

INFLUENCE OF PLANTING METHOD AND NITROGEN DOSE ON GROWTH AND YIELD OF QUINOA (*Chenopodium quinoa* Willd.)

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Abstract

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during *Rabi* season 2018-19 to find out the influence of planting methods and nitrogen dose on growth and yield of Quinoa-a highly nutritious super food newly introduced in Bangladesh. The experiment was laid out in a Split-plot design with 3 replications. Two planting methods viz., i) seed sowing (M_1) and ii) seedling planting (M_2) in the main plot and eight nitrogen doses viz., i) Control (F_1), ii) 50 kg N ha⁻¹ (F_2), iii) 100 kg N ha⁻¹ (F_3), iv) 150 kg N ha⁻¹ (F_4), v) 180 kg N ha⁻¹ (F_5), vi) 200 kg N ha⁻¹ (F_6), vii) 220 kg N ha⁻¹ (F_7) and ix) 250 kg N ha⁻¹ (F_8) in the sub-plot were assigned. Almost all the studied characters were found statistically significant due to variation in treatments. The higher plant height, leaf number plant⁻¹, branch number plant⁻¹ and inflorescence height were observed in seedling transplantation than seeds sowing. Increment of nitrogen doses increased the plant height, leaves number plant⁻¹, branch number plant⁻¹, inflorescence height and SPAD value up to 150-200 kg N ha⁻¹ and then decreased. Higher doses of nitrogenous fertilizer application increased the grain weight. Planting seedling with 150 kg N ha⁻¹ showed the highest seed yield (1227.43 kg ha⁻¹) which was similar to 180 kg N ha⁻¹. Cultivation of quinoa with 25 days old seedlings and 150 kg N ha⁻¹ gave 206.77% higher yield compared to that of control and it was 64.71% higher in case of seeds sowing with similar nitrogen dose.

Introduction

Quinoa (*Chenopodium quinoa* Willd.) has been recognized as a climate resilient crop of great value with most nutritious food crops and the seeds contains high quality protein, which has all the essential amino acids including lysine, methionine and threonine that are scarce in cereals and legumes (Repo-Carrasco *et al.*, 2003). Food and Agriculture Organization (FAO) has identified quinoa as one of the crops that will play an important role in ensuring future food security and designated the year 2013 as the “Year of Quinoa” (Bazile *et al.*, 2015). Worldwide, the demand for quinoa is growing, especially in the health food segment, but current supplies are inadequate. Besides the use for human consumption, quinoa seed has other uses as livestock and poultry feed. The whole plant can be used as green fodder and harvest residues can be fed to the animals. Quinoa seeds are an exceptionally nutritious food source, owing to their high protein content with all essential amino acids, lack of gluten, and high content of several minerals such as Ca, Mg, Fe, and it is also rich in vitamins (Bhargara *et al.*, 2006).

Worldwide quinoa is cultivating using true seeds as planting material, but Ramesh *et al.* (2019) reported that the crop can also be cultivate using 20 days old seedlings. Hirich (2014) reported that application and suggested the increased seed yield with increasing nitrogen supply. The yield was highest in the 50% of full irrigation with 240 kg N ha⁻¹. Another experiment conducted by Shams (2011) with nitrogen fertilization showed that high nitrogen fertilizer dose significantly increased quinoa yield. Alandia *et al.* (2016) reported that quinoa is a crop which can profit from relatively high levels of N-application under North European conditions.

Agronomy department of Sher-e-Bangla Agricultural University has been working with quinoa and agronomic management package have been identified where November as the optimum sowing time of quinoa in Bangladesh (Biswas and Tanni, 2020). The National Seed Board also registered the crop as 'SAU Quinoa-1' to cultivate in the country. The study was therefore undertaken with planting methods and nitrogen dose to find out the maximum yield potentiality of quinoa.

