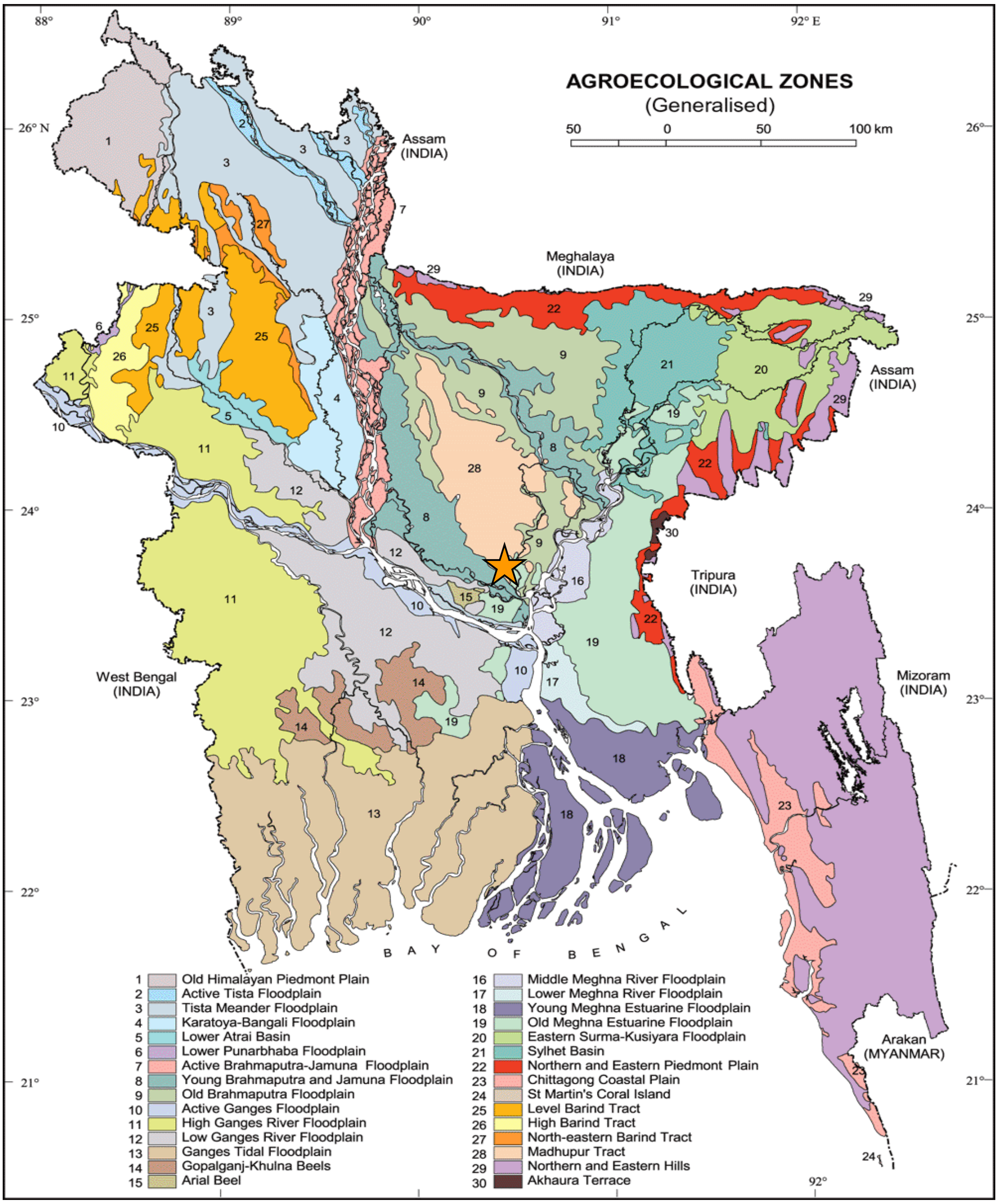
Shams, A. (2011). Response of quinoa to nitrogen fertilizer rates under sandy soilconditions. *Int J. Water Resour. Arid Environ*. **1**: 318–325.

