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Effect of different thermal regimes and fertility levels on growth and yield of quinoa (*Chenopodium quinoa* Willd.)

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Abstract
The experiment was carried out during 2019-20 and 2020-21 at KVK Farm, College of Agriculture, JNKVV, Tikamgarh (MP) to evaluate the performance of new emerging crop quinoa under different thermal regimes and fertility levels. Twelve treatments comprising of three thermal regimes i.e. 15th November, 30th November and 15th December and these were superimposed with four fertility levels *viz.*, F_0 (Control): (NPK 0:0:0), F_1: (NPK 80:40:40 kg/ha), F_2: (NPK 100:50:50 kg/ha) and F_3: (NPK 120:60:60 kg/ha), were laid out in split plot design with three replications. The results revealed that among different thermal regimes the plant height, dry weight, grain and stover yields of quinoa were significantly affected by different thermal regimes being the maximum when sown it was on thermal regimes of 15th November and proved significantly superior over thermal regimes of delayed sowing (30 November and 15th December). The plant height, dry weight, grain and stover yields were also affected by fertility levels These parameters were increased correspondingly with increasing levels of fertility being the maximum when the quinoa was fertilized with 120 N: 60 P_2O_5:60 K_2O kgha^{-1} and found superior to that of lower fertility levels.

Keywords: Thermal regimes, quinoa, fertility levels, growth and yield

Introduction
Quinoa (*Chenopodium quinoa* Willd.) is an ancient staple food crop and recently it has been spread across the world due to excellent quality parameters. It could flourish in various agro-ecological conditions under wide range of relative humidity (40 – 80%), temperature (-4 to 38 ^{o}C) and highly tolerant to soil moisture and salinity stress. Henceforth, it could be one of the good options for food scared areas. If good quality produce is made available through the introduction of quinoa, then it will not only help the local farmers to get better income but also overcome the serious problem of mallnutrition. The low productivity, undulated fields, lack of irrigation facilities and unscientific cultivation of crops in bundelkhand, has brought the agriculture at the verge of subsistence farming only. For the last few decades, the bundelkhand has witnessed extreme weather events such as more hot and coldness, recurrent droughts and the same has been apparently reflected in successive crop failures, lack of employment and migration of working youth (Anonymous, 2016) [1]. Farming communities of the region earnestly demand for the alternative crop that can fit well to existing agro-climatic conditions and can also prove to be a medium of sustainable livelihood. However, for the horizontal and vertical spread of this crop in bundelkhand region, there is need of sound agronomy like suitable thermai regime for sowing and fertility level for getting higher yields from quinoa. Keeping above facts in view, a comprehensive study has been done to adjudge the suitable thermal regime for sowing of quinoa during winter season and optimum fertility to enhance yield levels in bundelkhand region.

Material and Methods
The field experiment was carried out in the KVK Farm, College of Agriculture, JNKVV, Tikamgarh (M.P.) during rabi season of 2019-20 and 2020-21 to evaluate the performances of quinoa under different thermal regimes and fertitlty levels for bundelkhand region of Madhya Pradesh. The soil was medium black in texture, neutral in reaction (7.02 pH), medium in organic carbon (0.55%), low in available Nitrogen (266.5 kg/ha) and high in available phosphorous (27 kg/ha) and potassium (256 kg/ha). Twelve treatments comprising of three thermal regimes for sowwing (D_1: 15 November, D_2: 30 November and D_3: 15 December) as a

main plots and four fertility levels of N:P:K (F_0: 0:0:0 control, F_1: 80:40:40, F_2: 100:50:50 and F_3: 120:60:60 kg/ha) in sub-plots, were laid out in split plot design with three replications. The quinoa was sown in the respective plots using the seed rate 5 kg/ha and thinning was done after two weeks of sowing so as to maintain plant spacing of 45 cmX10 cm. The crop was irrigated 4 times during the crop season as and when crop plants showed moisture deficiency (drooping of leaves in the afternoon). The observations on growth parameters like plant height and dry weight were recorded at 30, 60 and 90 DAS. The grain and stover yields were recorded at harvest.