Materials and Methods

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2018 to April 2019. The farm belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series of AEZ-28. The seeds of 'SAU Quinoa-1' was used. The land was finally leveled with leveler to ensure uniform application of water. Urea for nitrogen as per treatment along with TSP and MoP @ 100 kg P & 80 kg K ha⁻¹, respectively were used. The whole amount of all fertilizers along with one third of urea was applied as a basal dose and the remaining urea was top dressed in two equal installments at 30 and 45 days after sowing. The seeds were sown on 20 November, 2018 in the main field as well as in surrounding nursery bed from where 25 days old seedlings were uprooted and planted in respective plots maintaining 30 cm x 10 cm spacing. The experiment was laid out in a Split-plot design with three replications. There were two planting methods viz., i) seed sowing (M₁) and ii) seedling planting (M₂) assigned in the main plot and eight nitrogen dose viz., i) control (F₁), ii) 50 kg N ha⁻¹ (F₂), iii) 100 kg N ha⁻¹ (F₃), iv) 150 kg N ha⁻¹ (F₄), v) 180 kg N ha⁻¹ (F₅), vi) 200 kg N ha⁻¹ (F₆), vii) 220 kg N ha⁻¹ (F₇) and ix) 250 kg N ha⁻¹ (F₈) in the sub-plot. The gap filling, weeding and other intercultural operations were done as and when necessary. No severe insects and disease infestations were observed during experimentation. The seeds sowing plots were harvested 10 February, 2019 and seedling transplanting on 20 February, 2019. Ten plants per plot was randomly selected for collecting yield contributing and other relevant data like plant height, leaves number plant⁻¹, branch number plant⁻¹, inflorescence height, SPAD value, 1000-grain weight and grain yield. The harvested plants were sundried and threshed from where collected seeds were dried to a constant temperature and weighed. Statistical analyses were done by using the Crop Stat computer package and the mean differences among the treatments were compared by least significant difference test (LSD) at 5 % level of significance following Gomez and Gomez (1984).

Results and Discussion

Plant height

Effect of planting method

Plant height at 21 and 35 days after sowing/planting (DAS/P) and at harvest was significantly differed for planting method (Table 1). The tallest plant at 21 DAP (12.95 cm), 35 DAP (56.67

cm) and at harvest (55.62 cm) was found in seedling planting compared to that of seed sowing. Planting seedling showed 38.80, 12.89 and 6.88% taller plants at 21, 35 DAS/Planting and at harvest, respectively compared to that of the plants from seed. Biswas and Tanni (2020) was found higher plant height (62.47 cm) of quinoa from sowing seeds at November 10.

Table 1. Effect of planting method and nitrogen dose on plant height and leaves number plant⁻¹ of quinoa

Treatments	Plant height (cm) at			Leaves plant ⁻¹ (no.)	
	21 DAS/P	35 DAS/P	Harvest	21 DAS/P	35 DAS/P
Planting material:					
M ₁	9.33 b	50.20 b	52.04	12.03 b	71.71
M ₂	12.95 a	56.67 a	55.62	35.95 a	68.93
LSD _(0.05)	1.103	4.084	NS	4.694	NS
CV (%)	8.20	4.98	8.25	15.21	30.77
Nitrogen dose:					
F ₁	10.41 bcd	44.95 c	47.55 c	19.17 b	61.47 c
F ₂	10.84 bcd	50.38 bc	52.37 abc	22.50 ab	73.77 ab
F ₃	10.09 cd	53.92 ab	50.88 bc	24.95 ab	76.30 ab
F ₄	9.83 d	54.86 ab	54.32 ab	22.73 ab	77.53 a
F ₅	11.71 ab	57.55 a	55.86 ab	27.43 a	75.43 ab
F ₆	11.51 bc	56.17 a	56.41 a	26.68 a	66.77 abc
F ₇	11.64 ab	55.19 ab	56.81 a	24.33 ab	66.45 abc
F ₈	13.07 a	54.43 ab	56.45 a	24.13 ab	64.85 bc
LSD _(0.05)	1.489	5.499	5.160	6.321	11.990
CV (%)	11.27	8.70	8.11	22.28	14.42

M₁ = Sowing seeds, M₂ = Planting seedlings, F₁ = 0 kg N ha⁻¹, F₂ = 50 kg N ha⁻¹, F₃ = 100 kg N ha⁻¹, F₄ = 150 kg N ha⁻¹, F₅ = 180 kg N ha⁻¹, F₆ = 200 kg N ha⁻¹, F₇ = 220 kg N ha⁻¹, F₈ = 250 kg N ha⁻¹

