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Response of Quinoa (*Chenopodium quinoa* Willd.) to Different Plant Density and Fertilizer Rate in *Terai* Region of West Bengal

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ABSTRACT

A field experiment was conducted during winter season of 2019-20 at Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal to evaluate the influence of different plant density and fertilizer rate on the productivity of quinoa. The experiment was formed in split plot design having 3 plant density as main-plot treatment (333333 plants ha^{-1}; 222222 plants ha^{-1}and 296296 plants ha^{-1}) and 3 fertilizer rates as sub-plot treatment (Control; $N_{30}P_{20}K_{20}$ and $N_{60}P_{40}K_{40}$kg ha^{-1}) replicated thrice. Results indicated that growth and yield attributes observed non-significant due to different plant density. However, 222222 plants ha^{-1} performed better. The performance of the treatment $N_{60}P_{40}K_{40}$ and $N_{30}P_{20}K_{20}$ observed statistically at par among all the stated parameters. The highest seed yield and protein content was recorded with $N_{60}P_{40}K_{40}$ (1.43 t ha^{-1} and 20.84 %) which was at par with $N_{30}P_{20}K_{20}$ (1.42 t ha^{-1} and 20.28 %).The treatment $N_{60}P_{40}K_{40}$ and $N_{30}P_{20}K_{20}$ in combination with 222222 plants ha^{-1} recorded superior results.

Key words : Fertilizer *rate, Plant density, Protein content, Seed yield, Quinoa*

Introduction :

Cereals play a pivotal role in human nutrition,c ontributing to the energy and protein intake. Wheat, barley, corn, sorghum and rice are the most important cereals worldwide. Small cereal grains such as quinoa, amaranth and buckwheat are also an excellent source of energy and protein. They are also known as nutri-cereals for their high nutritional values (Filho, 2017). Quinoa (*Chenopodium quinoa* Willd.) is originated in South America and currently cultivated in many countries like Europe, America and Asia (Bhargava, *et al.*, 2006). Quinoa is a potential nutritious crop for human consumption (Bhargava, *et al.*, 2006, Jacobsen, 2016), usually consumed as pseudo-cereal (Susack, 1984). Its grain is gluten-free and contains high quality protein similar to milk protein. That's why it plays an important role in human diet suffering from celiac (Kuhn, 1996,

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Doweidar and Kamel, 2011). The protein content is twice more than common cereal grains. Those proteins are high quantity and quality close to the Food and Agriculture Organization standard of human nutrition requirement (Shams, 2011). It is tolerant to abiotic stress, low nutrient requiring (Jacobsen and Christiansen, 2016) and economic produce is grain of superior nutritional profile. Seed yield of quinoa is quite low, around 500–700 kg ha^{-1} (FAO, 2011, Bazile *et al.*, 2015). However, seed yield can be increased through nitrogen fertilization (Jacobsen and Christiansen, 2016) and adjusting plant density (Risi and Galwey,1991, Bazile *et al.*, 2015). Therefore, higher seed yield may be achieved by optimizing nitrogen fertilization and plant density (Dao *et al.*, 2020).

Quinoa is usually cultivated without fertilizer, with high plant geometry, without thinning or weeding (Gomez-Pando *et al.*, 2015). Numerous crop management practices showed different responses like canopy expansion, physiological maturity and grain yield of quinoa (González *et al.*, 2012). The plant density models, stating yield as a function of plant density, simulate higher yields with 32.7 ± 22 plants m^{-2} (Jacobsen *et al.,* 1994). Adjusting the plant geometry and architecture of the branches parallel yield can be obtained because quinoa is capable to accommodate the left over spaces (Jacobsen *et al.,* 2005). A quadratic response of seed yield was noted to plant density (Gimplinger *et al.,* 2008).

