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Optimum sowing time of quinoa (*Chenopodium quinoa* Willd) in Telangana State, India

K. Indudhar Reddy ✉
Department of Agronomy, Professor Jayashankar Telangana State Agricultural University, Hyderabad

A.V. Ramanjaneyulu
AICRP on Agroforestry, Professor Jayashankar Telangana State Agricultural University, Hyderabad

M.V. Nagesh Kumar
Maize Research Centre, Professor Jayashankar Telangana State Agricultural University, Hyderabad

A. Geetha
Department of Crop Physiology, Agricultural College, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Hyderabad

G. Seshu
Department of Genetics and Plant breeding, Agricultural College, Jagtial, Professor Jayashankar Telangana State Agricultural University, Hyderabad

C.V. Sameer Kumar
Department of Genetics and Plant Breeding, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Hyderabad

M. Venkata Ramana
AICRP on IFS, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Hyderabad

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ABSTRACT

A field experiment was conducted in 2016-17 and 2017-18 during Rabi season at Regional Agricultural Research Station, Palem, Nagarkurnool District of Telangana State, India. The treatments consisted of 7 sowing dates with 15-day intervals (T1- October 10th, T2- October 25th, T3- November 10th, T4- November 25th, T5- December 10th, T6- December 25th and T7- January 10th). The experiment was laid out in a randomized block design and was replicated three times. This study was conducted with the objective of determining the optimum sowing time for quinoa in Telangana state, India. A greater seed yield was detected for the crops sown between October 10th (2174 kg/ha) and November 25th (1931 kg/ha); on further delay in sowing after November 25th, i.e., December 10th (1026 kg/ha), December 25th (600 kg/ha) and January 10th (590 kg/ha), the seed yields were drastically reduced due to the higher temperature at the reproductive stage of the crop. Hence, from this study, it can be noted that the optimum sowing date for quinoa in Telangana was from October 10th to November 25th.

Introduction

Quinoa (*Chenopodium quinoa* Willd.), which were originally cultivated in the Andean region, were primarily cultivated through subsistence farming in certain areas of South America until the early 20th century. The global recognition of quinoa's nutritional significance increased significantly in the latter part of the 20th century (Fleming and Galwey, 1995). Acknowledged by the FAO in 1996 as one of the most promising crops for humanity due to its exceptional properties and versatile applications, quinoa has emerged as a potential solution to human nutritional challenges (FAO, 2011). Known for its prolific biomass production, quinoa thrives in marginal soils and adverse environmental conditions, making it amenable to combined harvesting (Muhammad, 2015). With its ability to grow with minimal inputs, water, and resilience to various biotic and abiotic stresses, quinoa has gained

Corresponding author E-mail: *indu4reddy@gmail.com*
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significance as a valuable crop (Ruiz *et al*., 2014). In recognition of its importance and nutritive quality, the United Nations declared 2013 the 'Year of the Quinoa,' prompting a global effort to boost quinoa production. Consequently, numerous countries have initiated production and field evaluations to enhance quinoa cultivation (Ruiz *et al*., 2016; Jacobsen *et al*., 2003). Given its high nutritive value and market demand, there is interest in exploring the production potential of quinoa in the Indian state of Telangana. To achieve this goal, it is essential to standardize agricultural techniques such as the time of sowing, spacing, fertilizer dosage, and application timing. Consequently, this experiment was conducted to determine the optimal sowing time for achieving higher quinoa yields in Telangana State, India.

Material and Methods

A field experiment was conducted in 2016-17 and 2017-18 during Rabi season at Regional Agricultural Research Station, Palem, Nagarkurnool District of Telangana State-509215 (India). The treatments consisted of 7 sowing dates with 15-day intervals: T1- October 10th, T2- October 25th, T3- November 10th, T4- November 25th, T5- December 10th, T6- December 25th and T7- January 10th. The experiment was laid out in a randomized block design and was replicated three times. The experimental site was located at 16.51703°N and 78.2469°E and an altitude 478 m above mean sea level. The soil in the experimental field was an alfisol with low organic carbon (0.24%) and N (210 kg/ha) and high available P (75 kg P_2O_5 ha^{-1}) and available K (455 kg K_2O ha^{-1}). The irrigation was scheduled at 10- to 15-day intervals based on the feel and appearance of the soil method used for scheduling irrigation. The crop was sown by the dibbling method with a spacing of 45 cm between the rows and 10 cm between the plants in a row. Intercultivation and hand-weeding were performed to ensure that the field was weed free. A gross plot size of 4.5 m × 3 m was maintained for each treatment. Nitrogen doses of 20 kg/ha and 50 kg/ha P_2O_5 were applied as basal doses (*Telangana Vyavasayam- Diksoochi,* 2019). Both nitrogen and phosphorus were applied to the crop through diammonium phosphate (DAP). Single-plant data were collected for five tagged plants in each plot of each treatment, and yield data were collected from the net plot area. The data were statistically analyzed using ANOVA (Gomez and Gomez, 1984).