Effect of nitrogen dose

Plant height of quinoa was significantly influenced by nitrogen dose at all studied dates. At 21 DAS/P, the highest plant height (13.07 cm) was recorded in F₈ (250 kg N ha⁻¹) that similar to F₇ and F₅ whereas the lowest plant height (9.83 cm) by F₄ that similar to F₃, F₂ and F₁ (Table 1). Almost similar trend was also observed at 35 DAS/P but at harvest, application of 150 to 250 kg N ha⁻¹ resulted similar and significantly higher plant height and no nitrogen application treatment gave the shortest plant height (47.55 cm). Geren (2015) also reported that the plant height of quinoa increased noticeably by increasing nitrogen fertilizer rate up to 175 kg N ha⁻¹. Fawy *et al.* (2017) reported 33% higher plant height of quinoa by 240 kg N ha⁻¹ whereas Weisany *et al.* (2013) also reported 33% higher plant height of quinoa by soil application of nitrogen than control.

Interaction effect of planting method and nitrogen dose

The interaction effect of planting method and nitrogen dose showed significant variations of plant height. The tallest plant at 21 DAS/P was given by M₂F₈ (16.30 cm) that similar to M₂F₇ (15.30 cm) and the shortest plant (8.08 cm) found in M₁F₇ that similar to all nitrogen levels under seed sowing. At 35 DAS/P, the tallest plant (61.37 cm) was resulted in M₂F₃ that similar to all nitrogen doses of seedling planting except no nitrogen application and the shortest plant (43.30 cm) observed in M₁F₁ which was at par with M₁F₂, M₁F₄, M₁F₄ and M₂F₁ combinations (Table 2). At harvest, the tallest plant (60.53 cm) was found in M₁F₅ and the shortest plant (43.11 cm) at M₁F₁.

Number of leaves plant⁻¹

Effect of planting method

The maximum number of leaves plant⁻¹ (35.95) at 21 DAP was recorded in seedling planting as compared to that of sowing seeds (12.03) but at 35 DAS, the scenario was reverse where maximum leaves plant (71.71) was given by the plants of seeds though no significant variation observed between them (Table 1). Sadia (2018) also reported 29.19 leaves plant⁻¹ of quinoa using seeds as planting material.

Effect of nitrogen dose

At 21 DAS/P, the maximum number of leaves plant⁻¹ (27.43) was observed in F₅ that similar to F₆ whereas the lowest number of leaves plant⁻¹ in control plants (Table 1). Similar trend was also shown in 35 DAS/P. Application of 120 kg N ha⁻¹ gave 33.80 leaves plant⁻¹ of quinoa as reported by Sadia (2018).

Interaction of planting method and nitrogen dose

The number of leaves plant⁻¹ was significantly influenced by the interaction of planting method and nitrogen dose and the highest number of leaves plant⁻¹ at 21 DAS/P was observed in M₂F₅ (41.80) that similar to M₂F₆ (41.03). No variation was recorded among the interactions of M₁ irrespective of all nitrogen doses (Table 1) that exhibited the lower number of leaves plant⁻¹. The scenario was different at 35 DAS/P where M₁F₅ resulted the highest number of leaves plant⁻¹ and the lowest in M₂F₁ interaction (59.13).

Table 2. Effect of planting method and nitrogen dose on plant height and number of leaves plant⁻¹ of quinoa

