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QUINOA (*Chenopodium quinoa* Willd.) – A POTENTIAL NEW CROP IN BANGLADESH: AGRONOMIC PERFORMANCE WITH SOWING DATE

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Abstract

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka with the financial support of SAURES (Sher-e-Bangla Agricultural University Research System) to study the possibility of growing quinoa in Bangladesh with different sowing dates having two cultivars. The experiment comprised of two factors; Factor A: Cultivar (2) *viz.,* Titicaca (C_1) and Vikinga (C_2) and Factor B: Sowing date (5) viz. November -10 (S_1), December -10 (S_2), January -10 (S_3), February -10 (S_4) and March -10(S_5). The experiment was laid out in split-plot design with three replications. Results revealed that different growth parameters, yield attributes and yield were significantly varied with different sowing dates. At harvest, the tallest plant height (63.75 cm), highest seed yield (0.77 t ha^{-1}) and straw yield (0.89 t ha^{-1}) was found from Titicaca but the higher number of branches $plant^{-1}$ (17.71) from Vikinga. The tallest plant height (62.54 cm), highest branch number $plant^{-1}$ (22.82), longest inflorescence (29.62 cm), highest 1000-seed weight (2.56 g), seed yield (1.09 t ha^{-1}), straw yield (1.25 t ha^{-1}) and harvest index (46.58%) was exhibited by November -10 sowing. The interaction effect of Titicaca sown in November -10 (C_1S_1) resulted the highest plant height at harvest (72.83 cm), branches $plant^{-1}$ (25.20), 1000-seed weight (2.58 g), seed yield (1.16 t ha^{-1}) and straw yield (1.33 t ha^{-1}) but the highest inflorescence length (31.46 cm) and harvest index (47.02%) from C_2S_2 (Vikinga sown in December – 10). From the above results it can be concluded that quinoa – as a new crop is suitable to cultivate in *Rabi* season of Bangladesh with a complete agronomic management package.

Introduction

Quinoa (*Chenopodium quinoa* willd.) is a yearly herbaceous plant belongs to Amaranthaceae family that originated in the appeasing slopes of the Andes in South America. It was cultivated and worn 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 2018, world production of quinoa was 158,920 tonnes, led by Peru and Bolivia with 99% of the total combined (FAOSTAT, 2020).

Quinoa is a quick-rising plant, grows up to 2 m tall with exchange, thickly ragged, triangular to ovate vegetation. Every inflorescence produced hundreds of little achiness, approximately 2 mm in width. Quinoa is an achene (a seed-similar to fruit with a firm fur) with diversified colours ranging from white or pale yellow to orange, red, brown and black. An ideal average temperature for quinoa would be around 15–20°C, but some specific landraces can also withstand extreme temperatures from 8°C to +38°C (Bazile *et al.*, 2015).

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 crop is rich in protein (7.47 to 22.08%) 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 and its glycemic index is 53 which is much lower than white rice. The digest ability of quinoa protein is more than 80 per cent. Quinoa also have usual defiant Oxidants like -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. FAO declared 2013 as International year of Quinoa (Bhargava *et al.*, 2006).

The importance of quinoa is getting momentum around the world due to its ability to withstand in extreme conditions (Bazile *et al.*, 2015). The high genetic diversity of the crop provides its opportunities for leveraging its hardiness and further wide adaptation (Louafi *et al.,* 2013). Today, drought and soil salinization are major limiting factors in cultivation, a fact that is generating significant pressure on arable land availability. Considering these major challenges, the crop is presently cultivated, or is under experimentation, in more than 95 countries and its cultivation continue to expand rapidly worldwide (Bazile, 2014; Bazile *et al.,* 2016). The cultivation of quinoa spreading throughout the world as far as Tibet, Morocco, France, India, China, the United Kingdom, Sweden, Denmark, Netherlands, Canada, USA, Australia, Thailand, Kenya and Italy, among others (Bhargava *et al.*, 2006; Pulvento *et al.*, 2010; Bazile *et al.*, 2015).

A balanced diet, adequate in all necessary nutrients; energy, protein, vitamins and minerals, can satisfy both perceptible and hidden hunger (Jahan and Hossain, 1998). Though rice as a cereal is the main food of Bangladesh, it is not well balanced and as a result children and women suffer from high levels of malnutrition and micronutrient deficiencies such as low birth weight, undernutrition, vitamin A deficiency, iodine-deficiency disorders and iron-deficiency anaemia. At the same time, new health problems related to over-nutrition such as obesity are emerging (World Bank, 2005).

