GROWTH AND YIELD OF QUINOA (*Chenopodium quinoa*) AS AFFECTED BY SOWING DATE

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CERTIFICATE

This is to certify that the thesis entitled "**GROWTH AND YIELD OF QUINOA (*Chenopodium quinoa*) AS AFFECTED BY SOWING DATE**" submitted to the Institute of Seed Technology, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **Master of Science** in **Seed Technology**, embodies the result of a piece of bona fide research work carried out by **ZAMIN AKTER TANNI**, Registration number: **16-07585** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:
Dhaka, Bangladesh

Prof. Dr. Parimal Kanti Biswas
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DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

A field experiment was carried out at the research field of Sher-e-Bangla Agricultural University, Dhaka during the period of November to May, 2017-2018 to study the effect of variety and sowing date on growth and yield of quinoa. The experiment comprised of two factors; Factor A: Variety (2) viz. Titicaca (V_1) and Vikinga (V_2) and Factor B: sowing date (5) viz. S_1 (Nov-10), S_2 (Dec-10), S_3 (Jan-10), S_4 (Feb-10) and S_5 (Mar-10). The experiment was laid out in split-plot design with three replications. Data on different growth parameters, yield attributes and yield were significantly varied for different parameters. The highest plant height (63.75 cm), highest fresh straw weight of plant^{-1} (23.47 g) and (372.54 kg ha^{-1}) , dry straw weight of plant^{-1} (2.65 g), and (31.91 kg ha^{-1}), 1000-seed weight (2.04 g) seed weight plant^{-1} (3.16 g) and (52.22 kg ha^{-1}) and husk weight (17.13 kg ha^{-1}) was found from Titicaca variety. The sowing date resulted higher plant height (72.83 cm), highest fresh straw weight of plant^{-1} (36.67 g) and (614.31 kg ha^{-1}), dry straw weight of plant^{-1} (4.13 g) and (69.12 kg ha^{-1}), 1000-seed weight (2.58 g), seed weight plant^{-1} (7.47 g) and (180.01 kg ha^{-1}) and husk weight (42.46 kg ha^{-1}) was obtain from V_1S_1. Highest branch No. (25.88) provide by $V_1S_{3,}$ Higher inflorescence No. (31.46) and inflorescence diameter (14.41 cm) in $V_2S_{2.}$ From the above results it was appeared that Titicaca with sowing date November provided the best yield attributes and yield of quinoa.

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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* wild) is a yearly herbaceous plant which belongs to Amaranthaceae family, but once located in Chenopodiaceae family that originated in the appeasing slopes of the Andes in South America. It was cultivated and tattered by the Inca (ruling class) people since 5,000 B.C. It is obsessive in broad diversity of forms i.e., grains, flakes, pasta, bread, biscuits, beverages, meals etc. Quinoa is revealed as a strength rations by North Americans and Europeans in the 1970's and its reputation is dramatically increased in recent years because it is gluten-free (helpful for diabetic patients) and high in protein. In India, quinoa was refined in an area of 440 hectares with a standard yield of 1053 tons (Srinivasa, 2015). It is refined in the world with an area of 126 thousand hectares with a manufacture of 103 thousand tons. 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).

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 ash substance is 3.4 per cent containing high amount of Ca, Fe, Zn, Cu and Mn. The oil content is 1.8 to 9.5 per cent and loaded in necessary fatty acids like linoleate and linolenate. In adding up, quinoa seed is wealthy in thiamine (0.4 mg), folic acid (78.1 mg), vitamin C (16.4 mg), riboflavin (0.39 mg) and carotene (0.39 mg) in 100 g seed respectively. The calorific assessment is 350 cal per 100 g grains and is bigger than that of additional cereal and legume foods. The digest ability of quinoa protein is more than 80 per cent. In adding up to higher than dietary factors, the quiona grain is supple, gluten free, gets cooked rapidly and has an enjoyable flavor. Quinoa also have usual defiant

Oxidants like α-tocopheral (5.3 mg), γ-tocopheral (2.6 mg) in 100 g seed and phytoestrogens that avoid regular diseases such as osteoporosis, breast cancer, heart diseases and additional feminine troubles caused by require of estrogen during the menopause. Hence FAO nominated 2013 as International year of Quinoa (Bhargava *et al.*, 2006).

Quinoa is a quick-rising plant, grows up to 2 m tall with exchange, 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 produce hundreds of little achiness, approximately 2 mm in width. Quinoa is an achene (a seed-similar to fruit with a firm fur) with diversified colors ranging from white or pale yellow to orange, red, brown and black. Quinoa has superior smoothness of revision to photoperiod, altitude, soil pH etc. It can be developed from marine stage to 3,900 meters over denote marine stage and pH choice of 6 to 8.5 and warmth from sub-tropical to tropical and humid areas. The stand temperature of quinoa is 30 C with most favorable temperature of 15-300 C and can stand highest temperature of 500 C. Quinoa seems to be a quantitative small day type where the extent of the vegetative stage depends not just on the day duration and opportunity of the origin but also on elevation of starting point (Rishi and Galwey, 1984).

Rising time of quinoa diverse among 70 to 120 days and several entries did not grown-up in some locations. The research conducted to assess quinoa entries in America, Europe and Africa and reported that rising stage of quinoa in Kenya was 65-98 days and all cultivars developed by seed yield of 4000 kg ha^{-1}. In Denmark and Sweden, growing period was 120-160 days but yields were low down and only some varieties matured. The rising time in Greece was 110-160 days and the yield was 2000 kg ha^{-1} (Jacobsen, 2003). Quinoa can cooperate a most important part in future diversification of agriculture arrangement in India. In spite of its broad flexibility, dietary control, its profitable latent has remained unexploited. Quinoa is cold time of year crop and can be cultivated in rabi season. Literature on most favorable compactness, seed rate, spacing and other agro techniques for its cultivation in India is scanty. Optimum plant density for high yield as 220 - 327 plants m^{-2} and found large standard deviation indicating that similar yields may be obtained from a wide range of densities (Jacobsen, 2003).

There is no research has been conducted regarding Quinoa. Before this research no one of our country take any initiatives to introduce this crop. In our neighboring country India, very little research work has been done on the adoptability and standardization of pack up of practices of quinoa in. Bhargava *et al*. (2006) studied about hereditary unpredictability and adjustment in North India and reported that entries originated from inter- Andean valleys of Bolivia that are white or yellow in color with little size are more adoptable than additional entries. Andhra Pradesh Academy of Rural Development (APARD), Hyderabad initiated center funded project “Project Anantha” to development the invention and yield and in turn net earnings of farmers of Anantapur and tested quinoa as alternating crop to ground nut. They reported that quinoa (yellow color entry) has taken 90-120 days and produced average yield of 760 kg ha^{-1} (APARD, 2013-14). Optimum planting time is first step and measured as a base that leads to growth of appropriate manufacture technology particularly for a new-fangled crop in a particular area (Sajjad *et al*., 2014). Hence, an experiment was wished-for permitted “Evaluation of Quinoa (*Chenopodium quinoa* wild). At dissimilar dates of sowing and varied crop geometry in Bangladesh” during Rabi season, with the subsequent objectives.

1. Detection of appropriate date of sowing of quinoa in Bangladesh.

2. To find out the suitable variety of quinoa.

3. To find out suitable combination of variety and sowing date.

CHAPTER-II

REVIEW OF LITERATURE

This current study allowed "Introduction of two Quinoa (*Chenopodium quinoa* Wild.) Varieties at different dates of sowing. was lead through rabi season, 2015-16.The obtainable evidence on consequence of dates of sowing of quinoa at varieties on growth limits, yield, yield attaching typescripts and eminence of quinoa are appraised below suitable headers. As evidence on convinced types of quinoa is revealing, the evidence on crops associated to family Amaranthaceae also involved.

2.1 Performance of quinoa at different dates of sowing

2.1.1 Growth parameters

2.1.1.1 Plant height

Bill (2014) tested spring planted quinoa nursery grown-up at Malheur research station, Ontario, Canada, by implanting seven different cultivars (Brightest brilliant rainbow, Cherry vanilla, French vanilla, Kentucky black, Mint vanilla, Oro De valle, Red head) at two dates of sowing (24th June and 7th October) and found that the plant height was highest in Red head cultivar at 7th October (152 cm) date of sowing.

Fernando *et al*. (2012) assessed quinoa with six dissimilar dates (18 March, 2 April, 17 April, 2 May, and 10 June) during 2008 and they found that plant height at 18 March (77.5 cm) and at 17 April were on par with each other and developed significantly taller than 2 May date of sowing in off-season at Campo Mourao, Brazil.

Troiani *et al.* (2004) experimented *Amaranthus cruentus* L. in semi-arid Argentine Pampa to found the best sowing date for grain production and establish that plant height was higher when sowing was accomplished from the second half of the November to the end of December.

Hakan *et al.* (2014) studied six dates of sowing (1st March, 15th March, 1st April, 15th April, 1st May, 15th May) and found that plant height at 1st April (111.7 cm) and at 15th April were on par with each other and propagated significantly taller than 1st March date of sowing below Mediterranean ecological circumstances of Bornova-Izmir, Turkey.

Parvin *et al*. (2013) exposed that plant height varied with dates of sowing of Amaranth and found that plant height at 10thApril (83.5 cm) was significantly taller than 26th March (52.6 cm) and 25thApril (52.5 cm) at 40 days after sowing.

Yarnia (2010) informed that plant height varied with dates of sowing of amaranth and found that plant height at 20th April (70.33 cm) and 5th May (61.17 cm) were on par with each other and considerably grew taller than the 3rd June (49.6 cm) date of sowing at Islamic Azad University, Iran.

2.1.1.2 Leaf area

Yarnia (2010) tested leaf area of amaranth with five sowing dates (April 20th, May 5th, May 20th, June 3rd, June 18th) and found that 5th May (206.3 cm^2 $plant^{-1}$) date of sowing was recorded significantly higher leaf area than April 20th (117.7 cm^2 $plant^{-1}$), May 20th (163.4 cm^2 $plant^{-1}$), June 3rd (124.1 cm^2 $plant^{-1}$), June 18 th (61.2 cm^2 $plant^{-1}$) dates of sowing with planting density of 10 plants m^{-2} at Islamic Azad University, Iran.

2.1.1.3 Dry matter production and partitioning

Hirich *et al*. (2014) reported that 1st December (7.89 t ha^{-1}) and 15th November (7.01 t ha^{-1}) were found to record significantly higher dry matter production of quinoa than 15th March date of sowing among ten dates of sowing at an interval of 15 days from 1st November to 15th March. He further informed higher dry matter partitioning towards leaf, stem, and panicle (11.28, 20.90, and 57.47 g $plant^{-1}$) and in turn higher seed yield in 15th November date of sowing at Agadir, Morocco.

Lizica and Bjarne (2014) revealed that among four quinoa varieties (Jason Red, Jacobsen 2, Mixed Jacobsen and Jorgen), dry weight (g $plant^{-1}$) of Jacobsen 2 variety (30 g plant^{-1}) was the significantly higher than Jason Red (24.0 g plant^{-1}), Mixed Jacobsen (24.6 g plant^{-1}), Jorgen (20.1 g plant^{-1}) varieties under climatic conditions of University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania.

2.1.2 Yield Attributes and Yield

2.1.2.1 Days to 50 per cent flowering and maturity

Lizica and Bjarne (2014) reported that Jason red variety of quinoa took (130 days) significantly the least days to maturity compared to Jacobsen 2 (140 days), Mixed Jacobsen (138 days) and Jorgen (135 days) varieties under climatic conditions of Romania.

Sajjad *et al*. (2014) observed that 15th December (46.6 days) took significantly least number of days for 50 per cent flowering of quinoa than 15th January (55.9 days) date of sowing at Faisalabad, Pakistan. Rishi and Galwey (1991) reported that 14th April date of sowing took significantly the least number of days (70 days) for 50 per cent flowering of Baer variety of quinoa compared to 25th March (81 days) date of sowing in sandy clay loam soil at University farm, Cambridge, United Kingdom. They further inferred that 25th March date of sowing took least number of days to maturity (161 days) compared to 14th April (218 days) date of sowing.

2.1.2.2 Number of panicles plant^{-1}

Hakan Geren *et al*. (2014) revealed that 1st April (39.2) and 15th April (38.5) dates of sowing formed significantly higher number of panicles plant^{-1} than 1st March (15.2) date of sowing under Mediterranean ecological conditions of Bornova-Izmir, Turkey.

Yarnia (2010) found that the number of inflorescence (panicle) plant^{-1} of amaranth varied with date of sowing and 20th April (2.35) and 5th May (1.80) dates of sowing were on par with each other and produced considerably higher number of panicles plant^{-1} than 18th June date of sowing at Islamic Azad University, Iran.

2.1.2.3 Length of panicle, length of spikelet and number of grains panicle^{-1}

The trial was conducted to determine the effect of sowing dates on quinoa at Bornova Izmir, Turkey and found that 1st April (49.6 cm) and 15thApril (49.9 cm) produced significantly higher panicle length than 15th May (30.9 cm) date of sowing. (Hakan Geren *et al*., 2014).

Chaudhari *et al*. (2009) reported that 1st November (44.6 cm) and 15th November (39.4 cm) obtained significantly higher panicle length of grain amaranths than 15th December (32.7 cm) date of sowing. They also reported that 1st November (11.1 cm) showed significantly higher length of spikelets in grain amaranth than 15th December (8.1 cm) date of sowing at Navsari, Gujarat.

Sajjad *et al*. (2014) reported that 15th December (38.63 cm) had significantly higher panicle length than 15th January (31.97 cm) date of sowing at Faisalabad, Pakistan.

Yarnia (2010) concluded that grain number plant^{-1} of amaranth varied with date of sowing. The 20th April (7037) date of sowing and 5th May (5436) date of sowing were on par with each other and were significantly higher than 18th June (2010) at Islamic Azad University, Iran.

2.1.2.4 Test weight (1000 grain weight)

Chaudhari *et al*. (2009) recorded that 1st November (0.60 g) and 15th November (0.56 g) obtained significantly higher test weight of grain amaranthus than 15th December (0.49 g) date of sowing at Navsari, Gujarat.

Hakan *et al.* (2014) observed that 1st March (3.4 g) and 15th May (3.2 g) did not differ significantly in test weight of quinoa under Mediterranean ecological conditions of Bornova-Izmir, Turkey.

In the field trials of quinoa crop conducted at Faisalabad, Pakistan, test weight of 15th December (2.70 g) date of sowing was significantly higher than 15th January (2.60 g) date of sowing (Sajjad *et al*., 2014).

2.1.2.5 Seed yield

Chaudhari *et al*. (2009) reported that grain yield of amaranths in 1st November (1232 kg ha^{-1}) and 15th November (1171 kg ha^{-1}) date of sowing were on par with each other and significantly higher than 15th December date of sowing crop at Navsari, Gujarat.

Hakan *et al*. (2014) inferred that 1st April (217.9 kg ha^{-1}) and 15th April (216.6 kg ha^{-1}) produced significantly higher seed yield of quinoa than 1st March (150.6 kg ha^{-1}) date of sowing under Mediterranean ecological conditions of Bornova-Izmir, Turkey.

Hirich *et al* .(2014) found that seed yield of Quinoa during 1st November(3.03 t ha^{-1}), 15th November(3.07 t ha^{-1}) and 1st December (2.47 t ha^{-1}) dates of sowing were on par with each other and significantly higher than 15th March (0.13 t ha^{-1}) date of sowing at Agadir, Morocco.

Rishi and Galwey (1991) tested three sowing dates (25th March, 14th April and 7th May) and found that Baer variety of quinoa sown on 25th March (6.96 t ha^{-1}) recorded significantly higher grain yield than Blanca de Junin variety in sandy clay loam soil at University farm, Cambridge, United Kingdom.

Sajjad *et al*. (2014) reported that 15th December (285.93 kg ha^{-1}) was found to recorded significantly higher grain yield than 15th January (215.18 kg ha^{-1}) date of sowing at University of Faisalabad, Pakistan.

2.1.2.6 Stalk yield

Sajjad *et al*. (2014) observed significantly higher stalk yield of quinoa (6994 kg ha^{-1}) in 15th December than 15th January (6519 kg ha^{-1}) date of sowing at University of Faisalabd, Pakistan.

Parvin *et al.* (2013) reported that stalk yield of amaranth varied with dates of sowing and spacing and found that 10th April with 20×15 cm (91.4 t ha^{-1}), 10th April with 20×20 cm and 10th April 20×25 cm were on par with each other and significantly higher than 25th April with 20×30 cm (47.1 t ha^{-1}) when grown in sandy loam soil at Horticultural farm, Sher-e-Bangla Agricultural University, Dhaka.