Treatments	Plant height (cm) at			Leaves plant ⁻¹ (no.) at	
	21 DAS/P	35 DAS/P	Harvest	21 DAS/P	35 DAS/P
M ₁ F ₁	9.49 c-f	43.30 f	43.11 f	13.20 d	63.80 bcd
M ₁ F ₂	10.41 cde	45.27 ef	48.07 def	12.93 d	68.07 a-d
M ₁ F ₃	9.04 def	46.47 def	45.67 ef	11.67 d	69.33 a-d
M ₁ F ₄	8.95 ef	51.00 c-f	54.30 a-d	10.67 d	77.00 abc
M ₁ F ₅	9.81 c-f	57.40 abc	60.53 a	13.07 d	84.67 a
M ₁ F ₆	8.99 ef	53.20 bcd	54.79 a-d	12.33 d	68.27 a-d
M ₁ F ₇	8.08 f	52.27 b-e	55.93 abc	10.80 d	74.33 a-d
M ₁ F ₈	9.85 c-f	52.67 b-e	53.90 a-d	11.60 d	68.20 a-d
M ₂ F ₁	11.33 c	46.60 def	51.99 b-e	25.13 c	59.13 d
M ₂ F ₂	11.27 c	55.49 abc	56.67 abc	32.07 bc	79.47 ab
M ₂ F ₃	11.13 cd	61.37 a	56.09 abc	38.23 ab	83.27 a
M ₂ F ₄	10.70 cde	58.72 abc	54.33 a-d	34.80 ab	78.07 abc
M ₂ F ₅	13.60 b	57.70 abc	51.19 cde	41.80 a	66.20 bcd
M ₂ F ₆	14.03 b	59.13 ab	58.03 abc	41.03 a	65.27 bcd
M ₂ F ₇	15.20 ab	58.11 abc	57.68 abc	37.87 ab	58.57 d
M ₂ F ₈	16.30 a	56.20 abc	59.00 ab	36.67 ab	61.50 cd
LSD _(0.05)	2.09	7.78	7.30	8.94	16.96
CV (%)	11.27	8.70	8.11	22.28	14.42

M₁ = Sowing seeds, M₂ = Planting seedlings, F₁ = 0 kg N ha⁻¹, F₂ = 50 kg N ha⁻¹, F₃ = 100 kg N ha⁻¹, F₄ = 150 kg N ha⁻¹, F₅ = 180 kg N ha⁻¹, F₆ = 200 kg N ha⁻¹, F₇ = 220 kg N ha⁻¹, F₈ = 250 kg N ha⁻¹

Number of branches plant⁻¹

Effect of planting method

The higher number of branches plant⁻¹ at harvest was recorded from the plants of seedling (19.87) compared to that of seeds (10.89) which was 82.46% higher (Table 3). Sadia (2018) reported 17.67 branches plant⁻¹ of quinoa from seeds as planting method.

Effect of nitrogen dose

Application of various levels of nitrogen resulted significant variations on branch number plant⁻¹ of quinoa and the 100 kg N⁻¹ gave highest number of branches plant⁻¹ (17.07) that similar to all other doses except control, 220 and 250 kg N ha⁻¹ (Table 3). The lowest number of branches plant⁻¹ (11.53) was found in 250 kg N ha⁻¹. Application of 120 kg N ha⁻¹ resulted 20.00 branches plant⁻¹ of quinoa as reported by Sadia (2018).

Table 3. Effect of planting method and nitrogen dose on yield and other crop characters of quinoa

Treatments	Branches plant ⁻¹ (no.)	Inflorescence length (cm)	SPAD value	1000-seed weight (g)	Seed yield (kg ha ⁻¹)
<i>Planting material:</i>					
M ₁	10.89 b	23.69 b	55.53	2.94	945.46
M ₂	19.87 a	41.28 a	55.66	2.97	934.15
LSD _(0.05)	1.67	3.62	NS	NS	NS
CV (%)	11.18	5.01	6.06	3.20	7.68
<i>Nitrogen dose:</i>					
F ₁	15.07 bc	26.53 c	38.13 d	2.67 d	538.19 f
F ₂	16.60 ab	29.95 bc	46.02 c	2.75 c	756.71 e
F ₃	17.07 a	33.20 ab	55.77 b	2.87 b	993.22 cd
F ₄	16.77 ab	36.02 a	59.34 ab	3.06 a	1170.64 a
F ₅	16.40 ab	33.53 ab	57.75 b	3.06 a	1097.77 ab
F ₆	15.63 abc	35.98 a	64.61 a	3.09 a	1033.37 bc
F ₇	13.97 c	32.92 ab	61.85 ab	3.08 a	1003.73 cd
F ₈	11.53 d	31.77 ab	61.32 ab	3.10 a	924.80 d
LSD _(0.05)	1.83	4.87	6.20	0.06	87.24
CV (%)	10.08	12.67	9.44	1.80	7.85