Fertilizers of N, P and K are very important for the growth of quinoa and for the improvement of its production. Nitrogen requirement of quinoa is high, while its need for phosphorous (P) and potassium (K) is moderate to nominal (Mujica *et al.,* 2001). Response of quinoa to N is highly notable because quinoa is high in protein content (Jacobsen and Christiansen, 2016). Higher rate of nitrogen fertilization increases the seed yield of quinoa (Eisa and Abdel–Ati, 2014). Oelke *et al.* (1992) noted that high nitrogen decreased the yield of quinoa, because of slow maturity and intense lodging. However, Berti *et al.* (2000) observed that the yield of quinoa does not decrease with the increase of N fertilizer rate. Similarly, Johnson, and Ward, (1993) reported that the application of nitrogen increases both the seed yield and the seed content of proteinand can be taken as nutritional security in food staffs (Gonzalez *et al.*, 2012).

It is true that many researchers have undertaken the influence of fertilizer and plant density on quinoa; yet fertilizer in balanced amount and desired plant density are to be studied for obtaining high crop yield. Therefore, this investigation was assumed to evaluate the influence of different plant density and fertilizer rate on the productivity of quinoa.

Materials and methods

The field experiment was conducted during winter seasons of 2019-20 at Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal to evaluate the influence of different plant density and fertilizer rate on the productivity of quinoa. The farm is situated at 26^{0}19’86" N latitude and 89^{0}23’53" E longitude at an elevation of 43 meter above mean sea level. Thephysico-chemical properties of experimental soil was sandy loam with pH 5.46, medium in organic carbon (0.78%), medium in available nitrogen (138.1 kg/ha) andavailable phosphorus (14.8 kg/ha) and low in available potassium (79.9 kg/ha). The experiment was formed in split plot design with3 plant density as main-plot treatment (333333 plants ha^{-1}; 222222 plants $ha^{-1}$and 296296 plants ha^{-1}) and 3 fertilizer rate as sub-plot treatment (Control; $N_{30}P_{20}K_{20}$ and $N_{60}P_{40}K_{40}$) replicated thrice. The soil was prepared by tractor drawn cultivator followed by rotavator. The whole experimental field was divided into twenty seven sub-plots following the layout plan. Fertilizers were broadcasted through urea, single supper phosphate and muriate of potash before sowing. The quinoa variety 'EC 507742' was taken in the present study. The seed was sown on 14th November. One pre-sowing irrigation was given during the final land preparation for sowing seed and subsequent irrigation was given as per crop need. Hand weeding was applied to eradicate the weeds. The crop was matured in last week of March and harvested on 29th February during the season. Harvesting was done manually when all leaves and inflorescences turned yellow colour and grains moisture content around 20%. Other cultural operations were undertaken as and when required.

Seed yield and its components

Samples of ten plants were taken from each two inner rows of each sub plots and taken immediately to the laboratory to determine: Plants height (cm), Days to 50% Flowering, Days to 80% Flowering, Inflorescence length (cm), Seed yield (g $plant^{-1}$), Seed yield (t ha^{-1}) and Seed volume (g 10 ml^{-1}).

Determination of nitrogen and protein contents

Total protein content was calculated from the nitrogen content using a conversion factor of 6.25 (AOAC, 2009).

Statistical analysis

Data were analysed using ANOVA in split plot design and the treatment variations were tested at 5% level of significance by 'F' test.

Results and discussion

Plant height

Plant height was non-significantly affected by plant density. The fertilizer rate of $N_{60}P_{40}K_{40}$resulted in a significantly taller quinoa plant than $N_{30}P_{20}K_{20}$ treatments (Table 1). Quinoa height was significantly affected by treatment combination.Higher fertilization stimulated plant growth and canopy expansion showing higher plant growth (Jacobsen *et al.* 2005 and Alandia *et al.* 2016).

Yield attributes

Results indicated that yield attributes *viz.* days to 50% and 80% flowering, inflorescence length, seed yield $plant^{-1}$, seed volume were non-significantly affected by plant density (Table 1). However, 222222 plants ha^{-1} performed better than other spacing. Significant difference was observed among the fertilizer rate.Increasing fertilizer rate from $N_{30}P_{20}K_{20}$ to $N_{60}P_{40}K_{40}$ increased the yield attributes. The performance of the treatment $N_{60}P_{40}K_{40}$ and $N_{30}P_{20}K_{20}$ observed statistically at par among all the stated parameters. Interaction effect was non-significantly affected by treatment combination. However, the treatment $N_{60}P_{40}K_{40}$ and

$N_{30}P_{20}K_{20}$ in combination with the 222222 plants ha^{-1}recorded superior results than other treatment combination. Plant density did not affect seed volume and significantly consistent with the results of Spehar *et al.* (2009).