Chaudhari *et al.* (2009) reported that 1st November (2161 kg ha^{-1}), 15th November (2095 kg ha^{-1}) were on par with each other and noted significantly higher stalk yield than 15th December date of sowing of *Amaranthus* crop at Navsari, Gujarat.

Bhargava *et al.* (2007) tested three sowing dates (November 15, 30 and December 15) on foliage yield of quinoa and found that the highest foliage yield (3 cuts) was achieved at November 15th (18.99 tons ha^{-1}) date of sowing at Amity University, Lucknow, India.

2.1.2.7 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.

Hakan Geren *et al*. (2014) revealed that the harvest index of 1st April (49.6) and 15th April (51.9) date of sowing were on par with each other and significantly higher than 1st March date of sowing under Mediterranean organic conditions of Bornova Izmir, Turkey.

Hirich *et al*. (2014) observed that 1st November (45), 15th November (43) were not significantly different in their harvest index but these dates of sowing were significantly higher than 1st March date of sowing of quinoa at Agadir, Morocco.

The field trials were performed with *Amaranthus cruentus* L. in semi-arid Argentine Pampa region to establish the best sowing date and found that sowing performed from the second half of the November to the end of December recorded significantly higher harvest index as associated with the other dates of sowing. (Troiani *et al*., 2004).

2.1.3 Physiological growth parameters

Physiological growth parameters are indicators of increment of crop growth at different crop growth stages. Literature pertaining to crop growth rate, relative growth rate and net assimilation rate of quinoa and also amaranths is not available for reference.

Hirich *et al*. (2014) reported that growing degree days increased slightly from November to February, and then increasing rate started to be higher up to 2400 degree days till May. He further observed that photoperiod varied from November to May with lowest photoperiod in the end of December and highest photoperiod in May at Morocco.

Hirich *et al*. (2014) studied growth and development of quinoa at varied sowing dates of sowing from 1st November to 15th March and found that growing period is less (75 days) in 15th March sowing and in 1st December to 1st January sowing (130134 days). He found that rise in temperature decrease the growing period of quinoa. However, higher seed yield is informed in 15th November sowing with 121 days growing period because of higher dry matter separating towards generative parts (panicle) at Morocco.

2.1.4 Quality parameters

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

Bhargava *et al.* (2007) tested three sowing dates (November 15, 30 and December 15) on leaf protein content of quinoa and found considerably higher leaf protein content in 30th November (3.88 %) date of sowing than 15th December (3.50 %) at Amity University, Lucknow, India.

Silva *et al.* (2012) revealed that protein content in grain amaranth was significantly higher (16.5%) at June date of sowing as associated with May date of sowing, when G6 variety was sown in a sandy loam soil at University of Agriculture Centre, Slovenia, European Union.

Yarnia (2010) studied five sowing dates (April 20, May 5, May 20, June 3, June 18) on seed protein per cent of amaranth and found that significantly higher seed protein content was noticed on April 20 (8.81%) date of sowing than May 5 (5.1%), May 20 (5.0%) June 3 (5.0%) June 18 (4.1%) dates of sowing at planting density of 40 plants m^{-2}. Significantly higher seed oil was recorded on June18 (47.7%) sowing date than April 20 (2.0%), May 5 (9.5%), May 20 (20.7%), June 3 (25.1%) dates of sowing at planting density of 10 plants m-2 at Islamic Azad University, Iran.

2.1.5 Economics

Chaudhari *et al*. (2009) found that 1st November sowing of amaranth produced significantly higher B: C ratio (2.61) than 15th December date of sowing at Navsari, Gujarat.

2.2 Effect of crop geometry on growth, yield and quality of quinoa.

2.2.1 Growth parameters

2.2.1.1 Plant population

Law-Ogbomo and Ajayi (2009) revealed that the plant population of *Amaranthus cruentus* was significantly pretentious by varying row spacing and 30 × 30 cm gave maximum plant population of 1,11,111 plants ha^{-1} which was significantly higher than 45 × 45 cm that gave 62,500 plants ha^{-1} at Nigeria.

Olofintoye *et al*. (2015) studied two varieties of amaranth, TE81/28, CEN18/97 established at three planting densities (100000, 60000, 40000 plants ha^{-1}) and found that planting density did not show significant effect on the biological yield of amaranth crop in sandy loam soil at National Horticultural Research Institute, Nigeria.

Pourfarid *et al*. (2014) tested two genotypes of Amaranth, Amar and Anna at four densities (17, 35, 70, 140 plants m^{-2}) by hand thinning at a row spacing of 30 cm and found optimum yield from plant population of 140 plants m^{-2} at Tehran.

Carlos Roberto and Juliana Rocha (2008) tested plant densities varying between 1,00,000 to 6,00,000 plants ha^{-1} and reported that grain and biomass yield were not affected by varying plant densities and showed strange ability of quinoa to compensate for missing plants by amplified vigor and branching.

2.2.1.2 Plant height

Carlos Roberto and Juliana Rocha (2008) tested plant densities variable between 100000 to 600000 plants ha^{-1} and reported that plant height was expressively pretentious by varying plant densities and plant height was negatively associated with growing density of quinoa plants at Brazil.

Law-Ogbomo and Ajayi (2009) reported that Plant height of *Amaranthus cruentus* at row spacing 30 cm×30 cm (36.80 cm) was significantly greater than 45 cm×45 cm (29.60 cm) at four weeks after transplanting, when treated with different poultry manure treatments at Nigeria.

Pourfarid *et al*. (2014) tested two genotypes of Amaranth, Amar and Anna established at four densities (17, 35, 70, 140 plants m^{-2}) by hand thinning at a row spacing of 30 cm and found that the plant height was not significantly influenced with plant density levels at Tehran.

Rishi and Galwey (1991) reported that plant height of Baer variety of quinoa at wider row spacing of 40 cm (141 cm) was significantly higher compared to narrow row spacing of 20 cm (136 cm), in sandy clay loam soil at University farm, Cambridge, United Kingdom.

Smitha *et al*. (2011) observed significant increase in plant height of Amaranth with 30 cm row spacing (93.29 cm) and grew taller than plants growing at 45 cm row spacing (89.07) on clay soils during kharif at University of Agricultural Sciences, Dharwad, Karnataka.

2.2.1.3 Leaf Area (cm^2 plant^{-1}) and leaf area index

Law-Ogbomo and Ajayi (2009) revealed that leaf Area Index (LAI) of *Amaranthus cruentus* at row spacing 30 cm × 30 cm (8.71) was significantly higher than 45 cm × 45 cm (7.3) at six weeks after transplanting at Nigeria.

Pourfarid *et al.* (2014) reported that leaf area index (LAI) of Amaranth varied significantly due to different plant densities as the highest LAI (12.5) was saw at 140 plants m^{-2} than at 17 plants m^{-2} (6.1) at Tehran University.

Smitha *et al*. (2011) recorded that leaf area of Amaranth in row spacing of 30 cm (62.1 cm^2 $plant^{-1}$) and 45 cm (62.0 cm^2 $plant^{-1}$) were found to be non-significant.

Yarnia (2010) studied four planting densities (10, 20, 30, 40 plants m^{-2}) of amaranth crop and found that the leaf area obtained was significantly higher at planting density of 10 plants m^{-2} (206.3 cm^2 $plant^{-1}$) than 20 plants m^{-2} (165.8 cm^2 $plant^{-1}$), 30 plants m^{-2} (95.8 cm^2 $plant^{-1}$), 40 (87.8 cm^2 $plant^{-1}$) plants m^{-2} on May 5th date of sowing at Islamic Azad University, Iran.

2.2.1.4 Dry matter production and partitioning

Law-Ogbomo and Ajayi (2009) observed that row spacing of 30 × 30 cm produced significantly higher dry matter (10.5 g $plant^{-1}$) than row spacing of 45×45cm (7.6 g $Plant^{-1}$) at four weeks after transplanting of *Amaranthus cruentus* at Nigeria.

Olofintoye *et al.* (2015) reported that dry matter production (g $plant^{-1}$) was found to be significantly higher with planting density of 40000 plants ha^{-1} (157.01g $plant^{-1}$) than planting density of 100000 plants ha^{-1} (139.11 g $plant^{-1}$) and 60000 plants ha^{-1} (153.94 g $plant^{-1}$) of grain amaranth crop in sandy loam soil at National Horticultural Research Institute, Nigeria.

Pourfarid *et al.* (2014) referred that total dry matter production of Amaranth was significantly higher at planting density of 140 plants m^{-2} (2.41kg) than 17 plants m^{-2} (0.33 kg), 35 plants m^{-2} (0.62 kg), 70 plants m^{-2} (1.13 kg) respectively at Tehran University.

Prommarak (2014) reported that dry matter production in quinoa was significantly higher (15267 kg ha^{-1}) at harvest with row spacing of 30 cm when associated with row spacing of 40 cm (9938 kg ha^{-1}) and 50 cm (10560 kg ha^{-1}) respectively by testing Temuco variety of quinoa at Thailand.

Smitha *et al.* (2011) revealed that row spacing of 30 cm (59.51 g plant^{-1}) and row spacing of 45 cm (62.55 g plant^{-1}) were non-significant for dry matter production of Amaranth at University of Agricultural Sciences, Dharwad, Karnataka.

2.2.1.5 Physiological growth parameters

Law-Ogbomo and Ajayi (2009) tested plant densities and poultry manure doses and found that the crop growth rate (g m^{-2} w^{-1}) was varied significantly due to row spacing and higher CGR (2.15) was observed at 30 cm × 30 cm than at 45 cm × 45 cm (1.33) at eight weeks after transplanting.

2.2.1.6 Days to 50 per cent flowering and maturity

Rishi and Galwey (1991) reported that days taken to 50 percent flowering was found to be non-significant between wider row spacing of 40 cm (79.3) and narrow row spacing of 20 cm (79.0) of Baer variety of quinoa sown in a sandy clay loam soil at University farm, Cambridge, United Kingdom. They also observed narrow row spacing of 20 cm (146 days) took the lowest number of days compared to wider row spacing of 40 cm (150 days) for maturity of Baer variety of quinoa at University farm, Cambridge, United Kingdom. 2.2.2 Yield Attributes and Yield

2.2.2.1 Yield Attributes

Carlos Roberto and Juliana Rocha (2008) tested plant densities varying between 100000 to 600000 plants ha^{-1} and reported that test weight was not affected by varying plant densities of quinoa plants at Brazil.

Pourfarid *et al.* (2014) reported that test weight of Amaranth was found to be significantly higher at planting density of 17 plants m^{-2} (0.73 g) than the planting density of 140 plants m^{-2} (0.58 g) when tested with two varieties Amar and Anna at Tehran University.

2.2.2.2 Seed yield and stalk yield

Bhargava *et al*. (2007) tested three row spacing (15, 20, 25 cm) on foliage yield of quinoa and found that the highest foliage yield (3 cuts) was obtained at 25 cm (18.9 t ha^{-1}) spacing at Amity University, Lucknow, India.

Carlos Roberto and Juliana Rocha (2008) studied plant densities varying between 100000 to 600000 plants ha^{-1} and reported that grain and biomass yield was not affected by varying plant densities of quinoa plants at Brazil.

Olofintoye *et al*. (2015) reported that the seed yield of amaranth at planting density of 60000 plants ha-1 (3330 kg ha^{-1}) was significantly higher than the planting density of 100000 plants ha^{-1} (2799 kg ha^{-1}) and 40000 plants ha^{-1} (3211 kg ha^{-1}) in a sandy loam soil of National Horticultural Research Institute, Nigeria.

Pourfarid *et al*. (2014) found that the grain yield recorded significantly higher at planting density of 140 plants m^{-2} (1.04 kg ha^{-1}) than planting density was 17 (0.18 kg ha^{-1}), 35 (0.29 kg ha^{-1}), 70 (0.73 kg ha^{-1}) plants m^{-2} when tested with Amar and Anna varieties of amaranths at Tehran University.

Smitha *et al*. (2011) revealed that the seed rate of 2.5 kg ha^{-1} produced higher green forage yield (36.30 t ha^{-1}) compared to seed rate of 3 kg ha^{-1} (32.57 t ha^{-1}). However, seed rate of 2.5 kg ha^{-1} was on par with seed rate of 2 kg ha^{-1} (34.92 t ha^{-1}) in Amaranth at University of Agricultural Sciences, Dharwad, Karnataka

2.2.2.3 Harvest index

Carlos Roberto and Juliana Rocha (2008) studied plant densities varying between 100000 to 600000 plants ha^{-1} and found that harvest Index was non-significant by varying plant densities of quinoa plants at Brazil.

Olofintoye *et al*. (2015) reported that the harvest index at planting density of 100000 plants ha-1 (10.51) was significantly higher than the planting density of 60000 plants ha-1 (9.67), 40000 plants ha^{-1} (9.53) and these two planting densities were on par with each other for grain amaranth in sandy loam soil at National Horticultural Research Institute, Nigeria.

2.2.3 Quality parameters

2.2.3.1 Protein content (%) in grain and oil content (%) in quinoa grain

Bhargava *et al.* (2007) tested three row spacings (15, 20, 25 cm) on leaf protein content of quinoa and found that higher leaf protein content was obtained at row spacing of 15 cm (3.88%) associated to row spacing of 20 cm (3.71%) and 25 cm (3.57%) at Amity University, Lucknow, India.

Yarnia (2010) studied four planting densities (10, 20, 30, 40 plants m^{-2}) on seed protein per cent of amaranth and found that 10 plants m^{-2} (8.5%) and 40 plants m^{-2} (8.8%) were on par and significantly higher than 20 plants m^{-2} (7.1%) and 30 plants m^{-2} (7.3%) at 20th April date of sowing at Islamic Azad University, Iran. He further reported that seed oil per cent of amaranth was significantly higher at 10 plants m^{-2} (47.4%) than 20 plants m^{-2} (37.1%), 30 plants m-2 (36.7%) , 40 plants m^{-2} (36.1%) on 18th June date of sowing at Islamic Azad University, Iran.

2.2.4 Economics

Smitha *et al.* (2011) reported that net returns (18238 ha^{-1}) and benefit cost ratio (2.98) was significantly higher at row spacing of 45 cm than net returns (15126 ha^{-1}) and B:C ratio (2.64) at row spacing of 30 cm in Amaranth at University of Agricultural Sciences, Dharwad, Karnataka.

Smitha *et al.* (2011) reported that the seed rate of 2.5 kg ha^{-1} was recorded net returns of (17700 ha^{-1}) and benefit cost ratio of (2.92) and was on par with seed rate (2 kg ha^{-1}) and significantly higher than seed rate of 3 kg ha^{-1} that had net returns (15180 ha^{-1}) and B:C ratio (2.64) of Amaranth at University of Agricultural Sciences, Dharwad, Karnataka.

2.3 Effect of climatic parameters on growth and yield of quinoa.

2.3.1 Growth parameters

Bertero (2001) studied the relationship between leaf number and time from emergence in four dates of sowing i.e., November 1991, July 1992, February

1993, January 1994. Among all these dates, the leaf number was found to be higher during January 1994 (45 leaves) at date of sowing from 40-60 days from appearance than other dates that were to be found distributed with less number of leaves in Argentina.

Bertero *et al.* (1999) reported that effect of photoperiod on phasic development of quinoa and found that plants grown in short day (10 h) until anthesis produced seed and measured 66 days after anthesis were four fold larger in diameter than seed on plants grown in long day (14 h). Seed diameter was also found to be reduced by 24 per cent in long day for anthesis and 14 per cent by high temperature (28^{o}C), but combination of high temperature with long day gave the greatest inhibition of seed growth (73%).

Christiansen *et al.* (2010) observed that plant height (cm) of quinoa was positively affected by increased day length in Q52 variety of quinoa and reported that stem height increased from 42.8 cm under short day (10 h) to 57.9 cm under long day (14 h) but no significant difference in the length of the inflorescence. But stronger effect was observed in Real variety, which showed stem height increase from 45.3 cm under short day to 90.7 cm under long day and inflorescence from 12.8 cm to 46.7 cm. He further contingent that sensitivity to day length can also be described by the number of leaves formed on the main stem. Both varieties (Q52 and Real) formed more leaf nodes under long day treatment than under short day treatment, indicating that some sensitivity to day length remains in Q52 even though this was not evident from the assessed time to flowering. The number of nodes increased from 27.7 to 40.0 in Q52 and from 19.0 to 39.9 in Real variety at Denmark.