M₁ = Sowing seeds, M₂ = Planting seedlings, F₁ = 0 kg N ha⁻¹, F₂ = 50 kg N ha⁻¹, F₃ = 100 kg N ha⁻¹, F₄ = 150 kg N ha⁻¹, F₅ = 180 kg N ha⁻¹, F₆ = 200 kg N ha⁻¹, F₇ = 220 kg N ha⁻¹, F₈ = 250 kg N ha⁻¹

Interaction of planting method and nitrogen dose

Interaction of planting method and nitrogen dose showed significant variations for branches number plant⁻¹ where M₂F₃ gave significantly the higher number of branches plant⁻¹ (23.13) that similar to M₂F₄ (22.80) and M₂F₂ (22.67) but the lowest number of branches plant⁻¹ in M₁F₁ (9.80) that similar to all other nitrogen doses of seeds sowing method except M₁F₅ (Table 4). Biswas and Tanni (2020) reported 25.20 branches plant⁻¹ of quinoa from November-10 sowing of seeds with 180 kg N ha⁻¹.

Inflorescence length at harvest

Effect of planting method

The higher length of inflorescence was recorded in seedling planting (41.28 cm) compared to that of seeds sowing (23.69 cm) which was 74.25% higher than seed sowing method (Table 3).

Similar inflorescence length (22.01 cm) of quinoa using seeds as planting material was also reported by Biswas and Tanni (2020). Ramesh *et al.* (2019) also reported similar inflorescence length (19.00-23.50 cm) of quinoa in India.

Effect of nitrogen dose

Application of various levels of nitrogen fertilizer resulted significant variations on inflorescence length of quinoa and the 200 kg N⁻¹ gave maximum length (36.02 cm) that similar to all other doses except control and 50 kg N ha⁻¹ (Table 3). The lowest inflorescence length (26.53 cm) was found in control plots. Application of 120 kg N ha⁻¹ resulted 18.56 cm length of inflorescence as reported by Sadia (2018).

Interaction of planting method and nitrogen dose

Interaction of planting material and nitrogen dose showed significant variations for inflorescence length where M₂F₃ gave maximum length (45.13 cm) that similar to almost all other treatments of seedling planting except M₂F₂ and M₂F₁ and all treatments of seeds sowing. The lowest inflorescence length (17.50 cm) was observed in M₁F₁ that similar to M₁F₂, M₁F₃, M₁F₇ and M₁F₈ interactions (Table 4). Similar inflorescence length (21.10-31.70 cm) was also reported by Rao and Shahid (2012).

Table 4. Interaction effect of planting method and nitrogen dose on yield and other crop characters of quinoa

Treatment combinations	Branches plant ⁻¹ (no.)	Inflorescence height (cm)	SPAD value	1000-seed weight (g)	Seed yield (kg ha ⁻¹)
M ₁ F ₁	9.80 e	17.50 h	29.41 h	2.62 d	676.24 g
M ₁ F ₂	10.53 de	21.10 gh	40.79 g	2.72 c	841.53 f
M ₁ F ₃	11.00 de	21.27 fgh	58.53 a-e	2.88 b	939.12 def
M ₁ F ₄	10.73 de	28.13 ef	64.34 ab	3.06 a	1113.85 abc
M ₁ F ₅	12.40 de	28.97 de	59.36 a-e	3.08 a	1060.90 bcd
M ₁ F ₆	11.00 de	27.63 efg	66.37 a	3.06 a	1030.32 bcd
M ₁ F ₇	11.07 de	23.83 e-h	63.47 ab	3.05 a	1013.79 bcd
M ₁ F ₈	10.60 de	21.10 gh	61.99 abc	3.09 a	887.90 ef
M ₂ F ₁	20.33 b	35.57 cd	46.84 f	2.71 c	400.13 h
M ₂ F ₂	22.67 ab	38.80 abc	51.24 ef	2.77 c	671.88 g
M ₂ F ₃	23.13 a	45.13 a	53.00 def	2.87 b	1047.31 bcd
M ₂ F ₄	22.80 ab	43.90 ab	54.35 c-f	3.06 a	1227.43 a
M ₂ F ₅	20.40 b	38.10 bc	56.14 b-e	3.03 a	1134.65 ab
M ₂ F ₆	20.27 b	44.33 ab	62.85 abc	3.11 a	1036.42 bcd
M ₂ F ₇	16.87 c	42.00 abc	60.23 a-d	3.12 a	993.66 cde
M ₂ F ₈	12.47 d	42.43 abc	60.65 a-d	3.12 a	961.70 def
LSD _(0.05)	2.59	6.87	8.77	0.09	123.37
CV (%)	10.08	12.67	9.44	1.80	7.85

