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Influence of Sowing Time and Planting Geometry on Biochemical Parameters of Quinoa (*Chenopodium quinoa* Willd.)

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ABSTRACT: The present experiment entitled "Influence of sowing time and planting geometry on biochemical parameters of quinoa (*Chenopodium quinoa* Willd.)" was carried out at Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri. The field experiment was conducted at the PGI Farm, M.P.K.V., Rahuri, during the *Rabi* 2019-20 and *Rabi* 2020-21, and the laboratory experiment was carried out at Seed Technology Research Unit (STRU), Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri. It is essential to focus on developing edible cultivars with superior quality and higher seed yield with suitable growing periods on particular dates because early or late sowing causes reduction in yield and seed quality of crop. The objective of the study was to the effect of different sowing times and planting geometry on biochemical compositions such as protein and oil content of quinoa. two genotypes (IC-411824 and EC-507739) were sown at three different sowing times (15th November, 1st December, and 15th December) with three different spacing (30 × 10 cm, 45 × 10 cm, and 60 × 10 cm), the harvested seeds were stored until germination percentage declined below 70.00 % and observations for biochemical constituents such as protein and oil content were recorded at initial and at 90, 180, and 240 days after storage by using Factorial Completely Randomized Design (FCRD) design. In terms of biochemical parameters protein and oil percentage, the 15th November sowing had maximum protein and oil percentage throughout the storage periods, however, spacings had no influence on protein and oil content in quinoa during 240 days of storage. Referring to genotypes, genotype EC-507739 recorded maximum protein and oil percentage during 240 days of storage. All the interactions *viz.*, sowing time and spacing, sowing time and genotype, spacing and genotype, and sowing time, spacing and genotype were found non-significant.

Keywords: Quinoa, protein, oil, genotypes.

INTRODUCTION

The world is mostly unaware of quinoa, a primitive pseudo-grain used in the Andean region of southern America (*Chenopodium quinoa* willd.). It is an annual herbaceous plant that was originally found on the Pacific slopes of the Andes in South America and now belongs to the Amaranthaceae family, but it was previously classified as a Chenopodiaceae family. It has been cultivated and used since 5,000 B.C. by the Inca (ruling class) people. In the recent past, quinoa has gained global attention because of its nutritional and nutraceutical benefits for human health. It is emerging as a quality source of protein, fiber, minerals, and bioactives. It has been exploited in the development of gluten-free (helpful for diabetic patients) and nutrient-enriched novel food products. The North Americans and Europeans in the 1970s discovered quinoa as a healthy food and consumed it in a wide variety of forms, *i.e.*, grains, flakes, pasta, bread, biscuits, beverages, meals, etc. In India, quinoa was cultivated on an area of 440 hectares with an average yield of 1053 metric tons (Srinivasa Rao, 2015). It is cultivated in the world on an area of 126 thousand hectares with a production of 103 thousand metric tons. Bolivia in South America is the biggest producer of quinoa, with 46 percent of world production, followed by Peru with 42 percent and the United States of America with 6.3 percent (FAOSTAT, 2013). The protein content ranges from 7.47 to 22.08 percent, with higher concentrations of lysine, isoleucine, methionine, histidine, cystine, and glycine. The ash content is 3.4 percent and contains a high amount of Ca (874 mg/kg), Fe (81 mg/kg), Zn (48 ppm), and Mg (0.26%) in comparison to wheat (0.16%). The oil content ranges from 1.8% to 9.5% and is rich in important fatty acids like linoleate and linoleate. The quinoa seed is high in thiamine (0.4 mg/100 g), folic acid (78.1 mg/100 g), vitamin C (16.4 mg/100 g), riboflavin (0.39 mg/100 g), and carotene (0.39 mg/100 g). Compared to other cereal and legume foods, it has a higher calorific value of 350 cal/100 g. The quinoa grain is soft, gluten-free, cooks rapidly, and has a pleasing flavor in addition to the nutritional benefits mentioned above. Quinoa also has natural antioxidants, including α-tocopherol (5.3 mg/100g), γ-tocopherol (2.6 mg/100g), and phytoestrogens that protect against serious diseases like osteoporosis, breast cancer, heart disease, and other women's issues brought on by menopause's loss of estrogen. FAO declared 2013 the International Year of Quinoa (Bhargava *et al.,* 2006).