Optimum planting time is the 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). There is no research has yet been conducted to introduce quinoa in Bangladesh. Hence it is high time to introduce the crop like quinoa in Bangladesh to supplement for the malnutrition facing by the country people's. Therefore the experiment was undertaken during *Rabi* season taking two Danish cultivars and different dates of sowing to identify the optimum sowing date of quinoa for the prevailing climatic condition of Bangladesh.

Materials and Methods

The experiment was conducted at the Agronomy Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka that located in 23°77' N latitude and 90.26° E longitudes during November, 2017 to July, 2018. The general soil type of the experimental field was deep red brown terrace soil belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ-28). The soil was consuming a texture of silty clay with pH 5.6 and organic matter 0.78%, sand 26%, silt 45% and clay 29%. During the experimental period the maximum temperature (39.4°C), highest relative humidity (78%) and highest rainfall (277 mm) and the minimum temperature (17°C) and minimum relative humidity (64%) was recorded. The experiment comprised of two factors; Factor A: Cultivar (2) - Titicaca (C_1) and Vikinga (C_2), Factor B: Sowing dates (5) - November -10 (S_1), December -10 (S_2), January -10 (S_3), February -10 (S_4) and March -10 (S_5). Two Danish cultivars e.g., Titicaca and Vikinga was collected from DAE, Bangladesh. Initially the experiment was designed with a sowing date of each month but finally the plants of April and May sowing were damaged and June to October sowing were not possible due to excessive soil moisture.

The land was opened on the 05 November, 2017. Urea, Triple super phosphate (TSP) and Muriate of potash (MoP) @180, 152 and 63 kg ha^{-1} were added in the experimental soil as a source of nitrogen (N), phosphorous (P) and potassium (K), respectively. Full dose of TSP and MoP along with one third urea were applied in final land preparation as basal dose and the rest amount of urea was top dressed at 25 and 40 DAS (Risi and Nicholas, 1991). The experiment was laid out in a split-plot design with three replications where cultivars were assigned in the main plot and sowing dates in sub-plot. The first sowing was done 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. Other seed sowing were done as per treatment. Thinning was done two times; first at 10 DAS and second at 15 DAS to maintain optimum plant population in each plot. Irrigation was given at 15 and 30 DAS for optimizing the vegetative growth for all experimental plots equally and supplementary irrigation was maintained as and when necessary. Proper drainage facilities was also maintained accurately to remove excess water from the experimental plot. The field was weeded twice at 20 and 35 DAS by hand weeding. Five plants from each plot were randomly selected and marked with sample card from which plant height and branches plant^{-1} were recorded at different growth stages. Length of inflorescences plant^{-1}, 1000-seed weight, seed and straw yield were recorded at harvest. Harvesting was done when 90% of the grain became green to yellow (Titicaca) and red (Vikinga) in color. The matured crops were collected by hand picking from each plot. The collected crops were sun dried, threshed and the seeds were separated, cleaned and dried in the sun for 3 to 5 consecutive days for achieving safe moisture of seed. The dried seeds and straw were cleaned and weighed. The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of CropStat and the mean differences were adjudged by least significant difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

Results and Discussion

Effect of cultivar

Plant height at 15 DAS showed non-significant variation for different cultivars but at 30 DAS and harvest significant variation was observed (Table 1). At 30 DAS, the higher plant height (57.55 cm) was obtained from Titicaca and the lower (44.37 cm) from Vikinga. Similar trend was also followed at harvest with higher plant height (63.75 cm) of Titicaca compared to that of Vikinga (50.62 cm). The plant height of Titicaca at harvest was 20.58% higher than Vikinga. Such higher plant height of Titicaca might be due to its genetical character. The result was similar with the findings of Fernando *et al.* (2012) who conducted a research on quinoa cultivars viz. Titicaca and Vikinga and found higher plant height from Titicaca. Branches plant^{-1} at 30 DAS and harvest showed significant variation for cultivars but non-significant at 15 DAS (Table1). The higher number of branches plant^{-1} (16.11 and 17.11) was obtained from Vikinga compared to Titicaca (15.05 and 16.59) at 30 DAS and harvest, respectively. Inflorescence length and 1000-seed weight showed non-significant variation for cultivars. Seed yield of quinoa showed significant variation for cultivars. The higher seed yield (0.77 t ha^{-1}) from Titicaca and the lower (0.61 t ha^{-1}) from Vikinga. The Titicaca yield was 26.23% higher than Vikinga. Similarly higher straw yield (0.89 t ha^{-1}) was obtained from Titicaca and the lower (0.76 t ha^{-1}) from Vikinga. No significant variations for harvest index was observed between the two cultivars (Table 2).