M₁ = Sowing seeds, M₂ = Planting seedlings, F₁ = 0 kg N ha⁻¹, F₂ = 50 kg N ha⁻¹, F₃ = 100 kg N ha⁻¹, F₄ = 150 kg N ha⁻¹, F₅ = 180 kg N ha⁻¹, F₆ = 200 kg N ha⁻¹, F₇ = 220 kg N ha⁻¹, F₈ = 250 kg N ha⁻¹

SPAD value

Effect of planting method

There was no significant variation observed between the two planting methods for SPAD value though the numerically higher value (55.66) was found in seedling planting compared to that of seed sowing (55.53) (Table 3).

Effect of nitrogen dose

Various levels of nitrogen resulted significant variations on SPAD value of quinoa and the maximum value (64.61) was observed in 200 kg N⁻¹ that similar to F₇ (61.85), F₈ (61.32) and F₄ (59.34) (Table 3). The lowest SPAD value (38.13 cm) was found in control plants.

Interaction of planting method and nitrogen dose

Interaction of planting method and nitrogen dose showed significant variations for SPAD value where M₁F₆ gave significantly the maximum value (66.37) that similar to all other nitrogen doses of seed sowing except M₁F₁ and M₁F₂ as well as M₂F₆, M₂F₇ and M₂F₈. The lowest SPAD value (29.41) was observed in M₁F₁ (Table 4).

Weight of 1000 seeds

Effect of planting method

The 1000-seed weight was not significantly varied for the two planting methods where seedlings planting gave numerically higher 1000-seed weight (2.97 g) compared to that of seeds sowing (2.94 g) (Table 3). Biswas and Tanni (2020) reported that the 1000-seed weight of quinoa varied significantly with sowing dates that ranges from 1.17-2.58 g for March to November sowing with seed sowing method.

Effect of nitrogen dose

Application of various doses of nitrogen fertilizer resulted significant variations on 1000-seed weight and the maximum weight (3.10 g) was observed in F₈ (250 kg N⁻¹) that similar to F₆ (3.09 g), F₇ (3.08 g), F₅ (3.06 g) and F₄ (3.06 g) (Table 3). The lowest 1000-seed weight (2.67 g) was found in control treatment that showed 13.87% lower weight than F₈ treatment. Similar higher 1000-seed weight (3.06 g) of quinoa was also reported by application of 187.50 kg N ha⁻¹ (Kansomjet *et al.*, 2017) but dissimilar opinion was also given by Basra *et al.* (2014) who stated that 1000-grain weight of quinoa not affected by nitrogen fertilization from 0 to 120 kg N ha⁻¹.

Interaction of planting method and nitrogen dose

Interaction of planting method and nitrogen dose showed significant variations for 1000-seed weight where M₂F₈ and M₂F₇ gave significantly the highest identical 1000-seed weight (3.12 g) that similar to F₆, F₅ and F₄ irrespective of their planting material (Table 4). Sowing seeds with 120 kg N ha⁻¹ resulted similar (2.84 g) 1000-seed weight of quinoa as reported by Sadia (2018).

Seed yield

Effect of planting method

There was no significant variation of seed yield observed between the two planting methods. The numerically higher seed yield (945.46 kg ha⁻¹) was observed in seed sowing compared to that of seedling transplanting (934.15 kg ha⁻¹) (Table 3). Similar seed yield of quinoa (1.16 t ha⁻¹) was also reported by Biswas and Tanni (2020).