The sowing and harvesting times have a substantial impact on the quantity and quality of quinoa (Hirich *et al.,* 2014; Ramesh *et al.*, 2016; Uke, 2016). However, there are many reports on the seed quality of quinoa grown under various agro-climatic conditions. It is essential to focus on developing edible cultivars with superior quality and higher seed yields with suitable growing periods on particular dates because early or late sowing causes reductions in yield and seed quality of crops, and in various spacings, it also has an effect on the yield of the quinoa crop due to the average plant population. It would need effective knowledge dissemination about the crop to make quinoa popular in India among consumers and farmers through providing high-yielding and better seed-quality varieties.

MATERIAL AND METHODS

The experiment was conducted during *Rabi* 2019-20 and *Rabi* 2020-21 with two genotypes (IC-411824 and EC-507739) that were sown at three different sowing times (15th November, 1stDecember, and 15th December) at three different spacings (30 × 10 cm, 45 × 10 cm, and 60 × 10 cm) with three replications. The harvested seeds were stored until the germination percentage declined below 70.00%, and observations for biochemical constituents such as protein and oil content were recorded at initial and at 90, 180, and 240 days after storage. Protein content of the seed was estimated as per the method described by Lowry *et al.* (1951), and oil content was estimated as crude ether extract of the dry material using an automatic Soxtherm extraction unit (AOAC, 1997).

RESULTS AND DISCUSSION

Protein percentage

In Table 1, protein percentage data are shown to be influenced by various sowing times (D), spacing (S), genotypes (G), and their interactions. Protein percentage decreases as storage time increases.

Effect of sowing time. The data presented in Table 1, it was found that the protein percentage recorded non-significant differences in response to different sowing times up to 180 DAS, and significant differences were recorded at 240 DAS. At 240 DAS, the 15th November sowing (D_1) harvested seeds had the maximum protein percentage (10.28, 9.91, and 10.09%), followed by the 1st December sowing (D_2) (9.85, 9.53, and 9.69%) during the years *Rabi* 2019–20, *Rabi* 2020–21, and on a pooled basis, respectively. However, seeds harvested from 15th December sowing (D_3) observed minimum protein percentages (9.33, 9.03, and 9.18 % during the years *Rabi* 2019–20, *Rabi* 2020–21, and on a pooled basis, respectively, irrespective of spacing and genotype.

Effect of spacing. The data pertaining to Table 1 showed that the protein percentage recorded non-significant differences throughout the entire storage period during the years *Rabi* 2019–20, *Rabi* 2020–21, and on a pooled basis, respectively.

Effect of genotype. The data presented in Table 1 shows that genotypes significantly differed for the protein percentage during 240 days of storage on both a year-over-year and a pooled basis, respectively.

At the initial storage period, a higher protein percentage was recorded by genotype EC-507739 (12.93, 12.81, and 12.87%) during the years *Rabi* 2019–20, *Rabi* 2020–21, and on a pooled basis, respectively. Whereas, genotype IC-411824 recorded lower protein percentages (11.40, 11.26, and 11.33%) during the years *Rabi* 2019–20, *Rabi* 2020–21, and on a pooled basis, respectively. A similar trend was observed during the entire storage period of 240 days. At 240 DAS, maximum protein percentage was recorded by genotype EC-507739, *i.e.*, 10.30, 9.98, and 10.14% during the years *Rabi* 2019–20, *Rabi* 2020–21, and on a pooled basis, respectively. Whereas, the minimum protein percentage was recorded for genotype IC-411824, *i.e.*, 9.34, 8.99, and 9.16% during the years *Rabi* 2019–20, *Rabi* 2020–21, and on a pooled basis, respectively, irrespective of sowing time and spacing.

Effect of interactions

Interaction effect of sowing time and spacing. The sowing time (D) and spacing (S) interaction were found non-significant for protein percentage throughout the 240 days of storage both the year and pooled basis, respectively.

Interaction effect of sowing time and genotype. According to the findings, the effects of sowing time (D) and genotype (G) on the protein percentage of quinoa were found non-significant during the period of 240 days of storage on both the year and pooled basis.

Interaction effect of spacing and genotype. It was noticed that the interaction effects of spacing (S) and genotype (G) on the protein percentage of quinoa were found non-significant throughout the 240 days of storage, both on a year and a pooled basis, respectively.