Results and Discussion

Plant height

A review of the data presented in Table 1 reveals that the plant height of quinoa during 2016-17 was influenced by the different dates of sowing and was not affected during 2017-18. The plant height ranged from 94 cm to 110 cm on different sowing dates during the two years. However, the pooled data from 2 years also showed that plant height was not significantly affected by the different dates of sowing. The similarity in plant height among the quinoa plants on the tested sowing dates was due to the nearly uniform mean temperature range (19.5–30.1°C) during the crop growing period on the tested sowing dates, as presented in Table 2. Similarly, the number of plants per square meter was not influenced by the date of sowing.

Seed yield

The seed yield and forage yield data were recorded, analyzed and are presented in Table 3. Table 3 shows that the time of sowing significantly affected the seed yield of quinoa, whereas the forage yield was not significantly influenced by the treatment. During 2016-17, the seeds of the quinoa plants sown on October 10th were significantly greater in yield (2398 kg/ha) than those of the plants sown on December 10th (1071 kg/ha), December 25th (598 kg/ha) and January 10th (575 kg/ha) and were on par with those of October 25th (2270 kg/ha), November 10th (2315 kg/ha) and November 25th (1920 kg/ha). Similarly, during 2017-2018, the yield of quinoa sown on November 10th (2086 kg/ha) was significantly greater than that on December 10th (981 kg/ha), December 25th (602 kg/ha) and January 10th (604 kg/ha), and the yield was on par with that on October 10th (1950 kg/ha), October 25th (2050 kg/ha) and November 25th (1942 kg/ha). The pooled data from 2 years (2016-17 and 2017-18) revealed that the quinoa plants sown on November 10th (2201 kg/ha) had significantly greater seed yields than did those sown on December 10th (1026 kg/ha), December 25th (600 kg/ha) and January 10th (590 kg/ha) and were on par with those sown on October 10th (2174 kg/ha), October 25th (2160 kg/ha) and November 25th (1931 kg/ha).

Table 1: Plant height and no of plants per m^2 of quinoa as influenced by different dates of sowing during *Rabi* 2016-17, *Rabi* 2017-18 and pooled data

Treatments	Plant height (cm)			No of plants/m^2		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T1- October 10^{th}	102	98	100	26	24	25
T2- October 25^{th}	107	94	100	23	22	22
T3- November 10^{th}	100	101	100	24	26	25
T4- November 25^{th}	110	103	106	22	24	23
T5- December 10^{th}	107	98	102	24	23	23
T6- December 25^{th}	110	96	103	25	25	25
T7- January 10^{th}	110	98	104	22	24	23
SEm±	1.98	2.46	2.22	3.41	2.56	2.98
CD (0.05)	6.33	NS	NS	NS	NS	NS

Table 2: Treatment wise number of days taken to reach physiological maturity and T Mean (°C) range during the crop season

	No of days taken to physiological maturity			Range of T Mean (°C)		
Treatments	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Combined 2016-17 & 2017-18**
T1- October 10^{th}	78	78	78	19.5 - 27.0	19.5 - 27.8	19.5 - 27.8
T2- October 25^{th}	78	78	78	19.5 - 27.0	19.5 - 26.5	19.5 - 27.0
T3- November 10^{th}	73	73	73	19.5 - 26.4	19.5 - 26.5	19.5 - 26.5
T4- November 25^{th}	71	71	71	19.5 - 25.3	19.5 - 25.0	19.5 - 25.3
T5- December 10^{th}	71	71	71	19.5 - 25.3	19.5 - 26.3	19.5 - 26.3
T6- December 25^{th}	67	67	67	20.0 - 29.1	19.5 - 26.8	19.5 - 29.1
T7- January 10^{th}	63	63	63	20.0 - 30.1	20.8 - 28.5	20.0 - 30.1

Table 3: Seed yield and Forage yield of quinoa as influenced by different dates of sowing during *Rabi* 2016-17, *Rabi* 2017-18 and pooled data

Treatments	Seed yield (kg/ha)			Forage yield (kg/ha)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T1- October 10^{th}	**2398**	**1950**	**2174**	3723	3452	3588
T2- October 25^{th}	**2270**	**2050**	**2160**	3328	2964	3146
T3- November 10^{th}	**2315**	**2086**	**2201**	3849	3214	3532
T4- November 25^{th}	**1920**	**1942**	**1931**	3296	2856	3076
T5- December 10^{th}	1071	981	1026	3046	2931	2989
T6- December 25^{th}	598	602	600	2806	2250	2528
T7- January 10^{th}	575	604	590	3277	3125	3201
SEm±	290.2	264.2	235.4	500.1	419.2	405.6
CD (0.05)	904.3	702.2	742.1	NS	NS	NS