Jacobsen *et al.* (1999) observed that light had no influence on the germination rate. The number of seeds germinated was affected significantly by harvest time, moisture content of the seed at harvest and temperature. At higher temperatures, seed germinated quickly regardless of harvest time and moisture content of the seed at harvest, so that at 20^{o}C, average germination was 99%, while at 10^{o}C average germination was reduced to 85%. Lowering the temperature to 6o C reduced average germination to 25%. Drying seeds after harvest at 35°C resulted in 2% higher germination than drying at 25°C at Denmark.

Krzysztof Gesinski (2008) revealed that vegetation period length (days) of RU2-PQCIP, RU-5-PQCIP, NL-6-PQCIP, 02-EMBRAPA, BAER-II, E-DK-4-PQCIP, G205-95PQCIP varieties varied with different weather characters and found that higher vegetation period length was recorded in BAER-II variety with Cluster-I (minimum temperature 4.8°C, maximum temperature 14.7°C, precipitation 98.2 mm, sun exposure 5.2 h) than other varieties and lowest vegetation period length observed in same variety with Cluster-III (minimum temperature 16.7°C, maximum temperature .28.1°C, precipitation 157.5 mm, sun exposure 6.3 h) at Europe and South America.

Lizica and Bjarne (2014) revealed that among four quinoa varieties (Jason Red, Jacobsen 2, Mixed Jacobsen and Jorgen), plant height of Jacobsen 2 variety (166.1 cm) recorded significantly higher than Jason Red (122.5 cm), Mixed Jacobsen (152.3 cm), Jorgen (148.4 cm) varieties under temperate climatic conditions of University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania.

2.3.2 Yield and Yield attributes

Lizica and Bjarne (2014) revealed that among four tested quinoa varieties (Jason Red, Jacobsen 2, Mixed Jacobsen and Jorgen), seed yield of the cultivar Jacobsen 2 (2.96 t ha^{-1}) and mixed Jacobsen (2.53 t ha^{-1}) were on par with each other and were significantly higher in yield than Janson Red (1.70 t ha^{-1}) and Jorgen (1.84 t ha^{-1}) varieties under temperate climate conditions of Romania.

Christiansen *et al.* (2010) reported that difference between the varieties was their day length reaction after flowering and the less sensitive variety Q52, long day resulted in an increase in seed filling period from 39 days to 51 days with normally growing plants. In Real variety the seed filling lasted for 37 days at short day. However at long day this variety remained green until termination of experiment for 150 days after sowing and never developed fully matured seed. The sensitivity to long day during seed filling was introduced from onset of flowering to 40 days after sowing in Denmark.

Krzysztof Gesinski (2008) tested different varieties of quinoa at varied sets of weather parameters in green house condition and revealed that seed yield of E-DK-4PQCIP (2088 kg ha^{-1}), G-205-95PQCIP (1830.3 kg ha^{-1}) with Cluster-IV (minimum temperature. 10.9^{o}C, maximum temperature 24.0^{o}C, Precipitation 34.4 mm, sun exposure 8.4 h) was higher compared to other varieties in Europe and South America.

Margarita *et al*. (2010) studied process of dehydration of quinoa between 40-80^{o}C was in order to evaluate the effect of air drying temperature on quality attributes. And found that drying operation led to reduction of 10% proteins, 12% in fat and 27% both fibers and ashes, and vitamin E showed an abrupt increase at 70-80^{o}C at Chile.

2.4 Interaction between date of sowing and varied crop geometry on growth, yield and quality of quinoa.

Bhargava *et al.* (2007) reported that interaction effect between sowing date and crop geometry found that foliage yield of quinoa was significantly higher with November 15th date of sowing and row spacing of 25 cm (18.9 t ha-1) combination compared to other treatment combinations and the lowest foliage yield was recorded with 20th December date of sowing and row spacing of 20 cm (9.6 t ha^{-1}). Whereas leaf protein content was obtained significantly higher at 30th November and 15 cm row spacing(3.88) treatment combination and the lowest leaf protein was observed at 20th December with row spacing of 25 cm (3.43) at Amity University, Lucknow, India

Parvin *et al*. (2013) studied the interaction effect of dates of sowing and varied crop geometry and observed taller plants (83.5 cm) with 10th April date of sowing at 30 cm × 20 cm spacing with more number of leaves (46.8), leaf length (30.02 cm) and leaf width (16.0 cm) compared to rest of the treatment combinations. Whereas the lowest plant height was recorded at 25th April date of sowing with spacing of 15 cm × 20 cm. He further reported higher green yield with 10th April at 20 cm × 15 cm (91.4 t ha^{-1}) spacing combination compared to other combinations in sandy loam soil at Horticultural farm, Sher-e-Bangla Agricultural University, Dhaka.

Rishi and Galwey (1991) revealed that the highest grain yield (g m^{-2}) was noticed when the crop was sown on 25th March (568 g) date of sowing at a row spacing of 40 cm, whereas the lowest was (257 g) in 14th April under row spacing of 80 cm. The least number of days to anthesis was found to be with 14th April at 40 cm (70 days) row spacing. More number of days to anthesis was observed with 25th March at 80 cm (85 days) spacing in Bear cultivar of quinoa in a sandy clay loam soil at University farm, Cambridge, United Kingdom.

2.5 Effect of dates of sowing, crop geometry and climatic parameters on nutrient uptake and soil nutrient balance.

Gomaa (2013) reported that N, P and K (per cent) content in quinoa seed was 1.9% N, 0.4% P, 1.01% K and 0.08% Ca respectively in kg seed of quinoa, when 150 kg full dose of N, P and K conducted respectively Cairo University, Egypt.

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.

CHAPTER III

MATERIAL AND METHODS

The experiment was accompanied to find out the performance of Quinoa in different sowing date. 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 to May, 2017-2018.

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^{o} 26' E longitudes. As per the Bangladesh Meteorological Department, Agargaon, Dhaka-1207 the altitude of the location was 8 m from the sea level.

3.1.3 Characteristics of soil

The general soil type of the experimental field is Deep Red Brown Terrace soil and the soil belongs to the Tejgaon series under the Agro-ecological 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 I.

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 II. During the experimental period the maximum temperature (39.4^{o}C), highest relative humidity (78%) and highest rainfall (277 mm) was recorded in the month of June 2017, whereas the minimum temperature (17^{o}C), minimum relative humidity (64%) and no rainfall was recorded for the month of March 2017.

3.2 Experimental details

3.2.1 Treatments of the experiment

The experiment comprised of two factors

Factor A: variety

i) V_1: Titicaca

ii) V_2: Vikinga

Factor B: Date of Sowing:

i) S_1 (Nov-10)

ii) S_2 (Dec-10)

iii) S_3 (Jan-10)

iv) S_4 (Feb-10)

v) S_5 (Mar-10)

There were total 10 (5×2) treatment combinations as,

V_1S_1, V_1S_2, V_1S_3, V_1S_4, V_1S_5, V_2S_1, V_2S_2 V_2S_3, V_2S_4 and V_2S_5.

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 personal collection.

3.2.3 Land preparation

The land where the experiment was conducted it was opened on the 5th November, 2017 with the tractor drawn disc plough. Ploughed soil again and again to bring into desirable tilt by cross-ploughing, harrowing and laddering. The stubble and weeds were removed from the tilth soil. The first ploughing and the final land preparation were done on the 8th and 9th November, 2017, respectively. Experimental land was allocated into unit plots following the experimental design of this experiment.

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 180 kg ha^{-1} in the soil as per treatment of the experiment. TSP was applied at the rate of 152 kg ha^{-1}. MOP was applied at the rate of 63 kg ha^{-1}. All of the fertilizers of TSP and MOP along with one third area were applied in final land preparation. Rest urea was applied as top dressing at 25 and 40 DAS.

3.2.5 Experimental design

The two factors experiment was laid out in a split-plot design with three replications. An area of 17.4 m × 11.9 m was divided into three blocks. Different varieties were assigned in the main plot and management packages in sub-plot. The size of the each unit plot was 2.6 m × 2.4 m. The space between two blocks and two plots were .5 m and .75 m, respectively.

3.3 Growing of crops

3.3.1 Sowing of seeds in the field

The seeds of Quinoa were sown on November 10, 2017 in solid rows in the furrows having a depth of 2-3 cm and row to row distance was 30 cm.

3.3.2 Intercultural operations

3.3.2.1 Mulching

A natural mulching was done with breaking down the top soil on 25 November, 2017 which was 15 days after sowing.

3.3.2.2 Thinning

Seeds started germination on 4 Days after sowing (DAS). Thinning was done two times; first thinning was done at 10 DAS and second at 15 DAS to maintain optimum plant population in each plot.

3.3.2.3 Irrigation, drainage and weeding

Irrigation was delivered before 15 and 30 DAS for optimizing the vegetative growth of Quinoa for the all experimental plots equally. But additionally supplementary irrigation was delivered as per treatment before flowering. The crop field was weeded as per necessity. Proper drain also made for drained out excess water from irrigation and also rainfall from the experimental plot. The field was weeded at 15 and 30 DAS by hand weeding.

3.3.2.4 Plant protection measures

At stage of seed sowing Sevin was mixed to prevent Pest attack.

3.4 Crop sampling and data collection

Five plants from each treatment were randomly selected and marked with sample card. Plant height, number of branches plant^{-1}, number of leaves plant^{-1}, number of inflorescence plant$^{-1,}$ inflorescence diameter, fresh weight of biomass plant^{-1}, fresh weight of biomass five plant, dry weight of biomass plant$^{-1,}$ dry weight of biomass five plant, dry matter content of seed, seed weight were recorded at different DAS and at harvest. All of the yield parameters were recorded in 2 times and total or average was estimated as per the nature of yield parameters.

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 for two times namely 1st harvest at 31st January, 2018 and last harvest at 29th may, 2018**.** The matured crops were collected by hand picking from each plot. The collected crops were sun dried, threshed and weighted to a control 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 thrashing with hand.

3.7 Drying, cleaning and weighing

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

3.8 Data collection

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

A. Crop growth characters

a. Plant height (cm)
b. Number of branches plant^{-1}
c. Number of inflorescence plant^{-1}

B. Yield and other crop characters

a. Inflorescence diameter plant^{-1} (cm)
b. Fresh straw weight (g plant^{-1})
c. Fresh straw weight (kg ha^{-1})
d. Dry straw weight (g plant^{-1})

e. Dry straw weight (kg ha^{-1})

f. 1000-seed weight (g)

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

h. Seed weight (kg ha^{-1})

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

j. Husk weight (kg ha^{-1})

3.9 Procedure of data collection

3.9.1 Crop growth characters

i. Plant height

The height of plant was recorded in centimeter (cm) at 15, 30 DAS and 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.

ii. Number of branches plant^{-1}

Number of branches of five selected plants from each plot was counted at 15, 30 DAS and 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.

iii. Number of inflorescence plant^{-1}

Number of inflorescence of five selected plants from each plot was counted at 15, 30 DAS and at harvest. The number of inflorescence plant^{-1} was counted from five randomly sampled plants. It was completed by counting total number of inflorescence of all sampled plants then the average data were recorded

3.10. Yield and other crop characters

i. Inflorescence diameter plant^{-1} (cm)

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

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

Fresh weight of five selected plants from each plot was counted at harvest. The Fresh 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.

iii. Fresh straw weight (kg ha^{-1})

Fresh weight of total plants from each plot was counted at harvest. The Fresh weight of total plant was counted after harvest. It was completed by counting total fresh weight of all plants then the average data were recorded.

iv. Dry straw weight (g plant^{-1})

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

v. Dry straw weight (kg ha^{-1})

Dry weight of total plants from each plot was counted at harvest. The dry weight of total plant was counted after harvest. It was completed by counting total dry weight of all plants then the average data were recorded.

vi. 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.

vii. 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.

viii. 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}.

ix. Husk weight (g plant^{-1})

After separation of seeds from plant, the husk of harvested area from each plant was sun dried and the weight of husk plant^{-1} was taken.

x. Husk weight (kg ha^{-1})

After separation of seeds from plant, the husk of harvested area from each plant was sun dried and the weight of husk was taken and converted the yield in kg ha^{-1}.

3.9 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program cropstat-C and the mean differences were adjudged by Least Significance Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

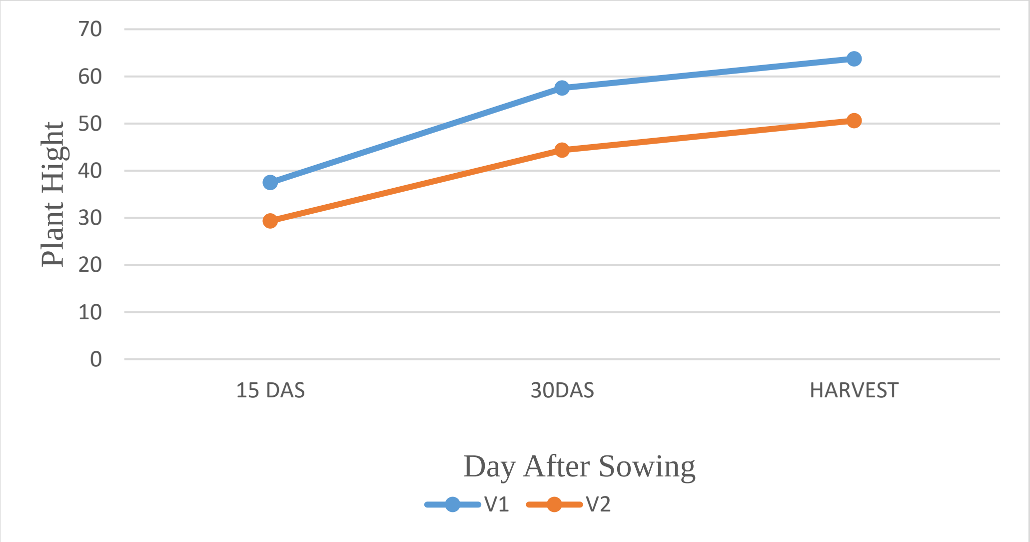
CHAPTER IV

RESULT AND DISCUSSION

4.1 Plant height:

4.1.1 Effect of Variety:

Plant height at 15 DAS showed non-significant variation for different varieties (Figure 1) but at harvest showed significant variation (Appendix IV and Figure 1). The result revealed that at 15 DAS, the maximum plant height (37.48 cm) was obtained from Titicaca (V_1) and the minimum plant height obtained from (29.35 cm) Vikinga (V_2). At 30 DAS, the maximum plant height (57.55 cm) was obtained from Titicaca (V_1) and the minimum plant height obtained from (44.36 cm) Vikinga (V_2). At harvest, the highest plant maximum (63.75 cm) was obtained from Titicaca (V_1) and the minimum plant height obtained from (50.62 cm) Vikinga (V_2). The maximum plant height Titicaca at harvest was 117% height than Vikinga. These results were similar with the findings of Fernando *et al*. (2012) who conducted a research on quinoa (*Chinopodium quinoa*) cultivars viz. Titicaca and Vikinga . Among the two cultivars, Titicaca cultivar had the highest plant height.

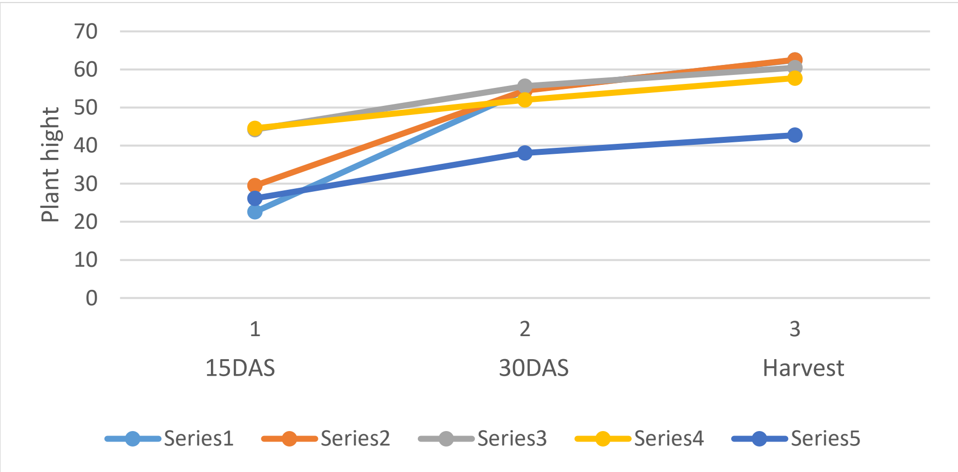


V_1 = Titicaca and V_2 = Vikinga

Figure 1. Plant height of quinoa as influenced by variety (LSD $_{(0.05)}$ at 30 DAS and at harvest = 13.936 and 12.728 respectively)

4.1.2 Effect of sowing date:

Plant height at 15, 30 DAS and harvest showed significant variation for different sowing date (Figure. 2). The result revealed that at 15 DAS, the highest plant height (44.57 cm) was obtained from time of February sowing (S_4) and the lowest plant height obtained from (22.62 cm) at November sowing (S_1). At 30 DAS, the maximum plant height (55.63 cm) was obtained from time January sowing (S_3) and the lowest plant height obtained from (38.10 cm) date March sowing (S_5). At harvest, the maximum plant height (62.54 cm) was obtained from date December sowing (S_2) and the lowest plant height obtained from (42.75 cm) time March sowing (S_5). The maximum plant height (62.54 cm) was recorded at harvest from sowing time December (S_2) and minimum (22.62 cm) at November sowing (S_1). These results were similar with the findings of Troiani *et al*. (2004) who conducted a research on quinoa (*Chenopodium quinoa*) time viz. November sowing, December sowing, January sowing and Feburuary sowing. Among the four sowing time, second half of the November to the end of December had the highest plant height.