Effect of sowing date

Plant height at 15, 30 DAS and harvest showed significant variation for different sowing dates (Table1). At 15 DAS, the highest plant height (44.57 cm) was obtained from February -10 sowing and the lowest (22.62 cm) from November -10 sowing. At 30 DAS, the highest plant height (55.63 cm) was obtained from January -10 sowing and the lowest (38.10 cm) from March -10 sowing. At harvest, the maximum plant height (62.54 cm) was obtained from November -10 sowing that similar to all other sowings except March -10 sowing that showed the lowest plant height (42.75 cm). These results were supported with the findings of Troiani *et al.* (2004) who conducted a research on quinoa time sowing and reported second half of the November to the end of December showed the highest plant height. Number of branches $plant^{-1}$ at 15, 30 DAS and harvest showed significant variation for different sowing dates (Table1). At 15 and 30 DAS, the highest number of branches $plant^{-1}$ (23.60 and 25.83) was obtained from January -10 sowing and the lowest number of branches (5.50 and 10.13) obtained from November -10 sowing, respectively. At harvest, the highest branch number (23.45) was obtained from January -10 sowing that similar to December – 10 and November – 10 sowing and the lowest branch number (6.51) from March-10 sowing. The highest inflorescence length $plant^{-1}$ (29.62 cm) was obtained from November - 10 sowing that similar to December – 10 sowing (28.33 cm) and the lowest inflorescence length (13.85 cm) obtained from March -10 sowing. Weight of 1000-seed of quinoa showed significant variation for different sowing dates (Table 2) where the highest 1000-seed weight (2.56 g) was obtained from November -10 sowing that similar to December – 10 sowing (2.47 g) and the lowest 1000-seed weight (1.17 g) from March -10 sowing. November sowing produced seed with 118% higher 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.

Table 1. Effect of cultivar and sowing date on plant height and branch number $plant^{-1}$of quinoa

Treatments	Plant height (cm) at			Branches $plant^{-1}$ (no.) at		
	15 DAS	30 DAS	Harvest	15 DAS	30 DAS	Harvest
Effect of cultivar						
Titicaca	37.49	57.55 a	63.75 a	12.21	15.05 b	16.59 b
Vikinga	29.36	44.37 b	50.63 b	13.22	16.11 a	17.71 a
$LSD_{(0.05)}$	NS	12.936	12.728	NS	1.026	1.073
CV (%)	17.30	17.41	14.16	13.42	18.32	19.23
Effect of sowing date						
November – 10	22.62 b	54.57 a	62.54 a	5.50 d	10.13 c	22.84 a
December – 10	29.52 b	54.49 a	62.47 a	9.20 c	13.32 bc	22.80 a
January – 10	44.23 a	55.63 a	60.46 a	23.60 a	25.83 a	23.45 a
February – 10	44.57 a	52.01 a	57.73 a	14.65 b	16.79 b	10.15 b
March – 10	26.17 b	38.10 b	42.75 b	10.64 c	11.82 c	6.51 c
$LSD_{(0.05)}$	10.000	8.749	8.282	2.402	3.524	2.704
CV (%)	24.69	14.03	11.83	15.44	18.49	12.88

Figures in a column with common letter(s) do not differ significantly at 5% probability level.

Seed yield of quinoa showed significant variation for different sowing dates and the highest yield (1.09 t ha^{-1}) was obtained from November -10 sowing that followed by December -10 sowing (0.88 t ha^{-1}) and the lowest seed yield (0.26 t ha^{-1}) from March -10 sowing. The seed yield of quinoa was reduced by 19.27, 32.11, 55.96 and 76.15% for December, January, February and March sowing, respectively compared to that of November sowing. Higher seed yield of quinoa at 15 October sowing was also reported by Ramesh *et al.* (2017). The highest straw yield (1.25 t ha^{-1}) was obtained from November -10 sowing that similar to December (0.99 t ha^{-1}) and January (0.90 t ha^{-1}) sowing and the lowest straw yield (0.38 t ha^{-1}) from March -10 sowing. The highest harvest index (47.06%) was obtained from December-10 sowing that similar to November (46.58%) and January (45.12%) sowing and the lowest (40.63%) from March -10 sowing (Table 2).