Seed yield

Results indicated that seed yieldobserved non-significant due to the influence of different plant density. However, 222222 plants ha^{-1}performed better than other spacing (Table 1). The different fertilizer rate was significant and seed yield was enhanced by increasing fertilizer rate. The performance of the treatment $N_{60}P_{40}K_{40}$ and $N_{30}P_{20}K_{20}$ observed statistically at par. The highest seed yield was recorded with $N_{60}P_{40}K_{40}$ (1.43 t ha^{-1}) which was at par with $N_{30}P_{20}K_{20}$ (1.42 t ha^{-1}). Lowest seed yieldwas observed with control. The interaction effect of spacing and fertilizer was non-significant. However, the treatment $N_{60}P_{40}K_{40}$ and $N_{30}P_{20}K_{20}$ in combination with the 222222 plants ha^{-1}recorded superior results than other treatment combination.The increases in grain yield of quinoa with increasing fertilizer rates stimulate metabolic activity which contributed to the increase in metabolites amount most of which is used building yield and its components. These results agreed with Shams, (2012), Kansomjet *et al.* (2014, 2017) and Ibrahim *et al.* (2020).

Nitrogen content and uptake

Nitrogen content and uptake was non-significantlyaffected by different plant density (Table 1). The fertilizer rate was significant. The highest nitrogen content and uptake was recorded with $N_{60}P_{40}K_{40}$(3.33% and 47.52 kg ha^{-1}). Nitrogen content and uptake was non-significantly affected by treatment combination. Amount of nitrogen uptake by quinoa was significantly increased with the combined effects of sufficient high plant density and nitrogen supply (Gomaa, 2013 and Wang *et al.*, 2020).

Protein content

Seed protein content did not differ significantly among plant density treatments (Table 1). However, slightly higher protein content observed in 296296 plants ha^{-1}. Seed protein content was significantly affected by fertilizer rate and was enhanced by increasing fertilizer rate. The highest protein content was recorded with $N_{60}P_{40}K_{40}$ (20.84 %) which was at par with $N_{30}P_{20}K_{20}$ (20.28 %). Lowest seed yield was observed with control (18.54 %). Protein content was non-significantly affected by treatment combination. However, the treatment $N_{60}P_{40}K_{40}$ and $N_{30}P_{20}K_{20}$ in combination with the 222222 plants ha^{-1} recorded superior results than other treatment combination. Plant density did not affect seed quality (protein content) significantly, consistent with the results of Spehar *et al.* (2009) and Dao *et al.* (2020).Increasing the fertilizer application rate especially nitrogen showed higher seed volume and protein content (2.26 g and 21.3%) showing that seed protein of quinoa influenced by nitrogen application and might be further enhanced with higher nitrogen rate (Geren, 2015, Jacobsen and Christiansen, 2016 and Dao *et al.*, 2020).

Conclusion

The present study demonstrated that fertilizer rate is the most determining factors affecting plant growth, yield and protein content of quinoa than plant density. Plant density of 222222 plants ha^{-1} is the most optimal agronomic technique in terms of growth and yield. Higher fertilizer rate achieved significantly higher seed yield and seed protein content, representing seed quality might be further improved with higher fertilizer rate.

Conflicts of interest

Authors declare no conflicts of interest.