S_1: November sowing, S_2: December sowing, S_3: January sowing, S_4: February sowing, S_5: March sowing

Figure 2. Plant height (cm) of quinoa as influenced by sowing date (LSD $_{(0.05)}$ at 15 DAS, 30 DAS and harvest = 10.100, 8.749 and 8.282 respectively)

4.1.3 Interaction Effect:

Interaction between variety and sowing date showed significant differences on plant height at 15, 30 DAS and at harvest (Appendix IV and Table 1). At 15

DAS, the highest plant height was observed in V_1S_4 (Titicaca with sowing time February) which was not statistically similar with other interaction. The lowest plant height was observed in V_2S_1 (Vikinga with sowing date at November) which was not statistically similar with other interaction. At 30 DAS, the maximum plant height was observed in V_1S_1 (Titicaca with sowing date at November) which was statistically similar with V_1S_2 (Titicaca with sowing date at December). The minimum plant height was observed in V_2S_5 (Vikinga with sowing date at March) which was not statistically similar with other interaction. At harvest, the highest plant height was found in V_1S_1 (Titicaca with sowing date at November) which was statistically similar with V_1S_2 (Titicaca with sowing date at December). The lowest plant height was observed in V_2S_5 (Vikinga with sowing date at March).

Table 1. Interaction effect of variety and sowing time on plant height of quinoa at different growth stages.

	Plant height		
Treatment	15DAS	30DAS	Harvest
V_1S_1	24.34 d-f	65.36 a	72.83 a
V_1S_2	35.61 b-e	65.23 a	71.57 a
V_1S_3	48.5 ab	57.4 ab	62.8 ab
V_1S_4	50.78 a	57.55 ab	63.15 ab
V_1S_5	28.2 c-f	42.2 cd	48.4 cd
V_2S_1	20.89 f	43.78 cd	52.1 bc
V_2S_2	23.42 ef	43.74 cd	53.5 bc
V_2S_3	39.96 a-c	53.85 a-c	58.12 bc
V_2S_4	38.36 a-d	46.46 bc	52.31 bc
V_2S_5	24.13 d-f	33.99 d	37.09 d
$LSD_{(0.05)}$	14.284	12.373	11.713
CV (%)	24.69	10.31	10.31

In a column means having similar letter(s) are statistically similar

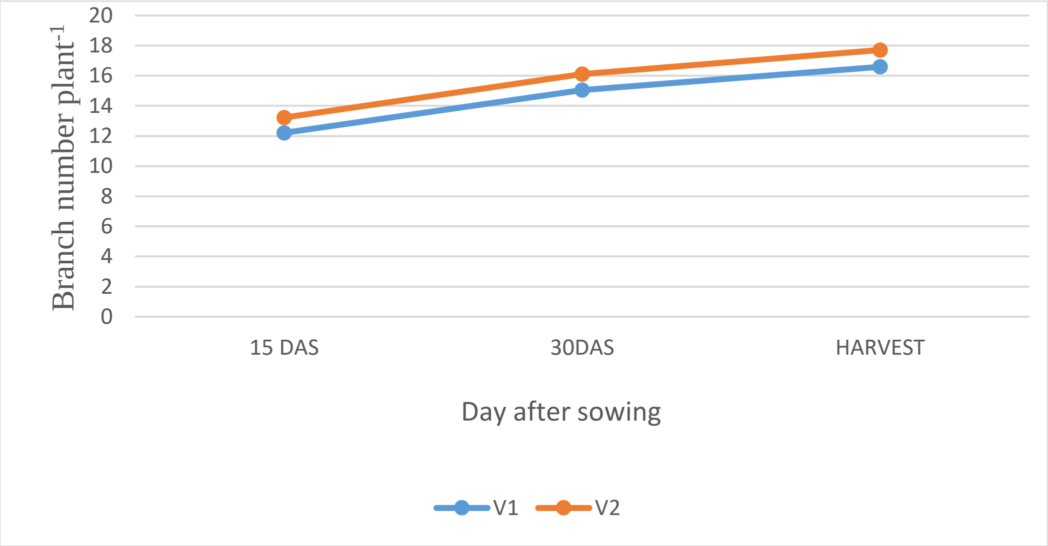
NS = Not significant, CV = Coefficient of variation, $LSD_{(0.05)}$ = Least significant difference at 5% level, DAS = Days after sowing, V_1 = Titicaca, V_2 = Vikinga

S_1 = November, S_2= December, S_3= January, S_4= February and S_5= March

4.2 Branch Number:

4.2.1 Effect of variety:

Branch number plant^{-1} at 30 DAS and harvest showed significant variation for different varieties but non-significant 15 DAS (Figure. 3). The result revealed that at 15 DAS, the maximum branch number (13.22 cm) was obtained from Vikinga (V_2) and the minimum branch number obtained from (12.21 cm) at Titicaca (V_1). At 30 DAS, the maximum branch number plant^{-1} (16.10 cm) was obtained from Vikinga (V_2) and the minimum branch number plant^{-1} obtained from (15.05 cm) at Titicaca (V_1). At harvest, the maximum branch number plant^{-1} (17.71 cm) was obtained from Vikinga (V_2) and the minimum branch number plant^{-1} obtained from (16.59 cm) Titicaca (V_1). The maximum branch number plant^{-1} (17.71 cm) was recorded at harvest from Vikinga (V_2) was 45% higher than Titicaca (V_1).

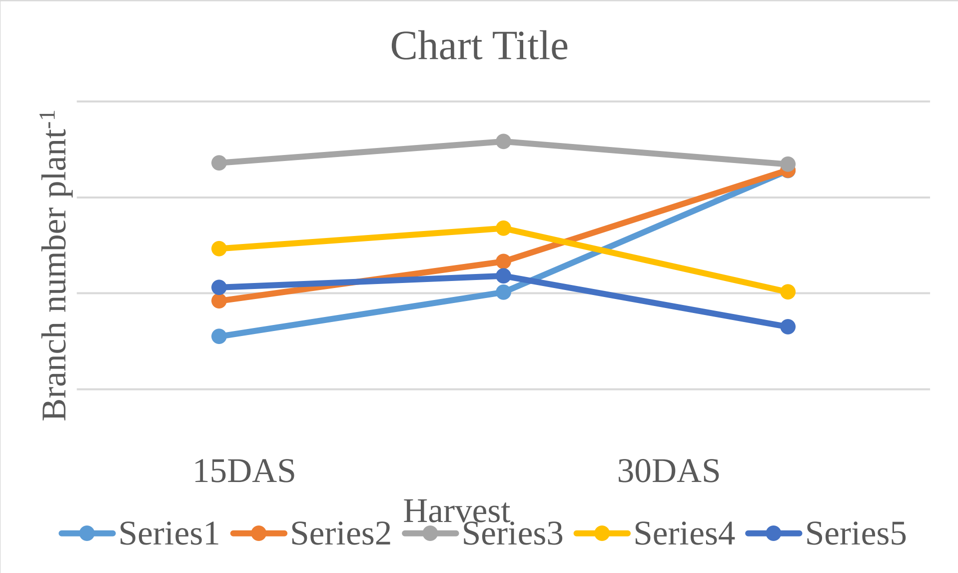


V_1 = Titicaca and V_2 = Vikinga

Figure 3. Branch number plant^{-1} of quinoa as influenced by variety (LSD $_{(0.05)}$ at 30 DAS and at harvest = 4.484 and 5.182 respectively)

4.2.2 Effect of sowing date:

Branch number plant^{-1} at 15, 30 DAS and harvest showed significant variation for different sowing date (Figure. 4). The result revealed that at 15 DAS, the highest branch number plant^{-1} (23.60 cm) was obtained from date of January sowing (S_3) and the lowest branch number obtained from (5.50 cm) at November sowing (S_1). At 30 DAS, the highest branch number (25.83 cm) was obtained from date January sowing (S_3) and the lowest branch number obtained from (10.13cm) at date November sowing (S_1). At harvest, the highest branch number (23.45 cm) was obtained from time January sowing (S_3) and the lowest branch number obtained from (6.51 cm) date March sowing (S_5). The maximum branch number (25.83 cm) was recorded at 30 DAS from date January sowing (S_3) and minimum (5.50 cm) at November sowing (S_1).



S_1: November sowing, S_2: December sowing, S_3: January sowing, S_4: February sowing, S_5: March sowing

Figure 4. Branch number plant^{-1} of quinoa as influenced by sowing date (LSD $_{(0.05)}$ at 15 DAS, 30DAS and harvest =2.402, 3.524 and 2.704)

4.2.3 Interaction effect:

Interaction between variety and sowing date showed significant differences on branch number at 15, 30 DAS and at harvest (Appendix V and Table 2). The highest branch number was observed in V_1S_3 (Titicaca with sowing date at January*)* which was statistically similar with V_2S_3 interaction. The lowest branch number was observed in V_2S_1 (Vikinga with sowing date November) which was statistically different with other interaction. At 30 DAS, the maximum branch number was observed in V_1S_3 (Titicaca with date January sowing) which was statistically similar with V_2S_3 (Vikinga with sowing date in January). The minimum branch number was observed in V_1S_1 (Titicaca with sowing date in November) which was statistically similar with V_1S_2 (Titicaca with date December sowing), V_1S_5 (Titicaca with sowing date in March), V_2S_1 (Vikinga with sowing date in November), V_2S_2 (Vikinga with sowing date in December), V_2S_5 (Vikinga with sowing date in March). At harvest, the highest branch number was found in V_1S_1 (Titicaca with sowing date in November that similar to V_2S_3, V_2S_2 and V_1S_3). The lowest branch number was observed in V_1S_5 (Titicaca with sowing date in March) that similar to V_2S_5.

Table 2. Interaction effect of variety and sowing date on branch number of quinoa at different growth stages

	Branch number		
Treatment	15DAS	30DAS	Harvest
V_1S_1	5.4 a	10.13 c	25.2 a
V_1S_2	9.33 cd	13.08 c	21.21 bc
V_1S_3	23.93 a	25.88 a	22.2 abc
V_1S_4	12.66 c	14.67 bc	8.46 de
V_1S_5	9.73 cd	11.5 c	5.86 f
V_2S_1	5.6 e	10.13 c	20.4 c
V_2S_2	9.06 d	13.56 c	24.47 ab
V_2S_3	23.26 a	25.78 a	24.7 ab
V_2S_4	16.63 b	18.9 b	11.83 d
V_2S_5	11.54 cd	12.14 c	7.15 ef
$LSD_{(0.05)}$	3.397	4.985	3.824
CV (%)	67.42	35.37	20.28

In a column means having similar letter(s) are statistically similar

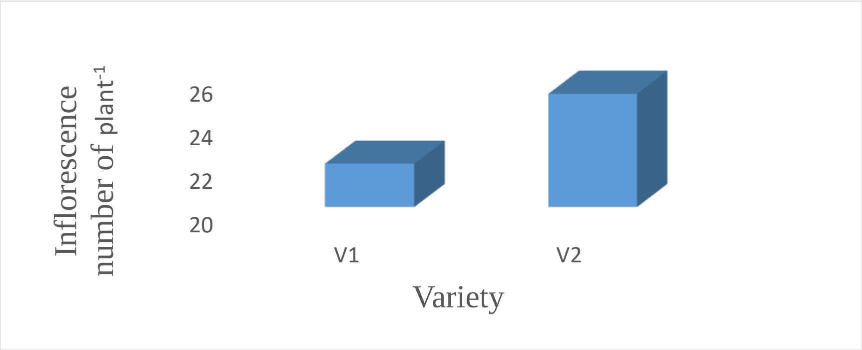
NS = Not significant, CV = Coefficient of variation, $LSD_{(0.05)}$ = Least significant difference at 5% level, DAS = Days after sowing, V_1 = Titicaca, V_2 = Vikinga

S_1 = November sowing, S_2= December sowing, S_3= January sowing, S_4= February sowing and S_5= March sowing

4.3 Inflorescence no. plant^{-1}:

4.3.1 Effect of variety:

Inflorescence number of plant^{-1} at harvest showed non-significant variation for different varieties (Figure 5). The result showed that at harvest, the maximum inflorescence number of plant^{-1} (25.18 cm) was obtained from Vikinga (V_2) and the minimum inflorescence number of plant^{-1} obtained from (21.99 cm) Titicaca (V_1).

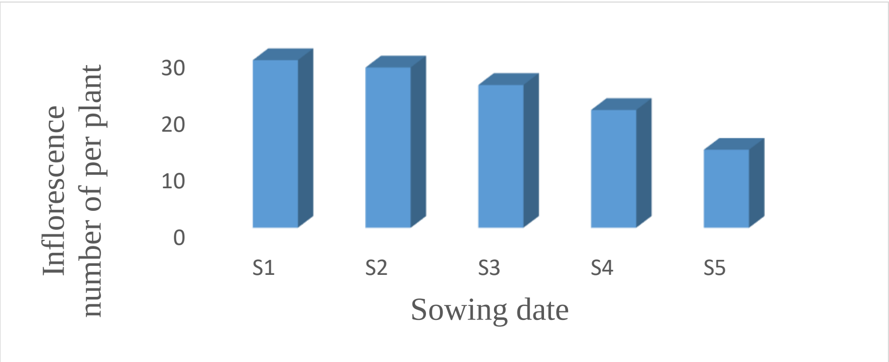


V_1 = Titicaca and V_2 = Vikinga

Figure 5. Inflorescence number of plant^{-1} of quinoa as influenced by variety.

4.3.2 Effect of sowing date:

Inflorescence number of plant^{-1} at harvest showed significant variation for different sowing date (Figure 6). The result revealed that at harvest, the highest inflorescence number of plant^{-1} (29.62 cm) was obtained from sowing date at November (S_1) and the lowest inflorescence number obtained from (13.85 cm) sowing date at March (S_5).



S_1: November sowing, S_2: December sowing, S_3: January sowing, S_4: February sowing, S_5: March sowing

Figure 6. Inflorescence number of plant^{-1} of quinoa as influenced by sowing date (LSD $_{(0.05)}$ at harvest = 3.093)

4.3.3 Interaction effect:

Interaction between variety and sowing date showed significant differences on inflorescence number of plant^{-1} at harvest (Appendix VI and Table 3). At harvest, the maximum inflorescence number of plant^{-1} was found in V_2S_2 (Vikinga with sowing date at December) which was statistically similar with V_2S_1 (Vikinga with sowing date at November). The minimum branch number was observed in V_1S_5 (Titicaca with sowing date at sowing) which was statistically similar with V_2S_5 (Vikinga with sowing date at March).