Result and Discussion

Effect of thermal regimes

Data given in Table 1 showed that thermal regimes had marked influence on plant height and dry weight of quinoa at different time intervals including grain and stover yields at harvest. The sowing of quinoa on thermal regimes of 15th November had higher values of plant height, dry weight at different time intervals (30, 60 and90 DAS) including grain and stover yields at harvest. This might be due the fact that 15 November sown crop received maximum length of growing period, favourable temperature and other climatological parameters for optimal growth, which alimentally facilitated cell division and cell elongation in compression to 30 November and 15th December thermal regimes of delayed sowing. In Hyderabad, Ramesh *et al.* (2017) [13] also reported superiority of October 15th date of sowing with respect to yield attributes and yield due to efficient utilization of natural resources (water and nutrients) with optimum vegetative growth and higher translocatation of photosyntheses from source to sink. However, the reverse was true in case of thermal regimes of delayed sowing (November 30th and December 15th. Therefore, thermal regimes of delayed sowing of quinoa had inferior values of plant height, dry weight at 30, 60 and 90 DAS including grain and stover yields. Similar results were obtained by Chaudhari *et al.* (2009), Dorji *et al.* (2020) [7], Khanalizadegan *et al.* (2020) [10] and Yarnia (2010) [16], Aslani and Mehrvar (2012) [3], Kumar *et al.* (2013) [11] and are closely related to above results.

Effect of fertility levels

Data given Table 1 showed that fertility levels had marked influence on plant height and dry weight of quinoa at different time intervals (30, 60 and 90 DAS) including grain and stower yields at harvest. The poor values of growth parameters namely plant height and dry weight including grain and stover yields were obtained under control plots (N:P:K 0:0:0 kg/ha). However, the plant height, dry weight, grain and stover yields were increased correspondingly with increasing fertility levels being the maximum when the qiunoa was fertilized with 120 N: 60 P_2O_5:60 K_2O kg/ha and proved significantly superior over lower of fertility levels. Adequate supply of nitrogen, phosphorus and potassium leads to high photosynthetic activity, vigorous vegetative growth and dark green colour and finally influences the better utilization of carbohydrates and led to record higher values of growth parameters at different time intervals and ultimately had higher grain and stover yields. The increase in growth and yield attributes characters gradually with increasing N-levels attributed to the role of nitrogen in improving quinoa growth by enhancement meristematic cell division and expansion (Roggatz *et al*. 1999 [14] and Basra *et al*. 2014) [4]. These findings are in close proximity to that of Daughtry (2000) [6], Khan *et al.* (2008) [9], Sharma *et al.* (2012) [15], Abbas *et al.* (2013) [2], Khalid *et al.* (2014) [8] and Maurya *et al.* (2014) [12].

Table 1: Effect on growth and yield parameters (mean data of two seasons)

Treatment	Plant height (cm)				Dry weight (g)				Grain yield (kg/ha)	Stover yield (kg/ha)
	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest		
Thermal regimes										
D1 (15th Nov.)	29.10	109.17	123.18	131.28	10.76	33.16	51.77	72.78	1,620.50	8,416.22
D2 (30th Nov.)	26.73	103.60	117.32	125.39	8.75	25.22	38.55	56.17	948.55	7,895.65
D3 (15th Dec.)	24.94	94.03	111.91	117.33	7.53	21.60	32.82	45.96	667.72	7,171.71
S.Em±	0.10	0.34	0.64	0.58	0.06	0.09	0.14	0.22	6.94	36.70
C.D. (P=0.05)	0.42	1.39	2.61	2.37	0.27	0.36	0.56	0.91	28.00	147.97
Fertility levels										
F0 (Control)	21.01	95.83	109.61	114.88	6.66	19.86	28.90	44.13	545.50	6,483.65
F1 80:40:40	24.14	100.15	114.98	120.50	8.56	24.31	39.66	54.78	828.66	7,483.90
F2 100:50:50	29.35	104.28	118.78	128.24	9.64	28.30	43.31	63.05	1,159.48	8,079.80
F3 120:60:60	33.20	108.81	126.51	135.06	11.18	34.16	52.31	71.26	1,782.05	9,264.10
S.Em±	0.15	0.52	0.78	0.84	0.04	0.19	0.27	0.30	4.37	52.58
C.D. (P=0.05)	0.47	1.58	2.36	2.52	0.13	0.57	0.82	0.90	13.09	157.44

Conclusion

It is concluded that thermal regime of 15th November and fertility levels of 120 N: 60 P_2O_5: 60 K_2O $kgha^{-1}$ were found more suitable for attaining superior values of growth and yield of quinoa in Bundelkhand region.

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