Interaction effect of sowing time, spacing and genotype. The interaction effects of sowing time (D), spacing (S), and genotype (G) on the protein percentage of quinoa were found non-significant throughout the 240 days of storage both the year and pooled basis, respectively. The protein content affected by sowing time was very different. Protein content was decreased by late sowing, while it was significantly higher in case of early sowing. The higher protein concentration in quinoa was achieved in favorable weather conditions (De Bock *et al*., 2022). Bhargava *et al*. (2007) stated that the protein content of quinoa was significantly affected by the sowing date in Indian conditions. Stikic *et al.* (2012) determined the protein content is between 15.69-17.41% in the quinoa variety. The results are in line with the findings of Buriro *et al.* (2015) in Maize.

Regarding planting density effects on chemical composition and the mineral contents of seed, Protein and ash concentrations in seeds increased at low planting density (60 × 10 cm), whereas carbohydrate concentrations decreased. The obtained results are in coincidence with Rahman and Hossain (2011). They reported that increasing plant density led to a decrease in protein content in soybean seeds, while the reverse occurred for seed yield. This result can be supported by the finding of Sital *et al*. (2011) regarding the influence of variable sowing time on the seed protein content of mung bean. Gonzalez *et al.* (2012) found variations in amino acids and protein content due to changes in environmental and climatic factors in the production of quinoa. During storage, seed protein content goes through several changes due to changes in moisture content of seeds, protein carbonation, the physical breakdown of seeds, and the attack of reactive oxygen species (Bailly, 2004).

Table 1: Effect of sowing time (D), planting geometry (S), genotype (G) and their interactions on protein percentage.

	Protein %					
	Initial			240 DAS		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
D. Date of sowing						
D_1- 15th November	12.30 (20.48)	12.18 (20.38)	12.24 (20.43)	10.28 (18.69)	9.91 (18.34)	10.09 (18.52)
D_2- 1st December	12.17 (20.37)	12.01 (20.23)	12.09 (20.30)	9.85 (18.29)	9.53 (17.97)	9.69 (18.13)
D_3- 15th December	12.03 (20.24)	11.91 (20.14)	11.97 (20.19)	9.33 (17.78)	9.03 (17.47)	9.18 (17.62)
SEm(±)	0.06	0.21	0.07	0.08	0.12	0.10
CD at 5%	NS	NS	NS	0.22	0.34	0.27
CD at 1%	NS	NS	NS	0.30	0.45	0.36
S. Spacing						
S_1- 30× 10 cm	12.19 (20.38)	12.07 (20.28)	12.13 (20.33)	9.86 (18.29)	9.47 (17.91)	9.67 (18.10)
S_2- 45 × 10 cm	12.16 (20.36)	12.03 (20.25)	12.09 (20.31)	9.82 (18.25)	9.50 (17.94)	9.66 (18.10)
S_3- 60 × 10 cm	12.14 (20.34)	12.00 (20.23)	12.07 (20.28)	9.78 (18.21)	9.49 (17.92)	9.63 (18.07)
SEm(±)	0.20	0.21	0.25	0.08	0.12	0.10
CD at 5%	NS	NS	NS	NS	NS	NS
CD at 1%	NS	NS	NS	NS	NS	NS
G. Genotype						
G_1- IC- 411824	11.40 (19.69)	11.26 (19.56)	11.33 (19.63)	9.34 (17.79)	8.99 (17.44)	9.17 (17.61)
G_2-EC- 507739	12.93 (21.03)	12.81 (20.94)	12.87 (20.99)	10.30 (18.72)	9.98 (18.41)	10.14 (18.56)
SEm(±)	0.16	0.17	0.20	0.06	0.10	0.08
CD at 5%	0.47	0.50	0.57	0.18	0.28	0.22
CD at 1%	0.63	0.67	0.75	0.24	0.37	0.29
Interaction (D × S)						
SE (m) ±	0.35	0.37	0.43	0.13	0.20	0.16
CD at 5%	NS	NS	NS	NS	NS	NS
CD at 1%	NS	NS	NS	NS	NS	NS
Interaction (D × G)						
SE (m) ±	0.28	0.30	0.35	0.11	0.17	0.13
CD at 5%	NS	NS	NS	NS	NS	NS
CD at 1%	NS	NS	NS	NS	NS	NS
Interaction (S × G)						
SE (m) ±	0.28	0.30	0.35	0.11	0.17	0.13
CD at 5%	NS	NS	NS	NS	NS	NS
CD at 1%	NS	NS	NS	NS	NS	NS
Interaction (D × S × G)						
SE (m) ±	0.49	0.52	0.60	0.19	0.29	0.23
CD at 5%	NS	NS	NS	NS	NS	NS
CD at 1%	NS	NS	NS	NS	NS	NS