Table 3. Interaction effect of variety and sowing date on inflorescence number of plant^{-1} of quinoa at harvest

Inflorescence number of plant^{-1}:	
Treatment	Harvest
V_1S_1	28.5 ab
V_1S_2	25.2 b-d
V_1S_3	23.13 c-e
V_1S_4	19.77 e
V_1S_5	13.37 f
V_2S_1	30.73 a
V_2S_2	31.46 a
V_2S_3	27.4 a-c
V_2S_4	21.96 de
V_2S_5	14.34 f
$LSD_{(0.05)}$	4.374
CV(%)	53.67

In a column means having similar letter(s) are statistically similar

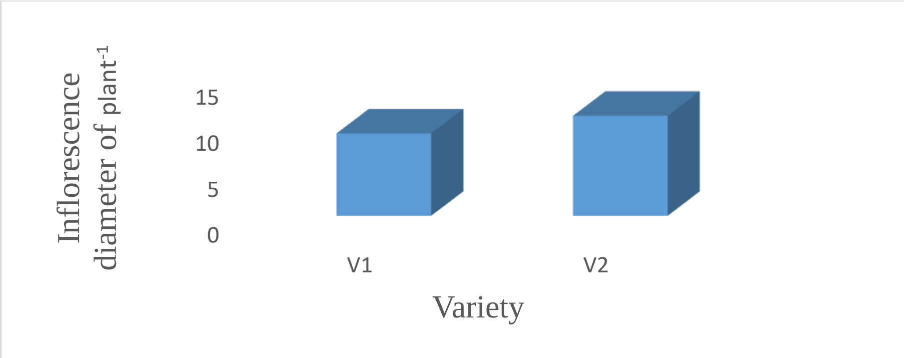
NS = Not significant, CV = Coefficient of variation, LSD $_{(0.05)}$ = Least significant difference at 5% level, DAS = Days after sowing, V_1 = Titicaca, V_2 = Vikinga

S_1 = November sowing, S_2= December sowing, S_3= January sowing, S_4= February sowing and S_5= March sowing

4.4 Inflorescence diameter plant^{-1} (cm):

4.4.1 Effect of variety:

Inflorescence diameter of plant^{-1} at harvest showed non-significant variation for different varieties (Figure 7). The result showed that at harvest, the maximum Inflorescence diameter of plant^{-1} (10.89 cm) was obtained from Vikinga (V_2) and the minimum inflorescence number of plant^{-1} obtained from (8.97 cm) Titicaca (V_1).

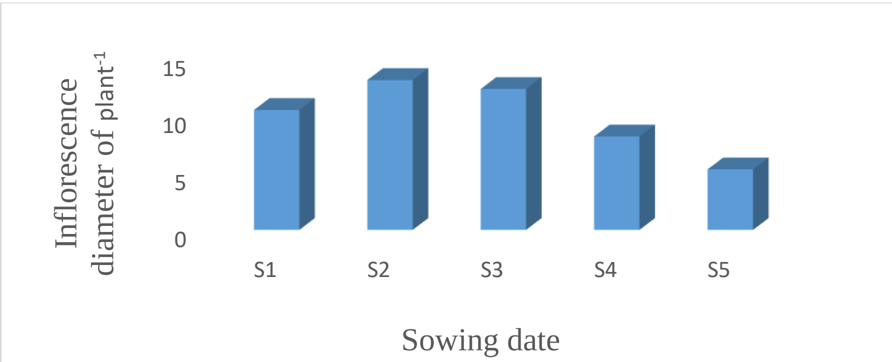


V_1 = Titicaca and V_2 = Vikinga

Figure 7. Inflorescence diameter of plant^{-1} of quinoa as influenced by variety.

4.4.2 Effect of sowing date:

Inflorescence diameter of plant^{-1} at harvest showed significant variation for different sowing date (Figure 8). The result revealed that at harvest, the maximum inflorescence diameter of plant^{-1} (13.16 cm) was obtained from sowing date at December (S_2) and the minimum inflorescence diameter of plant^{-1} obtained from (5.33 cm) sowing date at March (S_5).



S_1: November sowing, S_2: December sowing, S_3: January sowing, S_4: February sowing, S_5: March sowing

Figure 8. Inflorescence diameter of plant^{-1} of quinoa as influenced by sowing date (LSD $_{(0.05)}$ at harvest = 1.560).

4.4.3 Interaction effect:

Interaction between variety and sowing date showed significant differences on inflorescence diameter of plant^{-1} at harvest (Appendix VII and Table 4). At harvest, the maximum inflorescence diameter of plant^{-1} was found in V_2S_2 (Vikinga with sowing date in December) which was not statistically similar with V_2S_1 and V_1S_3 interaction. The minimum inflorescence diameter was observed in V_2S_5 (Vikinga with sowing date in March) which was statistically similar with V_1S_5 (Titicaca with sowing date in March).

Table 4. Interaction effect of variety and sowing date on inflorescence diameter of plant^{-1} of quinoa at different growth stages

Inflorescence diameter of plant^{-1}	
Treatment	Harvest
V_1S_1	8.01cd
V_1S_2	11.91 b
V_1S_3	12.65 ab
V_1S_4	6.78 de
V_1S_5	5.5 ef
V_2S_1	13.07 ab
V_2S_2	14.41 a
V_2S_3	12.13 b
V_2S_4	9.66 c
V_2S_5	5.17 ef
$LSD_{(0.05)}$	2.206
CV (%)	103.48

In a column means having similar letter(s) are statistically similar

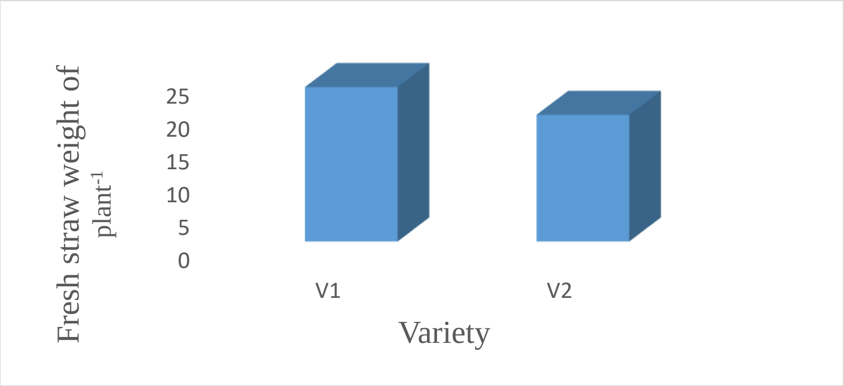
NS = Not significant, CV = Coefficient of variation, $LSD_{(0.05)}$ = Least significant difference at 5% level, DAS = Days after sowing, V_1 = Titicaca, V_2 = Vikinga

S_1 = November sowing, S_2= December sowing, S_3= January sowing, S_4= February sowing and S_5= March sowing

4.5 Fresh straw weight (g plant $^{-1}$)

4.5.1 Effect of variety:

Fresh straw weight of plant^{-1} at harvest showed significant variation for different varieties (Figure 9). The result showed that at harvest, the maximum fresh straw weight of plant^{-1} (23.47 g) was obtained from Titicaca (V_1) and the minimum fresh straw weight of per plant obtained from (19.24 g) Vikinga (V_2).

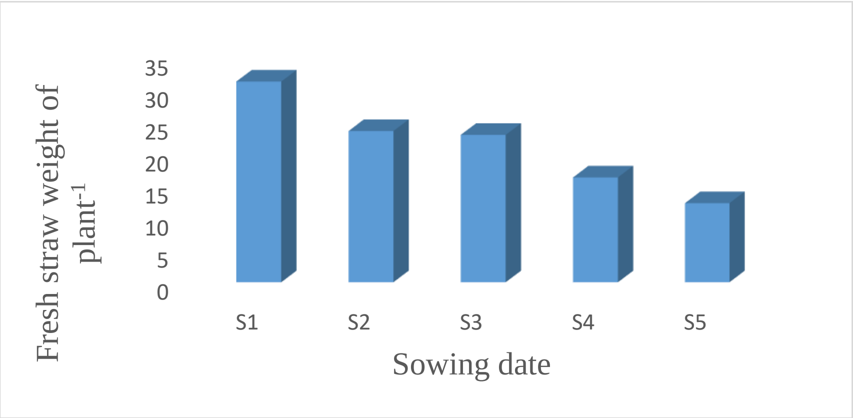


V_1 = Titicaca and V_2 = Vikinga

Figure 9. Fresh straw weight of plant^{-1} of quinoa as influenced by variety.

4.5.2 Effect of sowing date:

Fresh straw weight of plant^{-1} at harvest showed significant variation for different sowing date (Figure 10). The result revealed that at harvest, the maximum fresh straw weight of plant^{-1} (31.33 g) was obtained from date November (S_1) sowing and the minimum fresh straw weight of plant^{-1} obtained from (12.37 g) date March (S_5) sowing.



S_1: November sowing, S_2: December sowing, S_3: January sowing, S_4: February sowing, S_5: March sowing

Figure 10. Fresh straw weight of plant^{-1} of quinoa as influenced by sowing date (LSD $_{(0.05)}$ at harvest = 7.762)

4.5.3 Interaction effect:

Interaction between variety and sowing date showed significant differences on fresh straw weight of plant^{-1} at harvest (Table 5). At harvest, the maximum fresh straw weight of plant^{-1} was found in V_1S_1 (Titicaca with date sowing in November) which was not statistically similar with other interaction. The minimum fresh straw weight was observed in V_2S_5 (Vikinga with date sowing in March) which was statistically similar with V_1S_5 (Titicaca with date sowing in March).

Table 5. Interaction effect of variety and sowing date on fresh straw weight of plant^{-1} of quinoa at harvest

Fresh straw weight of (g plant^{-1})	
Treatment	Harvest
V_1S_1	36.67 a
V_1S_2	25.27 b
V_1S_3	26.27 ab
V_1S_4	16.53 bc
V_1S_5	12.6 c
V_2S_1	26 ab
V_2S_2	22 bc
V_2S_3	19.8 bc
V_2S_4	16.27 bc
V_2S_5	12.14 c
$LSD_{(0.05)}$	10.978
CV (%)	24.89

In a column means having similar letter(s) are statistically similar

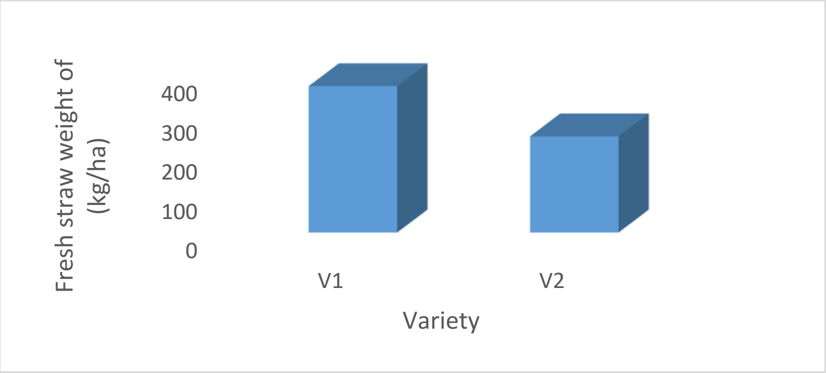
NS = Not significant, CV = Coefficient of variation, LSD $_{(0.05)}$ = Least significant difference at 5% level, DAS = Days after sowing, V_1 = Titicaca, V_2 = Vikinga

S_1 = November sowing, S_2= December sowing, S_3= January sowing, S_4= February sowing and S_5= March sowing

4.6 Fresh straw weight (kg ha^{-1})

4.6.1 Effect of variety:

Fresh straw weight (kg/ha) of plant at harvest showed non-significant variation for different varieties (Figure 11). The result showed that at harvest, the maximum fresh straw weight (372.54 kg ha^{-1}). was obtained from Titicaca (V_1) and the minimum fresh straw weight obtained from (244.65 kg ha^{-1}) Vikinga (V_2).

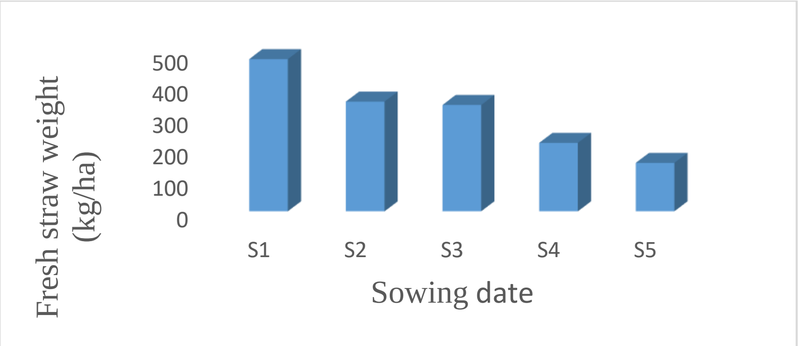


V_1 = Titicaca and V_2 = Vikinga

Figure 11. Fresh straw weight (kg ha^{-1}) of quinoa plant as influenced by variety.

4.6.2 Effect of sowing date

Fresh straw weight (kg ha^{-1}) of plant at harvest showed significant variation for different sowing time (Figure 12). The result revealed that at harvest, the maximum fresh straw weight of plant (483.43 kg ha^{-1}) was obtained from sowing date in November (S_1) and the minimum fresh straw weight of plant obtained from (154.11 kg ha^{-1}) sowing date in March (S_5).



S_1: November sowing, S_2: December sowing, S_3: January sowing, S_4: February sowing, S_5: March sowing

Figure 12. Fresh straw weight (kg ha^{-1}) of quinoa as influenced by sowing date (LSD $_{(0.05)}$ at harvest = 72.013)

4.6.3 Interaction effect:

Interaction between variety and sowing date showed significant differences on fresh straw weight (kg ha^{-1}) of plant at harvest (Table 6). The maximum fresh straw weight was found in V_1S_1 (Titicaca with date of sowing at November) which was statistically different with other interaction. The minimum fresh straw weight was observed in V_2S_5 (Vikinga with date sowing at March) which was not statistically similar with V_2S_4, V_1S_5 and V_1S_4 interaction.

Table 6. Interaction effect of variety and sowing date on fresh straw weight (kg ha^{-1}) of quinoa at harvest.

Fresh straw weight (kg ha^{-1})	
Treatment	Harvest
V_1S_1	614.31 a
V_1S_2	420.4 b
V_1S_3	427.35 b
V_1S_4	240.38 c-e
V_1S_5	160.257 de
V_2S_1	352.56 bc
V_2S_2	277.78 cd
V_2S_3	249.46 cd
V_2S_4	195.51 c-e
V_2S_5	147.97 e
$LSD_{(0.05)}$	101.843
CV(%)	0.46

In a column means having similar letter(s) are statistically similar

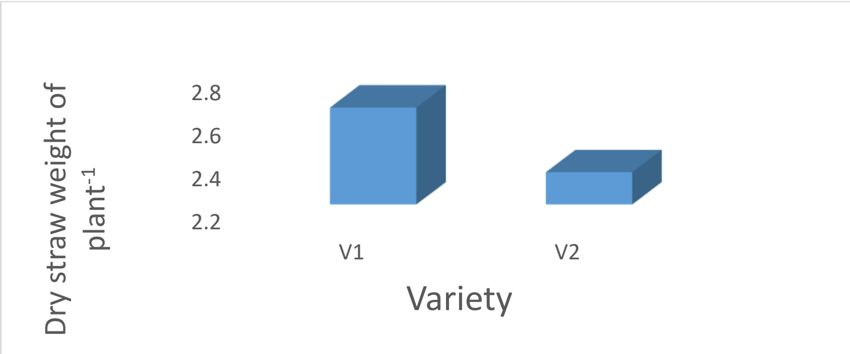
NS = Not significant, CV = Coefficient of variation, LSD $_{(0.05)}$ = Least significant difference at 5% level, DAS = Days after sowing, V_1 = Titicaca, V_2 = Vikinga

S_1 = November sowing, S_2= December sowing, S_3= January sowing, S_4= February sowing and S_5= March sowing

4.7 Dry straw weight (g plant^{-1}):

4.7.1 Effect of Variety:

Dry straw weight of plant^{-1} at harvest showed significant variation for different varieties (Figure 13). The result showed that at harvest, the maximum dry straw weight of plant^{-1} (2.65 g) was obtained from Titicaca (V_1) and the minimum dry straw weight of plant^{-1} obtained from (2.35 g) Vikinga (V_2).

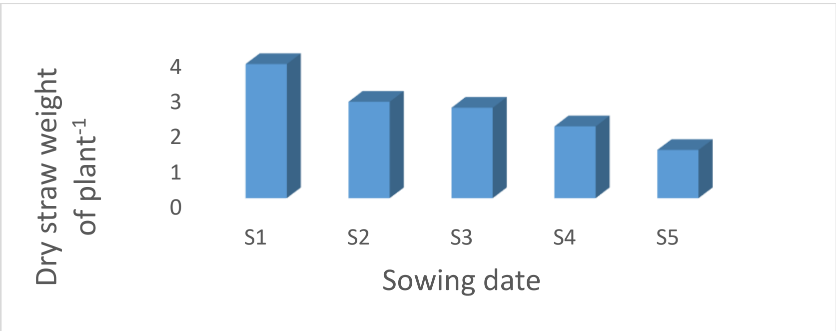


V_1 = Titicaca and V_2 = Vikinga plant^{-1}

Figure 13. Dry straw weight of quinoa as influenced by variety.