Table 2. Effect of cultivar and sowing date on yield and other parameters of quinoa

Treatments	Inflorescence length (cm)	Wt. of 1000 seeds (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Effect of cultivar					
Titicaca	22.01	2.05	0.77 a	0.89 a	46.39
Vikinga	25.18	2.03	0.61 b	0.76 b	44.53
$LSD_{(0.05)}$	NS	NS	0.089	0.104	NS
CV (%)	9.23	12.89	8.52	4.28	6.76
Effect of sowing date					
November – 10	29.62 a	2.56 a	1.09 a	1.25 a	46.58 a
December – 10	28.33 ab	2.47 a	0.88 bc	0.99 ab	47.06 a
January – 10	25.27 b	2.25 b	0.74 c	0.90 b	45.12 ab
February – 10	20.86 c	1.75 c	0.48 d	0.62 bc	43.64 b
March – 10	13.86 d	1.17 d	0.26 e	0.38 c	40.63 c
$LSD_{(0.05)}$	3.094	0.145	0.187	0.372	2.268
CV (%)	10.71	5.81	10.26	4.20	7.86

Figures in a column with common letter(s) do not differ significantly at 5% probability level.

Interaction effect of cultivar and sowing date

Interaction between cultivar and sowing date showed significant differences on plant height at 15 and 30 DAS and at harvest (Table 3). At 15 DAS, the highest plant height (50.78 cm) was observed in C_1S_4 (Titicaca with February -10 sowing) which was at par with C_1S_3, C_2S_3 and C_2S_4. The lowest plant height (20.89 cm) was observed in C_2S_1 (Vikinga with November -10 sowing) which was statistically similar with C_2S_2, C_2S_5, C_1S_1 and C_1S_5. At 30 DAS, the highest plant height (65.36 cm) was observed in C_1S_1 (Titicaca with November -10 sowing) that statistically similar with C_1S_2, C_1S_4, C_1S_3 and C_2S_3.

The lowest plant height (33.99 cm) was observed in C_2S_5 (Vikinga with March -10 sowing) that similar with C_1S_5, C_2S_2 and C_2S_1. At harvest, the highest plant height (72.83 cm) was found in C_1S_1 (Titicaca with November -10 sowing) which was statistically similar with C_1S_2, C_1S_4 and C_1S_3. The lowest plant height (37.09 cm) was observed in C_2S_5 (Vikinga with March -10 sowing) that similar to C_1S_5. At 15 DAS, the highest branch number $plant^{-1}$ (23.93) was observed in C_1S_3 (Titicaca with January -10 sowing) that similar to C_2S_3. The lowest branch number $plant^{-1}$ (5.60) was observed in C_2S_1 (Vikinga with November -10 sowing) that similar to C_1S_1.

Table 3. Interaction effect of cultivar and sowing date on plant height and branch number plant^{-1} of quinoa

Interactions	Plant height (cm) at			Branches plant^{-1} (no.) at		
	15 DAS	30 DAS	Harvest	15 DAS	30 DAS	Harvest
C_1S_1	24.34 def	65.36 a	72.83 a	5.40 e	10.13 c	25.20 a
C_1S_2	35.61 b-e	65.23 a	71.57 a	9.33 c	13.08 c	21.21 bc
C_1S_3	48.50 ab	57.40 ab	62.80 ab	23.93 a	25.88 a	22.20 abc
C_1S_4	50.78 a	57.55 ab	63.15 ab	12.66 c	14.67 bc	8.46 de
C_1S_5	28.20 c-f	42.20 cd	48.40 cd	9.73 cd	11.50 c	5.86 e
C_2S_1	20.89 f	43.78 cd	52.10 bc	5.60 e	10.13 c	20.40 c
C_2S_2	23.42 ef	43.74 cd	53.50 bc	9.06 d	13.56 c	24.47 ab
C_2S_3	39.96 abc	53.85 abc	58.12 bc	23.26 a	25.78 a	24.70 ab
C_2S_4	38.36 a-d	46.46 bc	52.31 bc	16.63 b	18.90 b	11.83 d
C_2S_5	24.13 def	33.99 d	37.09 d	11.54 cd	12.14 c	7.15 e
$LSD_{(0.05)}$	14.284	12.373	11.713	3.397	4.985	3.824
CV (%)	24.69	14.03	11.83	15.44	18.49	12.88