Table 2: Effect of sowing time (D), planting geometry (S), genotype (G) and their interactions on oil percentage.

	Oil %					
	Initial			240 DAS		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
D. Date of sowing						
D_1- 15th November	5.28 (13.28)	5.15 (13.10)	5.21 (13.19)	4.51 (12.25)	4.29 (11.95)	4.40 (12.10)
D_2- 1st December	4.95 (12.86)	4.82 (12.67)	4.89 (12.76)	4.19 (11.81)	3.99 (11.51)	4.09 (11.66)
D_3- 15th December	4.75 (12.59)	4.55 (12.30)	4.65 (12.44)	3.78 (11.20)	3.56 (10.86)	3.67 (11.03)
SEm(±)	0.10	0.16	0.12	0.08	0.07	0.10
CD at 5%	0.29	0.45	0.35	0.23	0.19	0.27
CD at 1%	0.39	0.60	0.46	0.31	0.25	0.36
S. Spacing						
S_1- 30 × 10 cm	5.01 (12.93)	4.87 (12.73)	4.94 (12.83)	4.21 (11.82)	4.00 (11.52)	4.10 (11.67)
S_2- 45 × 10 cm	5.00 (12.92)	4.84 (12.68)	4.92 (12.80)	4.15 (11.74)	3.93 (11.42)	4.04 (11.58)
S_3- 60 × 10 cm	4.97 (12.87)	4.82 (12.66)	4.89 (12.76)	4.12 (11.71)	3.90 (11.37)	4.01 (11.54)
SEm(±)	0.10	0.16	0.12	0.08	0.07	0.10
CD at 5%	NS	NS	NS	NS	NS	NS
CD at 1%	NS	NS	NS	NS	NS	NS
G. Genotype						
G_1- IC- 411824	4.95 (12.84)	4.77 (12.59)	4.86 (12.72)	4.06 (11.61)	3.85 (11.29)	3.96 (11.45)
G_2-EC- 507739	5.04 (12.97)	4.91 (12.78)	4.98 (12.88)	4.26 (11.89)	4.04 (11.58)	4.15 (11.74)
SEm(±)	0.08	0.13	0.10	0.06	0.05	0.08
CD at 5%	NS	NS	NS	0.19	0.15	0.22
CD at 1%	NS	NS	NS	0.25	0.21	0.30
Interaction (D × S)						
SE (m) ±	0.17	0.27	0.21	0.14	0.11	0.17
CD at 5%	NS	NS	NS	NS	NS	NS
CD at 1%	NS	NS	NS	NS	NS	NS
Interaction (D × G)						
SE (m) ±	0.14	0.22	0.17	0.11	0.09	0.14
CD at 5%	NS	NS	NS	NS	NS	NS
CD at 1%	NS	NS	NS	NS	NS	NS
Interaction (S × G)						
SE (m) ±	0.14	0.22	0.17	0.11	0.09	0.14
CD at 5%	NS	NS	NS	NS	NS	NS
CD at 1%	NS	NS	NS	NS	NS	NS
Interaction (D × S × G)						
SE (m) ±	0.25	0.38	0.30	0.19	0.16	0.24
CD at 5%	NS	NS	NS	NS	NS	NS
CD at 1%	NS	NS	NS	NS	NS	NS

From this experiment, it was found that as the storage time increased (120 DAS, 240 DAS), the seed protein content levels decreased in quinoa. Decreased levels of protein content are due to the breakdown of cell membranes and various cell organelles in seeds (Lounifi *et al.,* 2013; Pukacka *et al.*, 2007). A rise in mean germination time and electrical conductivity showed a deterioration of protein content in the seeds of quinoa (Li *et al.,* 2022). Temel and Keskin (2019) found that the ratio of crude protein ranged from 13.5% to 17.7% in the study of different row spaces in the quinoa plant.