The reduced seed yield in the crops sown on December 10^{th}, December 25^{th} and January 10^{th} was clearly due to the increasing trend in the daily mean temperatures from the 50^{th} standard meteorological week (lowest daily mean temperature) to the 11^{th} standard meteorological week (highest daily mean temperature), as shown in Figure 1. The low daily mean temperature coincided with germination, and the high daily mean temperature coincided with the reproductive stage of the crop sown from December

10th to January 10th, during which the seed yields decreased. Similar results were reported by Jacobsen (2003) and Choukrallah *et al.* (2016), who reported that the seed yield of quinoa was negatively affected by low temperatures at the vegetative stage and high temperatures at the reproductive stage. The data on seed yield during the two years and the pooled data clearly affirm that the crop sown between October 10th and November 25th had a greater seed yield. Thus, the optimum sowing date for quinoa in Telangana was between October 10th and November 25th.However, the forage yield of quinoa was not significantly influenced by the date of sowing during 2016-17 or 2017-18. This clearly showed that the biomass of the plant was not influenced by the date of sowing; however, the seed yield was significantly influenced by the date of sowing.

Crop duration and daily mean temperature

A review of the data in Table 3 reveals that the number of days taken to reach physiological maturity or crop duration decreased with the advancement of sowing dates from October 10 to January 10. The pooled data revealed that the crop duration was 78 days in T1- October 10th and T2- October 25th, 73 days in T3- November 10th, 71 days in T4- November 25th and T5- December 10th, 67 days in T6- December 25th and 63 days in T7- January 10th. This decrease in crop duration also had an impact on seed yield. The decreases in crop duration and seed yield were due to the increase in the daily mean temperature with the advancement of sowing dates from October 10th to January 10th. However, the higher daily mean temperature in T1- October 10th and T2-October 25th i.e., 19.5°C-27.8°C and 19.5°C-27.0°C, respectively, did not influence the crop duration or the seed yield due to the optimum higher mean temperatures during the vegetative stage of the crop. Similar findings were reported by Isobe *et al.* (2016) and Ujiie *et al.* (2007), who reported that, under optimum temperature, crop duration and seed yield were unaffected. In comparison to those sown during T6 and T7, those sown during T1 up to T5 experienced lower daily mean temperatures at the reproductive stage (the black lines in Figure 1 show the crop duration and the relative daily mean temperatures during 2016-17 and 2017-18).

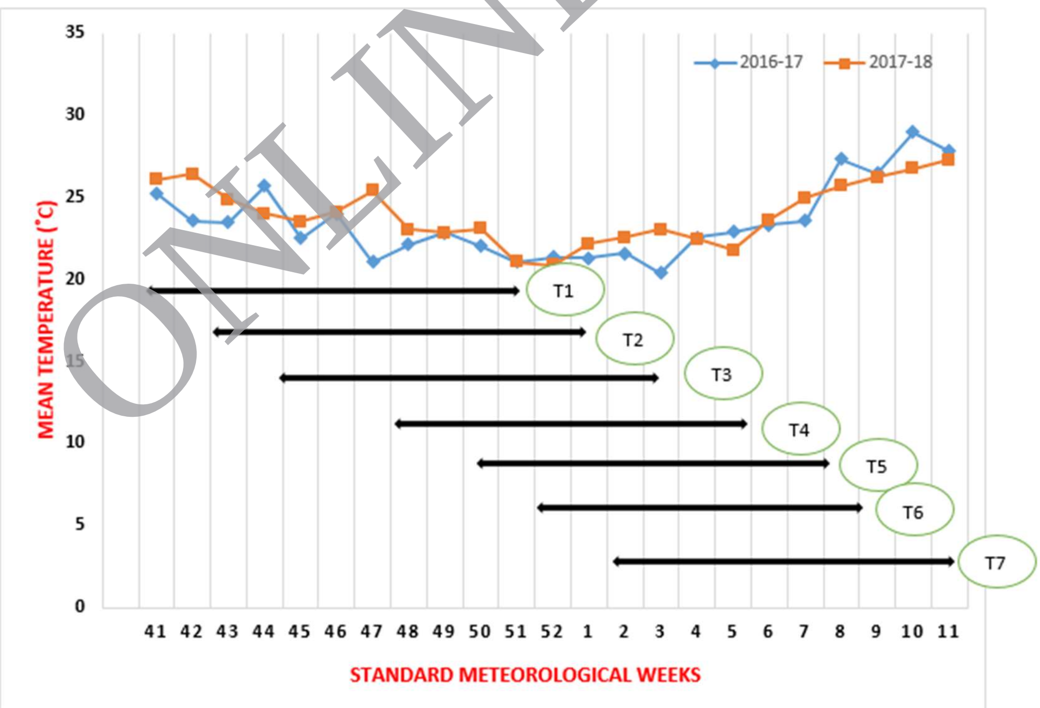

Figure 1: Standard meteorological weekwise mean temperature (°C) during the crop growing season