Figures in a column with common letter(s) do not differ significantly at 5% probability level.
C_1 = Titicaca, C_2 = Vikinga, S_1 = November -10, S_2 = December -10, S_3 = January -10, S_4 = February -10 and S_5 = March -10 sowing

At 30 DAS, the highest number of branches plant^{-1} (25.88) was observed in C_1S_3 (Titicaca with January -10 sowing) that also similar toC_2S_3 (Vikinga with January -10 sowing). The lowest number of branches plant^{-1} (10.13) was observed in C_1S_1 (Titicaca with November -10 sowing) that identical to C_2S_1 (Vikinga with November -10 sowing) and similar with C_1S_5, C_2S_5, C_1S_2, C_2S_2 and C_1S_4. At harvest, the highest branch number plant^{-1} (25.20) was found in C_1S_1 (Titicaca with November -10 sowing) that similar to C_2S_3, C_2S_2 and C_1S_3. The lowest number of branches plant^{-1} (5.86) was observed in C_1S_5 (Titicaca with March -10 sowing) that similar to C_2S_5.

Interaction between cultivar and sowing dates showed significant differences on inflorescence length plant^{-1} at harvest (Table 4). The tallest inflorescence (31.46 cm) was found in C_2S_2 (Vikinga with December -10 sowing) which was statistically similar with C_2S_1, C_1S_1 and C_2S_3. The shortest inflorescence (13.37 cm) was observed in C_1S_5 (Titicaca with March -10 sowing) that similar to C_2S_5. The highest 1000-seed weight (2.58 g) was found in C_1S_1 (Titicaca with November -10 sowing) which was similar to C_2S_1, C_2S_2 and C_1S_2. The lowest 1000-seed weight (1.10 g) was observed in C_2S_5 (Vikinga with March -10 sowing) that similar to C_1S_5 (Titicaca with March -10 sowing). The highest seed yield (1.16 t ha^{-1}) was found in C_1S_1 (Titicaca with November -10 sowing) that similar to C_2S_1 (1.01 t ha^{-1}) and C_1S_2 (0.96 t ha^{-1}) and the lowest seed yield (0.21 t ha^{-1}) in C_2S_5 (Vikinga with March -10 sowing) that similar to C_1S_5 and C_2S_4. The highest straw yield (1.33 t ha^{-1}) was found in C_1S_1 (Titicaca with November -10 sowing) which was statistically similar to C_2S_1 and C_1S_2 and the lowest straw yield (0.33 t ha^{-1}) was observed in C_2S_5 (Vikinga with March -10 sowing) that similar toC_1S_5, C_2S_4 and C_1S_4. The highest harvest index (47.02%) was found in C_2S_2 (Vikinga with December -10 sowing) that similar to all interactions except C_2S_5 and C_2S_4 those were statistically similar.

Table 4. Interaction effect of cultivar and sowing date on yield and other parameters of quinoa

Interactions	Inflorescence length (cm)	Wt. of 1000 seeds (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
C_1S_1	28.50 b	2.58 a	1.16 a	1.33 a	46.59 a
C_1S_2	25.20 b-d	2.47 ab	0.96 ab	1.09 abc	46.83 a
C_1S_3	23.13 c-e	2.20 c	0.86 bc	0.97 bc	46.99 a
C_1S_4	19.77 e	1.75 d	0.54 def	0.63 de	46.15 a
C_1S_5	13.37 f	1.24 e	0.31 fg	0.43 e	41.89 ab
C_2S_1	30.73 a	2.53 a	1.01 ab	1.16 ab	46.54 a
C_2S_2	31.46 a	2.46 ab	0.79 bcd	0.89 bcd	47.02 a
C_2S_3	27.40 a-c	2.30 b	0.62 cde	0.83 cd	42.76 ab
C_2S_4	21.96 de	1.74 d	0.41 efg	0.61 de	40.20 b
C_2S_5	14.34 f	1.10 e	0.21 g	0.33 e	38.89 b
$LSD_{(0.05)}$	4.374	0.205	0.249	0.326	5.875
CV (%)	10.71	5.81	10.26	4.20	7.86

C_1 = Titicaca, C_2 = Vikinga, S_1 = November -10, S_2 = December -10, S_3 = January -10, S_4 = February -10 and S_5 = March -10 sowing

Conclusion

Quinoa can be successfully cultivate in Bangladesh during *Rabi* season. The cultivar Titicaca performed better compared to that of Vikinga. Among the five sowing dates, sowing at November-10 gave the highest grain yield where cultivar Titicaca sown in November could be the best combination.

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