Effect of nitrogen dose

Application of various doses of nitrogen fertilizer resulted significant variations on seed yield of quinoa and the highest yield (1170.64 kg ha⁻¹) observed in F₄ (150 kg N⁻¹) that similar (1097.77 kg ha⁻¹) to F₅ (180 kg N⁻¹) and followed by F₆ (1033.37 kg ha⁻¹) (Table 3). The lowest seed yield

(538.19 kg ha⁻¹) was found in control treatment. Application of 150 kg N ha⁻¹ (F₄) showed 117.51% higher yield than control (no nitrogenous fertilizer application). Kansomjet *et al.* (2017) was found higher seed yield (2641.70 kg ha⁻¹) of quinoa by application of 93.75 kg N ha⁻¹ and its increment reduced seed yield (Lavini *et al.*, 2014). Jacobsen and Christiansen (2016) reported that quinoa yield increased significantly with an application up to 180 kg N ha⁻¹. In another study Jacobsen *et al.* (1994) reported that seed yield in quinoa increased with increasing N-application, however, on the other hand only small yield decreases were seen when decreasing N-level from highest N application of 160 kg ha⁻¹.

Interaction of planting method and nitrogen dose

Interaction of planting method and nitrogen dose showed significant variations for seed yield of quinoa where M₂F₄ gave significantly the maximum seed yield (1227.43 kg ha⁻¹) that similar to M₂F₅ (1134.65 kg ha⁻¹) and M₁F₄ (1113.85 kg ha⁻¹). The lowest seed yield (400.13 kg ha⁻¹) was observed in M₂F₁ that followed by M₁F₁ (676.24 kg ha⁻¹) (Table 4). The values obtained correspond to those reported by Erley *et al.* (2005) that nitrogen fertilizer rates at 80 and 120 kg N ha⁻¹ had the highest of quinoa grain yield at 3,083 and 3,495 kg ha⁻¹, respectively. Kaveeta *et al.* (2009), Oelke *et al.* (1992), Basra *et al.* (2014), Carlsson *et al.* (1984), Thanapornpoonpong (2004), Shams (2012), Gomaa (2013) and Geren (2015) also reported that nitrogen fertilizer rates affected grain yield of quinoa due to promoting vegetative growth behaviour of nitrogen fertilizer. Nitrogen had increased ability for photosynthesis and photosynthate translocation to promote grain and these results agreed with Thanapornpoonpong (2004) who noticed that seed yield plant⁻¹ increased with increasing nitrogen fertilizer rates. Kansomjet *et al.* (2017) reported that nitrogen fertilizer rate of 93.75, 187.50 and 312.50 kg N ha⁻¹ results on higher seed yield of quinoa than those of control. In Denmark, it is recommended to apply 80–120 kg of N ha⁻¹ at crop establishment in the spring to obtain a yield of about 2 t ha⁻¹ of seed. In Germany quinoa responded strongly to N fertilization to 120 kg N ha⁻¹, with a 94 % yield increase compared to 0 N (Schulte auf'm Erley *et al.*, 2005). Estimated yield potential may exceed the observed yields, indicating that even higher rates of nitrogen application may increase yield (Hirich *et al.*, 2013).

Conclusion

The planting method had significant effect on plant height at earlier stages, branches number plant⁻¹ and inflorescence height where seedling planting method showed superior performance but the other studied parameters resulted non-significant variations. The nitrogen dose significantly influenced all the studied parameters where no nitrogen (control) as well as higher nitrogen dose negatively influenced on yield and other characters. Higher yield (1170.64 kg ha⁻¹) was obtained in F₄ (150 kg N⁻¹) that similar (1097.77 kg ha⁻¹) to F₅ (180 kg N⁻¹). The highest grain yield (1227.43 kg ha⁻¹) was observed in M₂F₄ that similar to M₂F₅ (1134.65 kg ha⁻¹) and M₁F₄ (1113.85 kg ha⁻¹) and the lowest grain yield was observed in M₂F₁ (400.13 kg ha⁻¹). Based on the results of the study, it may be concluded that Quinoa can also be grown in Bangladesh by 25 days old seedling with 150 to 180 kg N ha⁻¹. However, to reach a specific conclusion and recommendation more experiments are suggested with different levels of other fertilizers and in different Agro-ecological zones.

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