This increase in the daily mean temperature at the reproductive stage of the crop drastically reduced the seed yield in T6 (600 kg/ha) and T7 (590 kg/ha). Similarly, Leonardo *et al.* (2018), Pulvento *et al.* (2010), Hirich *et al.* (2014), Präger *et al.* (2018), and Pires *et al.* (2017) and Peterson *et al.* (2015) reported that high temperatures during flowering and seed set can significantly reduce seed yield and are major barriers to the global expansion of quinoa. Similarly, the accumulated growing degree days (GDDs), Heliothermal units (HTUs), and Photothermal units (PTUs) are presented in Figure 2. The results revealed that the number of GDDs required to reach physiological maturity was in the range of 856 to 1047. Similarly, the number of heliothermal units required ranged from 7343 to 7759, and the number of photothermal units required ranged from 8681 to 11964.

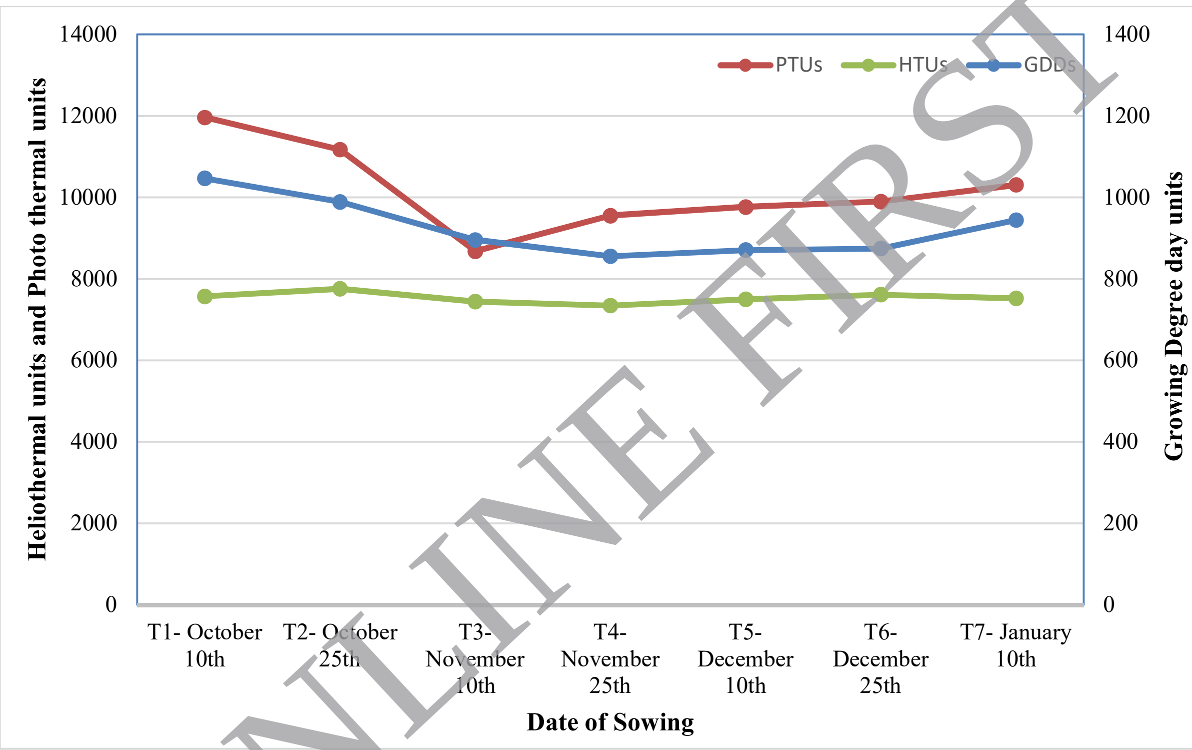

Figure 2: Accumulated GDDs, HTUs, and PTUs during the crop period on different dates after sowing

Conclusion

Based on the present study, it was concluded that lower temperature during germination and vegetative growth and higher temperature at the reproductive stage had negative effects on the seed yield of quinoa. Hence, among the tested sowing dates, higher seed yield was obtained for the crop sown from October 10th to November 25th; thus, this period may be considered the optimum sowing date for quinoa in Telangana.

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Conflict of interest

The authors declare that they have no conflicts of interest.

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