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Table 1: Influence of different plant density and fertilizer rate on the productivity of quinoa

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Treatment	Plant length (cm)	Days to 50% Flowering	Days to 80% Flowering	Inflorescence length (cm)	Seed yield plant^{-1} (g)	Seed volume (g 10 ml^{-1})	Seed yield (t ha^{-1})	N content (%)	N uptake (kg ha^{-1})	Protein content (%)
Plant density (P)										
333333 plants ha^{-1}	89.37	50.89	88.89	21.70	44.7	6.66	1.20	3.17	38.52	19.79
222222 plants ha^{-1}	95.54	50.11	88.22	22.32	46.3	6.73	1.29	3.17	41.39	19.79
296296 plants ha^{-1}	95.46	50.89	88.78	22.90	45.7	6.72	1.22	3.21	39.57	20.07
SEm±	2.24	0.22	0.38	0.62	0.27	0.05	0.02	0.04	0.99	0.27
CD (P=0.05)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Fertilizer rate (F)										
Control	72.30	52.78	96.11	18.19	30.0	6.82	0.87	2.97	25.72	18.54
$N_{30}P_{20}K_{20}$	103.24	49.67	84.56	23.91	53.0	6.66	1.42	3.24	46.23	20.28
$N_{60}P_{40}K_{40}$	104.82	49.44	85.22	24.82	53.7	6.63	1.43	3.33	47.52	20.84
SEm±	0.66	0.18	0.45	0.818	0.21	0.06	0.02	0.03	0.86	0.17
CD (P=0.05)	2.07	0.55	1.41	2.55	0.64	ns	0.07	0.08	2.69	0.52
Interaction CD (P=0.05)										
P×F	4.48	ns	ns	ns	ns	ns	ns	ns	ns	ns
F×P	9.46	ns	ns	ns	ns	ns	ns	ns	ns	ns

Note: ns = non-significant

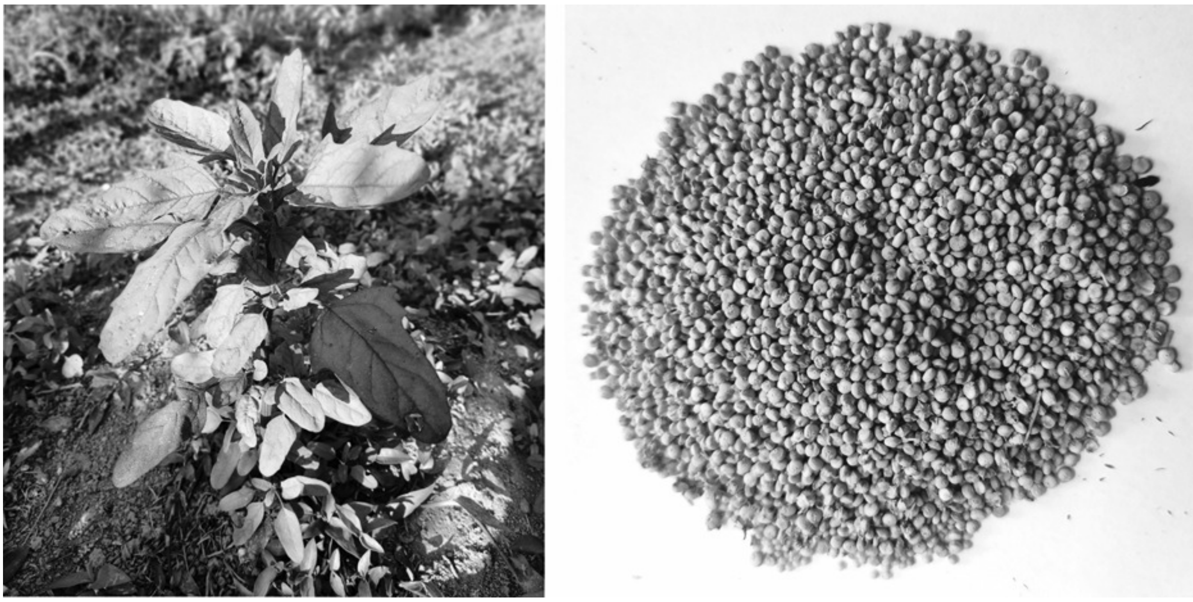

Fig. 1 : Quinoa (*Chenopodium quinoa* Willd.) plant and seed