4.7.2 Effect of sowing date:

Dry straw weight of per plant at harvest showed significant variation for different sowing date (Figure 14). The result revealed that at harvest, the highest dry straw weight of plant^{-1} (3.81g) was obtained from time November (S_1) sowing and the lowest dry straw weight of plant^{-1} obtained from (1.37 g) date March (S_5) sowing.



S_1: November sowing, S_2: December sowing, S_3: January sowing, S_4: February sowing, S_5: March sowing

Figure 14. Dry straw weight of plant^{-1} of quinoa as influenced by sowing date ($LSD_{(0.05)}$ at harvest = 0.937)

4.7.3 Interaction effect:

Interaction between variety and sowing date showed significant differences on dry straw weight of plant^{-1} at harvest (Appendix VIII and Table 7). The highest dry straw weight of plant^{-1} was found in V_1S_1 (Titicaca with date of sowing at November) which was statistically similar with V_1S_2 and V_2S_1 interactions. The lowest dry straw weight was observed in V_2S_5 (Vikinga with date of sowing at March) which was statistically similar with V_1S_5, V_2S_4, V_1S_4 and V_2S_3 interactions.

Table 7. Interaction effect of variety and sowing date on dry straw weight of plant^{-1} of quinoa at harvest

Dry straw weight of (g plant^{-1})	
Treatment	Harvest
V_1S_1	4.13 a
V_1S_2	2.9 a-c
V_1S_3	2.67 b-d
V_1S_4	2.05 c-e
V_1S_5	1.54 de
V_2S_1	3.49 ab
V_2S_2	2.58 b-d
V_2S_3	2.48 b-e
V_2S_4	2.03 c-e
V_2S_5	1.2 e
$LSD_{(0.05)}$	1.326
CV(%)	81.76

In a column means having similar letter(s) are statistically similar

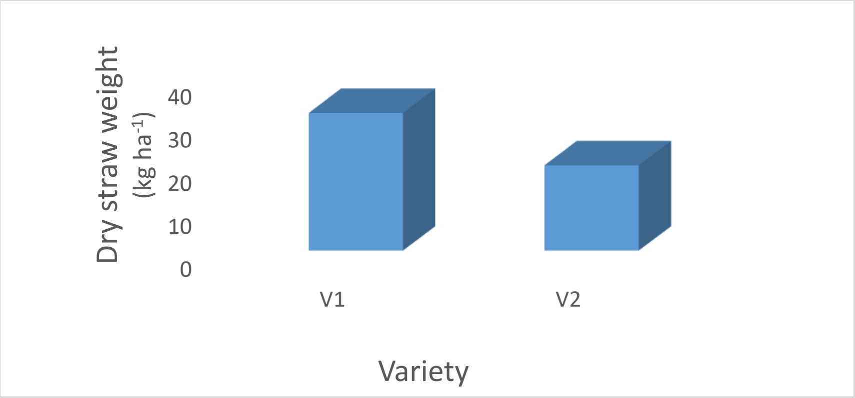
NS = Not significant, CV = Coefficient of variation, LSD $_{(0.05)}$ = Least significant difference at 5% level, DAS = Days after sowing, V_1 = Titicaca, V_2 = Vikinga

S_1 = November sowing, S_2= December sowing, S_3= January sowing, S_4= February sowing and S_5= March sowing

4.8 Dry straw weight (kg ha^{-1})

4.8.1 Effect of variety:

Dry straw weight (kg ha^{-1}) of plant at harvest showed significant variation for different varieties (Figure 15). The result showed that, the highest dry straw weight (31.91 kg ha^{-1}) was obtained from Titicaca (V_1) and the lower dry straw weight obtained from (19.81 kg ha^{-1}) Vikinga (V_2).

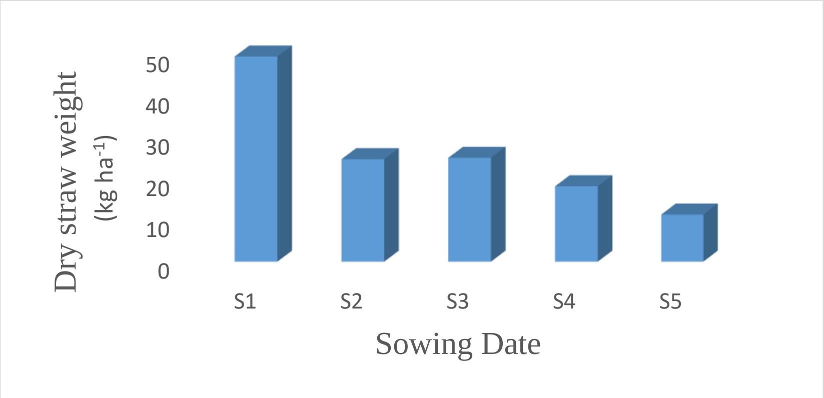


V_1 = Titicaca and V_2 = Vikinga

Figure 15. Dry straw weight of quinoa as influenced by variety (LSD $_{(0.05)}$ at harvest = 8.896)

4.8.2 Effect of sowing date:

Dry straw weight (kg ha^{-1}) of plant at harvest showed significant variation for different sowing date (Figure 16). The result revealed that, the highest dry straw weight of plant (49.72 kg ha^{-1}) was obtained from date November sowing (S_1) and the lowest fresh straw weight of plant obtained from (11.40 kg ha^{-1}) sowing date March sowing (S_5).



S_1: November sowing, S_2: December sowing, S_3: January sowing, S_4: February sowing, S_5: March sowing

Figure 16. Dry straw weight of quinoa as influenced by sowing date (LSD $_{(0.05)}$ at harvest = 6.790)

4.8.3 Interaction effect:

Interaction between variety and sowing date showed significant differences on dry straw weight (kg ha^{-1}) of plant at harvest (Appendix IX and Table 8). The highest dry straw weight of plant was found in V_1S_1 (Titicaca with date sowing in November) which was statistically different with other interactions. The lowest dry straw weight was observed in V_2S_5 (Vikinga with date sowing in March) which was statistically similar with V_1S_5 (Titicaca with date sowing in March).

Table 8. Interaction effect of variety and sowing date on dry straw weight (kg ha^{-1}) of plant of quinoa at harvest

Dry straw weight (kg ha^{-1})	
Treatment	Harvest
V_1S_1	69.12 (a)
V_1S_2	29.17 (b)
V_1S_3	29.11 (b)
V_1S_4	19.92 (c)
V_1S_5	12.23 (e)
V_2S_1	30.32 (b)
V_2S_2	20.43 (c)
V_2S_3	21.18 (c)
V_2S_4	16.55 (d)
V_2S_5	10.58 (e)
$LSD_{(0.05)}$	9.603
CV (%)	17.3

In a column means having similar letter(s) are statistically similar

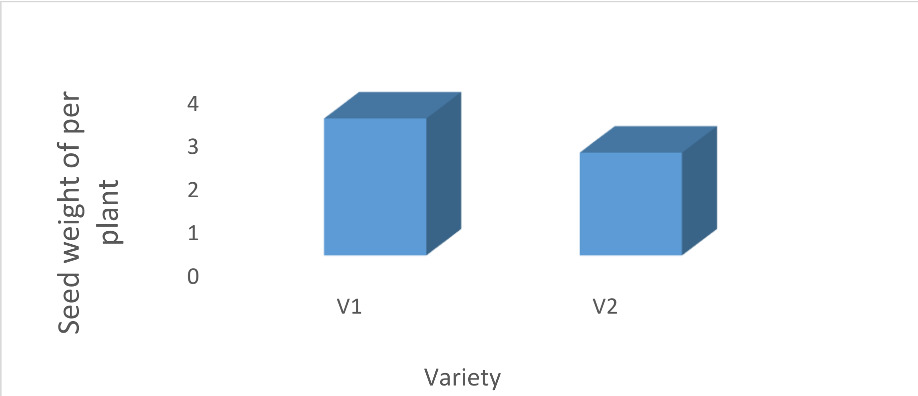
NS = Not significant, CV = Coefficient of variation, LSD $_{(0.05)}$ = Least significant difference at 5% level, DAS = Days after sowing, V_1 = Titicaca, V_2 = Vikinga

S_1 = November sowing, S_2= December sowing, S_3= January sowing, S_4= February sowing and S_5= March sowing

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

4.9.1 Effect of variety:

Seed weight plant^{-1} at harvest showed non-significant variation for different varieties (Figure 17). The result showed that at harvest, the maximum seed weight plant^{-1} (3.16 g) was obtained from Titicaca (V_1) and the minimum seed weight plant^{-1} obtained from (2.37 g) Vikinga (V_2).

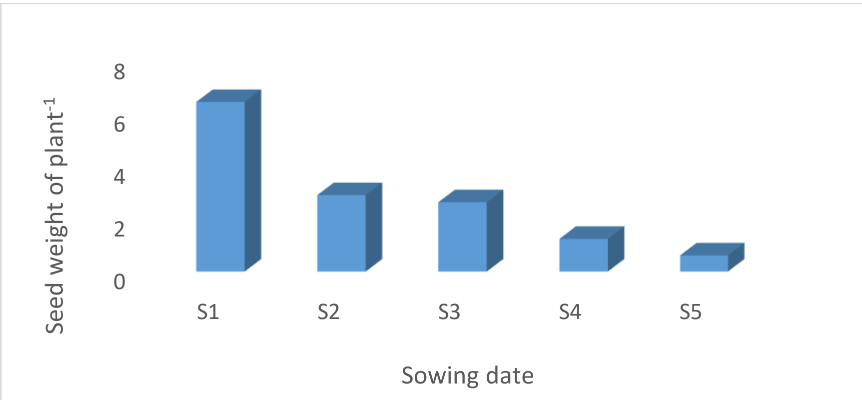


V_1 = Titicaca and V_2 = Vikinga

Figure 17. Seed weight of plant^{-1} of quinoa as influenced by variety

4.9.2 Effect of sowing date:

Seed weight of plant^{-1} at harvest showed significant variation for different sowing date (Figure 18). The result revealed that at harvest, the highest seed weight of plant^{-1} (6.44 g) was obtained from date November (S_1) sowing and the lowest seed weight of plant^{-1} obtained from (0.61 g) date March (S_5) sowing.



S_1: November sowing, S_2: December sowing, S_3: January sowing, S_4: February sowing, S_5: March sowing

Figure 18. Seed weight of plant^{-1} of quinoa as influenced by sowing date (LSD $_{(0.05)}$ at harvest = 1.62)

4.9.3 Interaction effect:

Interaction between variety and sowing date showed significant differences on seed weight of per plant at harvest (Appendix X and Table 9). The highest seed weight of plant^{-1} was found in V_1S_1 (Titicaca with date sowing at November) which was statistically similar with V_2S_1 interaction. The lowest seed weight of per was observed in V_2S_5 (Vikinga with date sowing at March) which was statistically similar with V_1S_5, V_2S_4, V_1S_4, V_2S_5 and V_2S_2 interaction.

Table 9. Interaction effect of variety and sowing date on seed weight of plant^{-1} of quinoa at harvest

Seed weight of plant^{-1}	
Treatment	Harvest
V_1S_1	7.47 a
V_1S_2	3.2 bc
V_1S_3	3.01 cd
V_1S_4	1.4 c-e
V_1S_5	0.71 de
V_2S_1	5.42 ab
V_2S_2	2.6 c-e
V_2S_3	2.24 c-e
V_2S_4	1.08 c-e
V_2S_5	0.52 e
$LSD_{(0.05)}$	2.303
CV (%)	229.5

In a column means having similar letter(s) are statistically similar

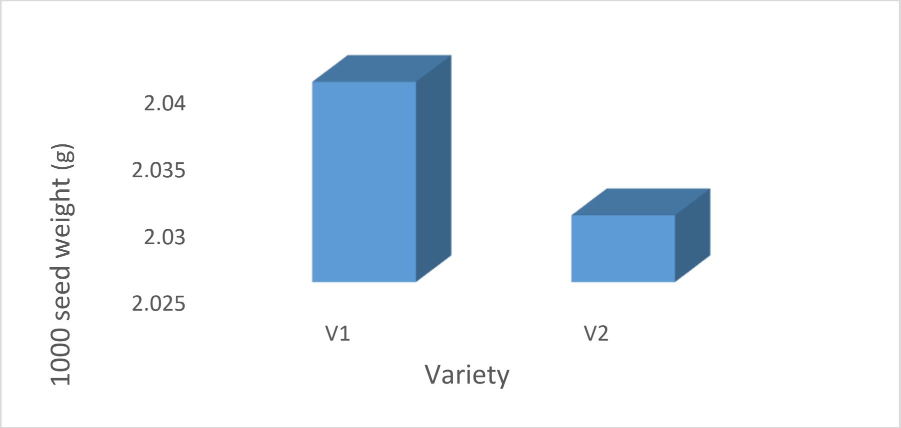
NS = Not significant, CV = Coefficient of variation, $LSD_{(0.05)}$ = Least significant difference at 5% level, DAS = Days after sowing, V_1 = Titicaca, V_2 = Vikinga

S_1 = November sowing, S_2= December sowing, S_3= January sowing, S_4= February sowing and S_5= March sowing

4.10 1000-Seed weight (g)

4.10.1 Effect of variety:

1000 seed weight of quinoa at harvest showed significant variation for different varieties (Figure 19). The result showed that at harvest, the highest 1000-seed weight (2.04 g) was obtained from Titicaca (V_1) and the lowest 1000-seed weight obtained from (2.03 g) Vikinga (V_2).



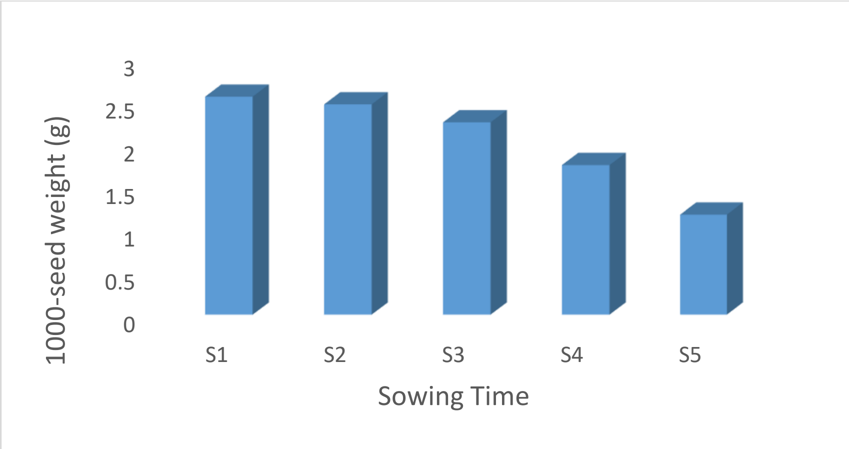
V_1 = Titicaca and V_2 = Vikinga

Figure 19. 1000-seed weight of quinoa as influenced by variety (LSD $_{(0.05)}$ at harvest = 1.306)

4.10.2 Effect of sowing date:

1000-seed weight of quinoa at harvest showed significant variation for different sowing date (Figure 20). The result revealed that at harvest, the maximum 1000-seed weight (2.55 g) was obtained from date November sowing (S_1) and the minimum 1000-seed weight (1.17 g) was obtained from date March sowing (S_5).

November sowing produced seed with 118% height size compared to that of March sowing. Seed size is an important parameter for quinoa seed germination capacity as Koyro and Eisa (2007) reported that smaller seed size of quinoa showed lower germination capacity.



S_1: November sowing, S_2: December sowing, S_3: January sowing, S_4: February sowing, S_5: March sowing

Figure 20. 1000-seed weight of quinoa as influenced by sowing date (LSD $_{(0.05)}$ at harvest = 0.145)

4.10.3 Interaction effect:

Interaction between variety and sowing date showed significant differences on 1000-seed weight of quinoa at harvest (Appendix XI and Table 10). The highest 1000-seed weight was found in V_1S_1 (Titicaca with date sowing in November) which was statistically similar with V_2S_1 (Vikinga with date sowing in November).