Thanapornpoonpong, S., (2004). Effect of nitrogen fertilizer on nitrogen assimilation and seed quality of amaranth (*Amaranthus* spp.) and quinoa (*Chenopodium quinoa* Willd.). Ph.D. Thesis, Georg August University of Gottingen, Phayao, Thailand.

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

APPENDICES

Appendix I. Map showing the experimental sites under study



★ **The experimental site under study**

Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-BanglaAgricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B.The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Chemical characteristics	
Soil characters	**Value**
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

Source: Soil Resource and Development Institute (SRDI), Farmgate, Dhaka

Appendix III. Monthly average air temperature, relative humidity and total rainfall of the experimental site during the period from March to June, 2017

Month (2017)	*Air temperature (ºC)		*Relative humidity (%)	*Rainfall (mm) (total)
	Maximum	Minimum		
November	28.60	8.52	56.75	14.40
December	25.50	6.70	54.80	0.00
January	23.80	11.70	46.20	0.00
February	22.75	14.26	37.90	0.00

* Monthly average

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

Appendix IV. Mean square values of leaf number of quinoa as influenced by variety and different fertilizer levels

Source of variation	Degrees of freedom	Mean square		
		Number of leaves at		
		30 DAS	45DAS	60DAS
Replication	2	332.159	96.695	110.887
Fertilizer levels	6	64.434	425.047	16.392
Variety	1	542.569	232.587	27.484
Fertilizer levels X variety	6	47.683	83.269	34.019
Error	26	55.607	45.375	55.570
Total	41			

Appendix IV. Mean square values of plant height of quinoa as influenced by variety and different fertilizer levels

Source of variation	Degrees of freedom	Mean square			
		Plant height at			
		30 DAS	45 DAS	60 DAS	At harvest
Replication	2	0.8596	1.1319	0.4303	22.977
Fertilizer levels	6	34.1305	87.0842	67.3397	133.451
Variety	1	1.7031	59.4751	23.2041	80.433
Fertilizer levels X variety	6	8.1426	18.6478	31.2662	25.189
Error	26	121.072	18.0790	18.0817	23.338
Total	41				

Appendix V. Mean square values of number of branches plant^{-1} of , length inflorescence, straw weight plant^{-1}, Seed weight plant^{-1} of quinoa as influenced by Variety and different fertilizer levels

Source of variation	Degrees of freedom	Mean square			
		At harvest			
		Branch Number Plant^{-1}	Length Of inflorescence	straw weight plant^{-1}	Seed weight Plant^{-1}
Replication	2	16.8257	22.1896	0.61429	0.6815
Fertilizer levels	6	33.4600	76.0135	5.69022	12.8516
Variety	1	32.7492	56.8081	0.01575	0.2318
Fertilizer levels X variety	6	19.2013	14.2156	0.34829	2.7696
Error	26	14.7248	10.6798	0.62864	0.9625
Total	41				

Appendix VI. Mean square values of seed weight, straw weight , 1000-Seed weigh, biological yield of quinoa as influenced by Variety and different fertilizer levels

Source of variation	Degrees of freedom	Mean square			
		At harvest			
		Seed weight	straw weight	1000-Seed weight	biological yield
Replication	2	18961	22960	0.17065	77701
Fertilizer levels	6	214773	227215	0.29301	874806
Variety	1	293052	843324	0.10098	2130630
Fertilizer levels X variety	6	7548	91347	0.05287	97642
Error	26	13398	101126	0.07352	141166
Total	41				

* Significant at 5% level

Appendix VII. Mean square values of harvest index of quinoa as influenced by Variety and different fertilizer levels

Source of variation	Degrees of freedom	Mean square
		harvest index (%) at
		Harvest
Replication	2	6.485
Fertilizer levels	6	156.543
Variety	1	308.796
Fertilizer levels X variety	6	169.695
Error	26	240.440
Total	41	