Oil percentage. The data on oil percentage as influenced by different sowing times(D), spacing (S), genotypes (G), and their interactions are presented in Table 2.

Effect of sowing time. From the data presented in Table 2, it was found that the oil percentage recorded significant differences in response to different sowing times at initial as well as at 90, 180, and 240 DAS. At initial storage, among the sowing times, seeds harvested from the 15th November sowing (D_1) showed a higher oil percentage (5.28, 5.15, and 5.21%), followed by the 1st December sowing (D2) (4.95, 4.82, and 4.89%) during the years *Rabi* 2019-20, *Rabi* 2020-21 and on a pooled basis, respectively. However, seeds harvested from the 15th December sowing (D_3) showed lower oil percentages of 4.75, 4.55, and 4.65 percent at initial during the years *Rabi* 2019-20, *Rabi* 2020-21 and on a pooled basis, respectively, irrespective of spacing and genotype. A similar trend was noticed during the entire storage period of 240 days. At 240 DAS, seeds harvested from the 15th November sowing (D_1) recorded a maximum oil percentage of 4.51, 4.29, and 4.40 percent, followed by the 1st December sowing (D2) at 4.19, 3.99, and 4.09 percent during the years *Rabi* 2019-20, *Rabi* 2020-21 and on a pooled basis, respectively. However, 15th December sowing (D_3) harvested seeds had minimum oil percentages of 3.78, 3.56, and 3.67 (%) during the years *Rabi* 2019-20, *Rabi* 2020-21 and on pooled basis, respectively, irrespective of spacing and genotype.

Effect of spacing. According to the results in Table 2, the oil percentage recorded non-significant differences in response to different spacing throughout the 240 days of storage on the year and pooled basis, respectively.

Effect of genotype. Genotypes were found non-significant for the oil percentage up to 180 DAS, and a significant difference was observed at 240 DAS. At 240 DAS, maximum oil percentage was noted by genotype EC-507739 (4.26, 4.04, and 4.15%) during the years *Rabi* 2019-20, *Rabi* 2020-21 and on a pooled basis, respectively. Whereas, the minimum oil percentage was noted for genotype IC-411824 (4.06, 3.85, and 3.96%) during the years *Rabi* 2019-20, *Rabi* 2020-21 and on a pooled basis, respectively, irrespective of sowing time and spacing.

Effects of interactions

Interaction effect of sowing time and spacing. The sowing time (D) and spacing (S) interactions were found non-significant for oil percentage throughout the 240 days of storage, both the year and pooled basis, respectively.

Interaction effect of sowing time and genotype. According to the findings, the interaction effects of sowing time (D) and genotype (G) on the oil percentage of quinoa were found non-significant throughout the 240 days of storage, both the year and on a pooled basis, respectively.

Interaction effect of spacing and genotype. It was seen that the interaction effects of spacing (S) and genotype (G) on the oil percentage of quinoa were found non-significant throughout the 240 days of storage, both the year and on a pooled basis, respectively.

Interaction effect of sowing time, spacing and genotype. The findings showed that the interaction effects of sowing time (D), spacing (S), and genotype (G) on quinoa oil percentage were non-significant during the 240 days of storage on both a year and a pooled basis. The decrease in protein content is delayed in sowing. This might be due to the reduced span of the reproductive phase due to the decrease in days to maturity, which might have also affected the fat synthesis of the seed and the undeveloped seeds of the crop. Stikic *et al.* (2012) determined the fat ratio is between 4.79-5.20% in quinoa variety. The timely sown crop experienced favourable weather conditions for a longer duration and recorded better growth and seed yield, which resulted in higher oil productivity. In our experiment, spacing had no influence on oil content throughout the storage; higher oil content was experienced at 30 × 10 cm spacing. These results lend support to those reported by Al-Doori (2012). Tan *et al.* (2019) determined the fat ratio is between 4.37-7.08% in different quinoa genotypes.

CONCLUSIONS

The highest protein and oil content was recorded in genotype EC-507739 as compared to IC-411824 on all three dates of sowing during 240 days of storage.

FUTURE SCOPE

Systematic breeding programme is required for development of tolerant genotypes in unfavourable environmental conditions in future.

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