The lowest 1000-seed weight was observed in V_2S_5 (Vikinga with date sowing at March) which was statistically similar with V_1S_5 (Titicaca with date sowing at March)

Table 10. Interaction effect of variety and sowing date on 1000 seed weight of quinoa at harvest

1000 seed weight (g)	
Treatment	Harvest
V_1S_1	2.58 a
V_1S_2	2.47 ab
V_1S_3	2.2 c
V_1S_4	1.75 d
V_1S_5	1.24 e
V_2S_1	2.53 a
V_2S_2	2.46 ab
V_2S_3	2.3 b
V_2S_4	1.74 d
V_2S_5	1.1 e
$LSD_{(0.05)}$	0.205
CV(%)	54.18

In a column means having similar letter(s) are statistically similar

NS = Not significant, CV = Coefficient of variation, LSD $_{(0.05)}$ = Least significant difference at 5% level, DAS = Days after sowing, V_1 = Titicaca, V_2 = Vikinga

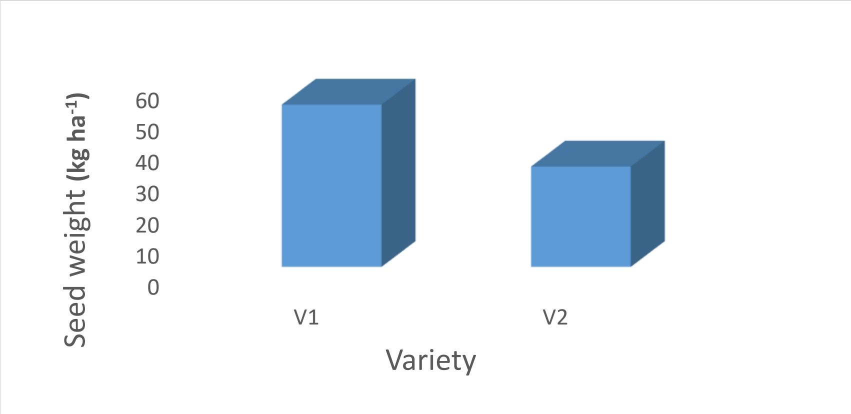
S_1 = November sowing, S_2= December sowing, S_3= January sowing, S_4= February sowing and S_5= March sowing

4.11 Seed weight (kg ha^{-1})

4.11.1 Effect of variety:

Seed weight (kg ha^{-1}) of quinoa at harvest showed significant variation for different varieties (Figure 21). The result showed the higher seed weight (52.22

kg ha^{-1}) from Titicaca (V_1) and the lowest seed weight (32.36 kg/ha) from Vikinga (V_2).

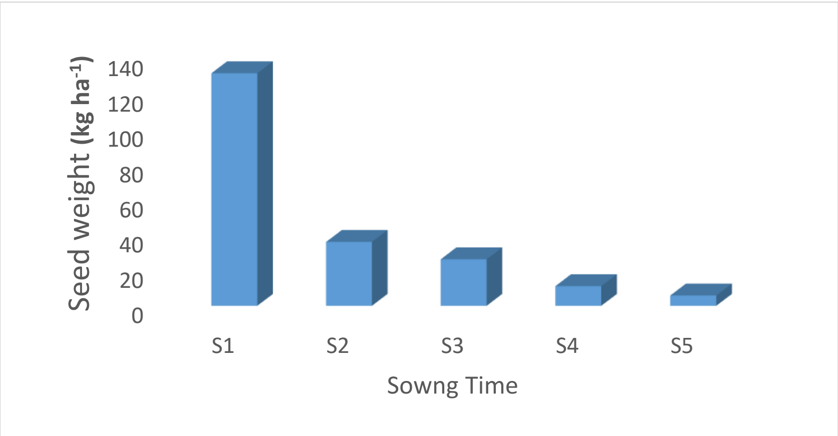


V_1 = Titicaca and V_2 = Vikinga

Figure 21. Seed weight (kg ha^{-1}) of quinoa as influenced by variety (LSD $_{(0.05)}$ at harvest = 15.131)

4.11.2 Effect of sowing date:

Seed weight (kg ha^{-1}) of quinoa at harvest showed significant variation for different sowing date (Figure 22). The result revealed that, the maximum seed weight (131.76 kg ha^{-1}) was obtained from date November sowing (S_1) and the minimum seed weight (5.84 kg ha^{-1}) was obtained from date March sowing (S_5).



S_1: November sowing, S_2: December sowing, S_3: January sowing, S_4: February sowing, S_5: March sowing

Figure 22. Seed weight (kg ha^{-1}) of quinoa as influenced by sowing date (LSD $_{(0.05)}$ at harvest = 13.899)

4.11.3 Interaction effect:

Interaction between variety and sowing date showed significant differences on seed weight (kg ha^{-1}) of quinoa at harvest (Appendix XII and Table 11). The maximum seed weight was found in V_1S_1 (Titicaca with date sowing at November) which was statistically different with other interaction. The minimum seed weight was observed in V_1S_5 (Titicaca with date sowing at March) which followed by V_2S_5, V_2S_4 and V_2S_3 interactions.

Table 11. Interaction effect of variety and sowing date on seed weight (kg ha^{-1}) of quinoa at harvest

Seed weight (kg ha^{-1})	
Treatment	Harvest
V_1S_1	180.01 a
V_1S_2	36.64 c
V_1S_3	27.74 cd
V_1S_4	11.47 de
V_1S_5	5.22 f
V_2S_1	83.52 b
V_2S_2	35.89 c
V_2S_3	25.06 c-e
V_2S_4	10.87 de
V_2S_5	6.47 e
$LSD_{(0.05)}$	19.656
CV (%)	12.24

In a column means having similar letter(s) are statistically similar

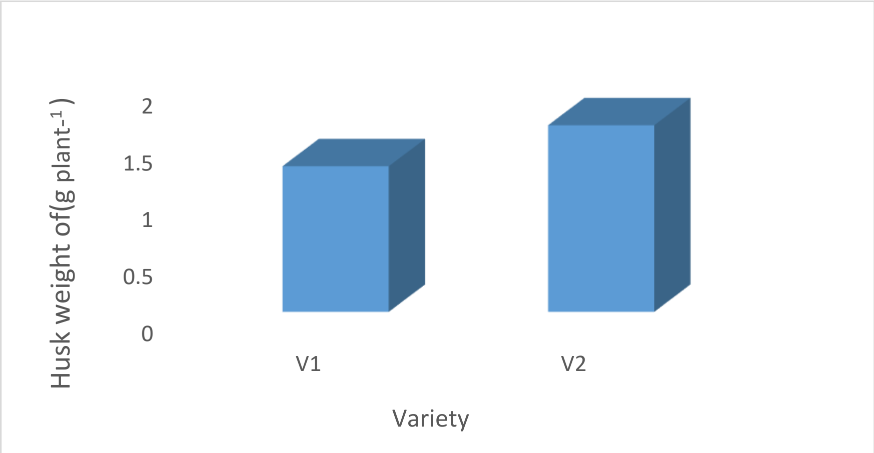
NS = Not significant, CV = Coefficient of variation, $LSD_{(0.05)}$ = Least significant difference at 5% level, DAS = Days after sowing, V_1 = Titicaca, V_2 = Vikinga

S_1 = November sowing, S_2= December sowing, S_3= January sowing, S_4= February sowing and S_5= March sowing

4.12 Husk weight (g plant-1)

4.12.1 Effect of variety:

Husk weight of plant-1 at harvest showed non-significant variation for different varieties (Figure 23). The result showed that, the maximum husk weight of plant-1 (1.64 g) was obtained from Vikinga (V_2) and the minimum husk weight of plant-1 obtained from (1.28 g) Titicaca (V_1).

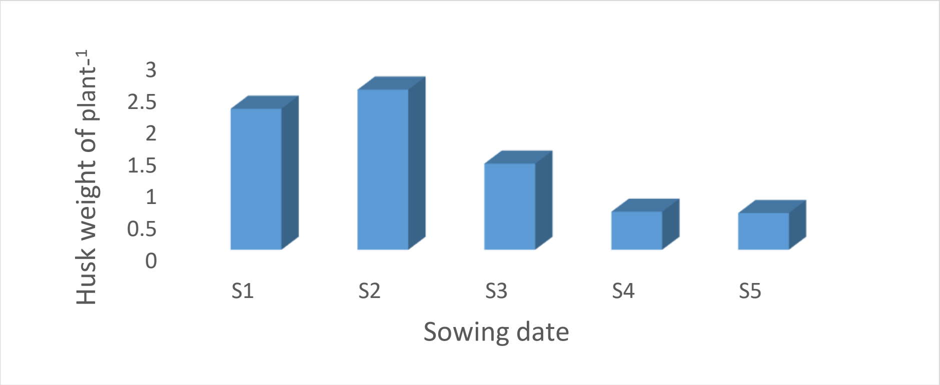


V_1 = Titicaca and V_2 = Vikinga

Figure 23. Husk weight of plant-1 of quinoa as influenced by variety (LSD $_{(0.05)}$ at harvest = 1.801)

4.12.2 Effect of sowing date:

Husk weight of plant-1 of quinoa at harvest showed non-significant variation for different sowing time (Figure 24). The result revealed, the maximum husk weight of plant-1 (2.52 g) was obtained from December sowing (S_2) and the minimum husk weight of plant-^{1} (0.58 g) was obtained from time March sowing (S_5).



S_1: November sowing, S_2: December sowing, S_3: January sowing, S_4: February sowing, S_5: March sowing

Figure 24. Husk weight of plant-^{1} of quinoa as influenced by sowing date (LSD $_{(0.05)}$ at harvest = 1.040)

4.12.3 Interaction effect:

Interaction between variety and sowing time showed significant differences on husk weight of plant-^{1} of quinoa at harvest (Appendix XIII and Table 12). At harvest, the highest husk weight of plant-^{1} was found in V_2S_2 (Vikinga with sowing at December) which was not statistically similar with other interaction.

The lowest husk weight was observed in V_2S_4 (Vikinga with sowing in February) which was statistically similar with V_2S_5 (Vikinga with sowing in March) V_1S_5 (Titicaca with sowing in March) and V_1S_4 (Titicaca with sowing in February).

Table 12. Interaction effect of variety and sowing date on husk weight of plant^{-1} of quinoa at harvest

Husk weight (g plant-^{1})	
Treatment	Harvest
V_1S_1	1.93 a-c
V_1S_2	1.79 a-c
V_1S_3	1.44 bc
V_1S_4	0.64 c
V_1S_5	0.56 c
V_2S_1	2.52 ab
V_2S_2	3.24 a
V_2S_3	1.28 bc
V_2S_4	0.56 c
V_2S_5	0.59 c
$LSD_{(0.05)}$	1.47
CV (%)	64.86

In a column means having similar letter(s) are statistically similar

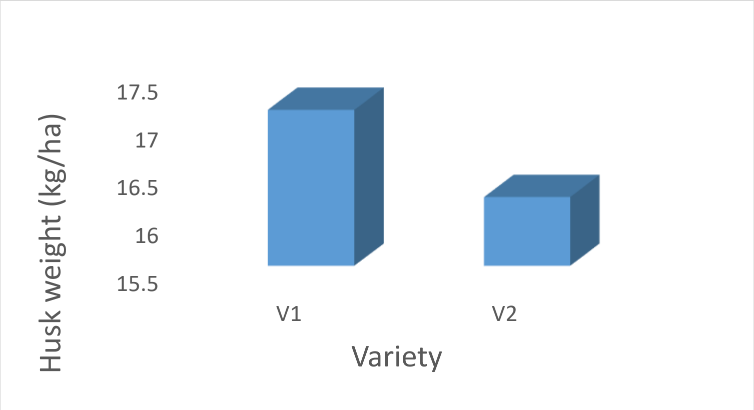
NS = Not significant, CV = Coefficient of variation, LSD $_{(0.05)}$ = Least significant difference at 5% level, DAS = Days after sowing, V_1 = Titicaca, V_2 = Vikinga

S_1 = November sowing, S_2= December sowing, S_3= January sowing, S_4= February sowing and S_5= March sowing

4.13 Husk weight (kg ha^{-1})

4.13.1 Effect of variety:

Husk weight (kg ha^{-1}) of quinoa at harvest showed non-significant variation for different varieties (Figure 25). The result showed that, the maximum seed weight (17.13 kg ha^{-1}) was obtained from Titicaca (V_1) and the minimum seed weight (16.22 kg ha^{-1}) obtained from Vikinga (V_2).

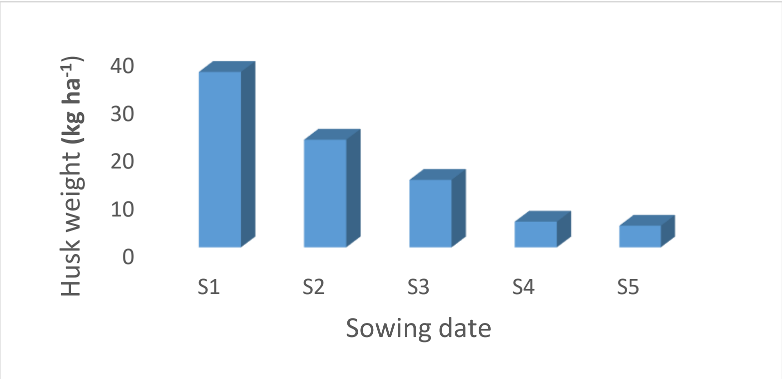


V_1 = Titicaca and V_2 = Vikinga

Figure 25. Husk weight of quinoa as influenced by variety (LSD $_{(0.05)}$ at harvest = 4.021)

4.13.2 Effect of sowing date:

Husk weight (kg ha^{-1}) of quinoa at harvest showed significant variation for different sowing date (Figure 26). The result revealed that, the highest husk weight (36.77 kg ha^{-1}) was obtained from sowing date at November (S_1) and the lowest seed weight (4.53 kg ha^{-1}) was obtained from sowing date at March (S_5).



S_1: November sowing, S_2: December sowing, S_3: January sowing, S_4: February sowing, S_5: March sowing

Figure 26. Husk weight (kg ha^{-1}) of quinoa as influenced by sowing date (LSD $_{(0.05)}$ at harvest = 4.49

Interaction effect:

Interaction between variety and sowing date showed significant differences on husk weight (kg ha^{-1}) of quinoa at harvest (Appendix XIV and Table 13). At harvest, the highest husk weight was found in V_1S_1 (Titicaca with sowing in November) which was not statistically similar with other interaction. The minimum seed weight was observed in V_1S_5 (Titicaca with in March sowing) which was statistically similar with V_1S_4 (Titicaca with sowing in February) and V_2S_5 (Vikinga with sowing in March).

Table 13. Interaction effect of variety and sowing date on husk weight (kg ha^{-1}) of quinoa at harvest

Husk weight (kg ha^{-1})	
Treatment	Harvest
V1S1	42.46 a
V1S2	19.65 cd
V1S3	15.58 de
V1S4	4.39 g
V1S5	3.6 g
V2S1	31.08 b
V2S2	25.48 bc
V2S3	12.71 ef
V2S4	6.37 fg
V2S5	5.47 g
$LSD_{(0.05)}$	6.359
CV(%)	56.07

In a column means having similar letter(s) are statistically similar

NS = Not significant, CV = Coefficient of variation, LSD $_{(0.05)}$ = Least significant difference at 5% level, DAS = Days after sowing, V_1 = Titicaca, V_2 = Vikinga

S_1 = November sowing, S_2= December sowing, S_3= January sowing, S_4= February sowing and S_5= March sowing

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was conducted at the Research farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the period from November 2017 to May 2018 to study growth and yield of (*Chenopodium quinoa)* as affected by sowing date in Rabi season under the Madhupur Tract (AEZ-28). The treatment of the experiment consists of two varieties viz. Titicaca and Vikinga and five sowing date viz. November (S_1), December (S_2), January (S_3), February (S_4) and March (S_5). The experiment was laid out in Split-plot design following the principles of randomization with three replications. Variety was placed in the main plot with different sowing date in the sub plot. Data on different growth stage, yield contributing characters and yield were recorded and statistically significant variation was observed for different treatment .The first sowing date was on November 10, 2017.

The data on growth parameters viz. plant height, number of inflorescence plant^{-1}, number of branches plant^{-1} were recorded during the period from 15 DAS to harvest. Yield contributing characters and yield parameters like number of inflorescence plant^{-1}, inflorescence diameter plant^{-1}, fresh straw weight of total randomly selected five plant at harvest, fresh straw weight (kg ha^{-1}) of total plant at harvest, dry straw weight of total randomly selected five plant at harvest, dry straw weight (kg ha^{-1}) of total plant at harvest, Seed weight of per plant at harvest, 1000-seed weight, Seed weight (kg ha^{-1}), husk weight of per plant, husk weight (kg ha^{-1}) were recorded. Five plants were randomly selected from each unit plot for taking observations on plant height, number of leaves plant$^{-1,}$ number of inflorescence plant^{-1} and number of branches plant^{-1} with 15 days interval at 15, 30 days after sowing and at harvest. Thousand seed weight was measured from sampled seed. Data were analyzed using cropstat-C package. The mean differences among the treatments were compared by least significant difference (LSD) test at 5% level of significance. Data on different growth parameters, yield attributes and yield were significantly varied for different treatments.

Plant height of Titicaca was higher (37.48, 57.55 and 63.75 cm respectively) at 15, 30 and harvest, but at 15, 30 and harvest plant height was higher (29.35, 44.36 and 50.62 cm respectively) in (Vikinga) that was comparatively lower than (Titicaca). At 15, 30 DAS and harvest, the maximum number of branches plant^{-1} (13.22, 16.10 and 17.71 respectively) was found from V_1 (Titicaca). At harvest, the number inflorescence plant^{-1} (25.18) was found from V_2 (Vikinga) that was higher than V_1 (Titicaca). At harvest, the higher diameter (cm) inflorescence plant^{-1} (10.89) that was higher than V_1 (Titicaca). Fresh straw weight plant^{-1} at harvest (2.65 g) was produced by V_1 (Titicaca) and minimum weight fresh straw weight (g) plant^{-1} at harvest (23.47 g) was produced by V_2 (Vikinga). Same trend was observed for fresh straw weight (kg ha^{-1}) plant^{-1}. Here, maximum fresh straw weight (372.54 kg ha^{-1}) was recorded from V_1 (Titicaca) and the minimum one (244.657 kg ha^{-1}) was given by V_2 (Vikinga). At harvest, the higher dry straw weight (g) of plant^{-1} (2.65 g) was found from V_1 (Titicaca). At harvest the lower dry straw weight of plant^{-1} (2.35 g) was found from V_2 (Vikinga). The highest dry straw weight (31.91 kg ha^{-1}) was recorded in V_1 (Titicaca) whereas the lowest dry straw weight plant^{-1} (19.81) was recorded in V_2 (Vikinga). The maximum 1000 seed weight (2.04 g) was recorded by V_1 (Titicaca) and the minimum 1000 seed weight (2.03 g) was recorded by V_2 (Vikinga). The highest seed weight plant^{-1} (3.16 g) was recorded by V_1 (Titicaca) and the lowest seed weight plant^{-1} (2.37 g) was recorded by V_2 (Vikinga). The maximum seed weight (52.22 kg ha^{-1}) was recorded by V_1 (Titicaca) and the minimum seed weight (32.36 kg ha^{-1}) was recorded by V_2 (Vikinga). For sowing date, at 15 days and 30 days plant height was higher (44.57, and 55.63 cm, respectively) in S_4-(February), and S_3-(January) respectively and lower (22.62, and 38.10 cm, respectively) in S_1-(November) and S_5-(March), respectively. But at harvest, plant height was higher (62.54 cm) found from S_2-(December) and lower (22.62 cm) in S_1-(November). At 15 days, 30 days, and harvest, the maximum number of branches plant^{-1} (23.60, 25.83 and 23.45 respectively was found from S_3-

(January) and the minimum number of branches plant^{-1} (5.50, 10.13 and 6.51, respectively) was found from S_3-(January) and S_4-(February). At harvest, the higher number inflorescence plant^{-1} (29.62) was produce by S_1-(November) and lower (13.85) by S_5-(March). The higher diameter inflorescence plant^{-1} at harvest (13.16 cm) was found from S_2-(December) and lower (5.33 cm) from S_5-(March). Maximum fresh straw weight plant^{-1} at harvest (31.33 g) was produced by S_1-(November) and minimum weight (12.37 g) was produced by S_5-(March). Same trend was observed for highest fresh straw weight (kg/ha). Here, maximum fresh straw weight (483.43 kg ha^{-1}) was recorded from S_1-(November) and the minimum one (154.11 kg ha^{-1}) was given by S_5-(March). At harvest, the higher dry straw weight (g) of plant^{-1} (3.81 g) was found from S_1-(November) while the lower dry straw weight plant^{-1} (1.37 g) was found from S_5-(March). The highest dry straw weight (49.72 kg ha^{-1}) was recorded in S_1-(November) whereas the lowest dry straw weight (11.40 kg ha^{-1}) was recorded in S_5-(March). The maximum 1000 seed weight (2.55 g) was found from S_1-(November) and the minimum 1000 seed weight (1.17 g) was recorded by S_5-(March). The highest seed weight plant^{-1} (6.44 g) was recorded by S_1-(November) and the lowest seed weight plant^{-1} (0.61 g) was recorded by S_5-(March). The maximum seed weight (131.76 kg ha^{-1}) was recorded by S_1-(November) and the minimum seed weight (11.40 kg ha^{-1}) was recorded by S_5-(March).The maximum husk weight plant^{-1} (2.52 g) was obtained from S_2-(December) and the minimum (12.37 g) was obtained from S_5-(March). The higher husk weight (36.77 kg ha^{-1}) was recorded by S_1-(November) and the minimum seed weight (4.53 kg ha^{-1}) was recorded by S_5-(March). Due to interaction effect of variety and sowing date, at plant height of V_1S_4 and V_1S_1 was higher (50.78 and 65.36 cm, respectively) at 15 and 30 DAS, But at harvest plant height was higher (72.83 cm) in V_1S_1. The maximum number of branches plant^{-1} (23.93, 25.88 and 25.20, respectively) was found from both V_1S_3 and V_1S_1 and the minimum number of branches plant^{-1} (5.40, 10.13 and 5.86 respectively) was found from both V_1S_1 and V_1S_5 At harvest, the higher number of inflorescence plant^{-1} (31.46) was produce by V_1S_2 and the lower (13.37) was found from V_1S_2. At harvest the higher diameter of inflorescence plant^{-1} at harvest (14.41) was found from V_2S_2 and the lower (5.17) was from

V_2S_5. The higher fresh straw weight of plant^{-1} at harvest (36.67 g) was produced by V_1S_1 and minimum number (12.14) was produced by V_2S_5. Same trend was observed for fresh straw weight (kg ha^{-1}). Here, fresh straw weight (614.31 kg ha^{-1}) was recorded from V_1S_1 and the minimum one (147.97 kg ha^{-1}) was given by V_2S_5. The higher dry straw weight of plant^{-1} (4.13 g) was found from V_1S_1 while at harvest, the lower dry straw weight plant^{-1} (1.20 g) was found from V_2S_5. The highest dry straw weight (69.12 kg ha^{-1}) was recorded in V_1S_1 at harvest whereas lower is (10.58 kg ha^{-1})) from V_2S_5. The highest seed weight plant^{-1} (7.47 g) was recorded by V_1S_1 and lowest weight was (0.52) from V_2S_5. The maximum seed weight (180.01 kg ha^{-1}) was recorded by V_1S_1 and the minimum seed weight (5.22 kg ha^{-1}) was recorded by V_1S_5. The maximum husk weight plant^{-1} (3.24 g) was obtained from V_2S_2 and the minimum (0.56) was obtained from V_1S_5 and V_2S_4. The higher husk weight (42.46 kg ha^{-1}) was recorded by V_1S_1 and the minimum seed weight (3.60 kg ha^{-1}) was recorded by V_1S_5.

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

- The quinoa variety, Titicaca showed higher yield than other variety.
- The sowing date November showed maximum growth and yield in Quinoa.
- The application of Titicaca with sowing date November could be the better production package for maximum growth and yield of Quinoa.

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

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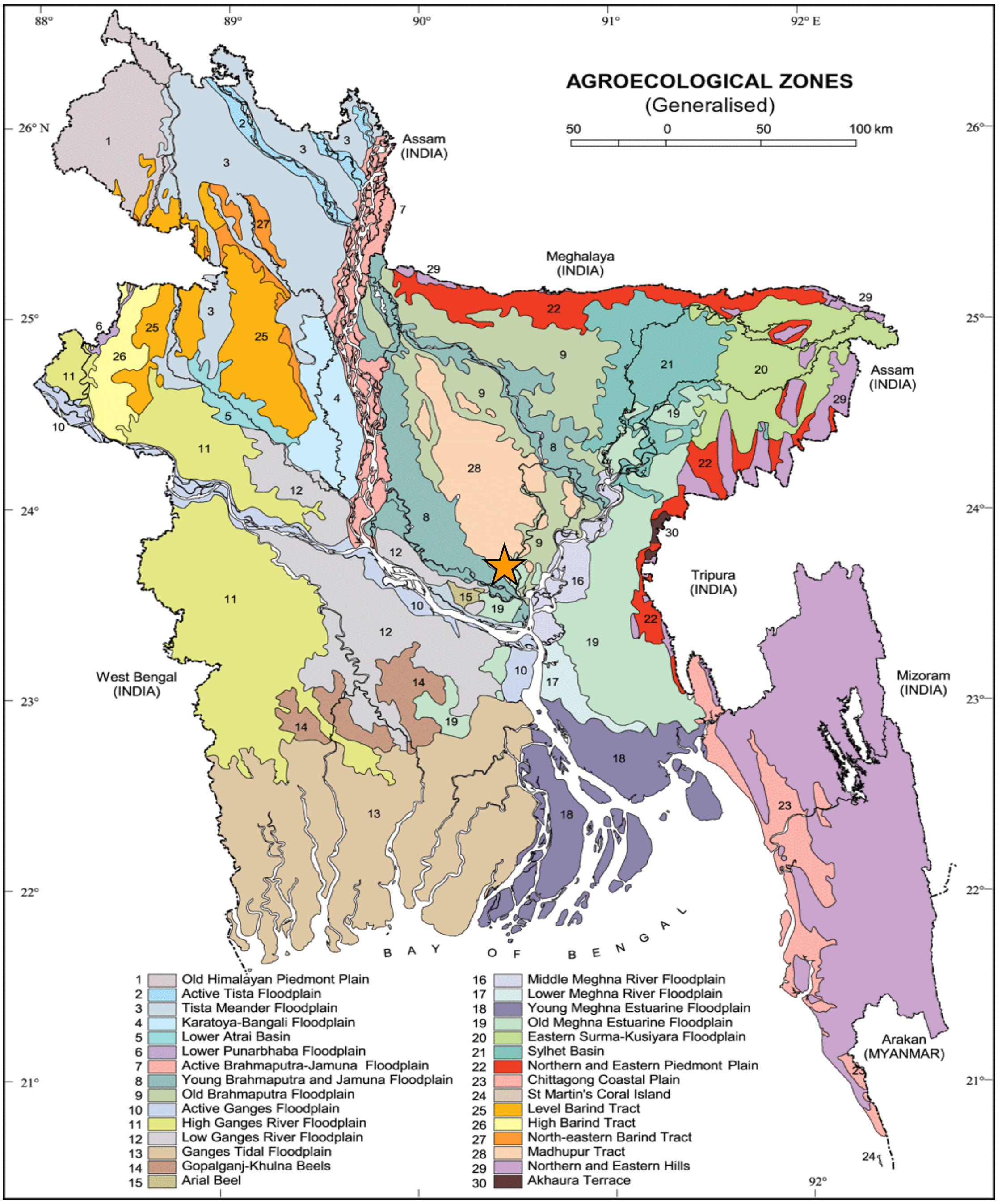
APPENDICES

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-Bangla Agricultural University Research Farm, Dhaka-1207.
AEZ	AEZ-28, Madhupur 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		
March	32	17	64	00
April	35.5	20.5	72	78
May	36.6	21.1	71	185
June	39.4	24.4	78	277

* Monthly average

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

Appendix IV. Mean square values of plant height of quinoa as influenced by variety and sowing date

Source of variation	Degrees of freedom	Mean square		
		Plant height at		
		15 DAS	30 DAS	Harvest
Replication	2	184.307	556.490	885.190
Variety (A)	1	496.133	1304.03	1292.45
Error I	2	33.4265	78.6696	65.6305
Sowing Date (B)	4	638.606*	320.648*	414.026*
Interaction (A×B)	4	27.5738*	98.0771*	60.7770*
Error II	16	68.1062	51.1045	45.7968

* Significant at 5% level

Appendix V. Mean square values of number of branches plant^{-1} of quinoa as influenced by Variety and sowing date

Source of variation	Degrees Of freedom	Mean square		
		Number of branches plant^{-1} at		
		15 DAS	30 DAS	Harvest
Replication	2	19.1740	38.8563	28.6778
Variety (A)	1	7.63056	8.27926	9.46408
Error I	2	2.91240	8.14646	10.8783
Sowing Date (B)	4	286.427*	233.125*	399.452*
Interaction (A×B)	4	5.42965*	4.87788	17.4790
Error II	16	3.85237	8.29457	4.88167

* Significant at 5% level

Appendix VI. Mean square values of Number of inflorescence plant^{-1} of quinoa as influenced by Variety and sowing date

Source of variation	Degrees Of freedom	Mean square
		Number of inflorescence plant^{-1} at
		Harvest
Replication	2	17.5193
Variety (A)	1	76.0658
Error I	2	4.71510
Sowing Date (B)	4	245.774
Interaction (A×B)	4	6.56126
Error II	16	6.38845

* Significant at 5% level

Appendix VII. Mean square values of Inflorescence diameter plant^{-1} of quinoa as influenced by Variety and sowing date

Source of variation	Degrees of freedom	Mean square Inflorescence diameter plant^{-1} Harvest
Replication	2	12.1566
Variety (A)	1	27.5713
Error I	2	1.23156
Sowing Date (B)	4	61.3921*
Interaction (A×B)	4	8.29821
Error II	16	1.62459

* Significant at 5% level

Appendix VIII. Mean square values of dry straw weight g plant^{-1} of quinoa as influenced by Variety and sowing date

Source of variation	Degrees of freedom	Mean square Dry straw weight g plant^{-1} Harvest
Replication	2	64.3844
Variety (A)	1	17.9878
Error I	2	18.0325
Sowing Date (B)	4	123.442*
Interaction (A×B)	4	3.18661*
Error II	16	14.7805

* Significant at 5% level

Appendix IX. Mean square values of dry straw weight (kg/ha) of quinoa as influenced by Variety and sowing date

Source of variation	Degrees of freedom	Mean square
		Dry straw weight (kg/ha)
		Harvest
Replication	2	10952.7
Variety (A)	1	42741.3
Error I	2	1248.01
Sowing Date (B)	4	48949.1*
Interaction (A×B)	4	13531.4*
Error II	16	1199.01

* Significant at 5% level

Appendix X. Mean square values of seed weight (g plant^{-1}) of quinoa as influenced by Variety and sowing date

Source of variation	Degrees of freedom	Mean square
		seed weight (g plant^{-1})
		Harvest
Replication	2	185.547
Variety (A)	1	100.321
Error I	2	13.4268
Sowing Date (B)	4	880.361 *
Interaction (A×B)	4	23.2625 *
Error II	16	46.0220

* Significant at 5% level

Appendix XI. Mean square values of 1000-Seed weight (g) of quinoa as influenced by Variety and sowing date

Source of variation	Degrees of freedom	Mean square
		1000-Seed weight (g)
		Harvest
Replication	2	.343000E-02
Variety (A)	1	.261333E-02
Error I	2	.691633E-01
Sowing Date (B)	4	1.99412 *
Interaction (A×B)	4	.117383E-01 *
Error II	16	.140467E-01

* Significant at 5% level

Appendix XII. Mean square values of seed weight (kg/ha) of quinoa as influenced by Variety and sowing date

Source of variation	Degrees of freedom	Mean square
		Seed weight (kg/ha)
		Harvest
Replication	2	3568.27
Variety (A)	1	118045.
Error I	2	3460.75
Sowing Date (B)	4	645104. *
Interaction (A×B)	4	106581. *
Error II	16	5009.15

* Significant at 5% level

Appendix XIII. Mean square values of husk weight (g plant^{-1}) of quinoa as influenced by Variety and sowing date

Source of variation	Degrees of freedom	Mean square
		Husk weight (g plant^{-1})
		Harvest
Replication	2	2.31846
Variety (A)	1	.990083
Error I	2	1.31520
Sowing Date (B)	4	4.85264*
Interaction (A×B)	4	.678775
Error II	16	.722192

* Significant at 5% level

Appendix XIV. Mean square values of husk weight (kg/ha) of quinoa as influenced by Variety and sowing date

Source of variation	Degrees of freedom	Mean square
		Husk weight (kg/ha)
		Harvest
Replication	2	13.9683
Variety (A)	1	6.29292
Error I	2	6.55059
Sowing Date (B)	4	1079.75 *
Interaction (A×B)	4	65.6259
Error II	16	13.4971

* Significant at 5% level