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Performance of Quinoa under Rainfed *Alfisols* of South Peninsular India

Y. Pavan Kumar Reddy [a++*] and B. Sahadeva Reddy [a#]

[a] *ANGRAU-ARS, Ananthapuramu, Acharya N.G. Ranga Agricultural University, India.*

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Quinoa, an ancient crop to contribute to world food security and it is a crop with high potential to contribute to food security in various Regions worldwide, especially in those countries where the population does not have access to protein sources or where production conditions are limited by low humidity, reduced availability of inputs, and aridity. An attempt was done at ARS, Ananthapuramu to study the feasibility to raise the quinoa under rainfed conditions during *kharif*, 2015 and 2016 under RBD with 6 treatments in four replications. The crop was grown on 24th standard week and harvested at 40th standard week. Among the different varieties highest yield was recorded with under transplanting with 2150 kg/ha, with water use efficiency of 7.32 kg hamm^{-1} with IC-411824. Further highest germination percentage was recorded with the vermicompost when compared with soil when germination was kept under trays.IC-411824 recorded highest germination percentage (98 %) with vermicompost. The seed vigour and viability characters viz., germination index, seedling length and seed vigour index was highest with IC-411824. Under transplanting all the varieties matures earlier than direct sowing. The vegetative characters viz., plant height increases from vegetative to flowering in all varieties and recorded highest with IC-411824.

Keywords: Quinoa; seed yield; rainfed.

[++] *Scientist;*
[#] *Principal Scientist (DLA)&Head;*
**Corresponding author: E-mail: y.pavankumarreddy@angrau.ac.in;*

1. INTRODUCTION

In the recent past, productivity of agriculture worldwide in general was on the decline, which prompted the per capita availability of food grain to fall from 510 g per day (1991) to 463g per day (2004). These declining trends across the world can be attributed to ever growing population, raising incomes of populous Asian nations and discovery of new uses such as bio fuels, besides weather-based abnormalities owing to climate change [1]. To feed the ever-burgeoning population of India, it is emphasized that agricultural production should be improved on sustainable basis by efficiently and judiciously utilizing the available resources. Under these circumstances, ensuring self-sufficiency and food security are challenging tasks before the populous nations like India. Drought status rising due to climate change is one of the factors limiting agricultural productivity. The World Bank (2016) predicted that because rainfed circumstances currently affect more than 70% of the production area, agricultural output will soon become less effective [2]. To ensure food security and also answer the above challenges quinoa is emerged with a new hope and it is called as super grain and mother grain of feature [3]. In South America, quinoa (Chenopodium quinoa Willd.) has been a staple food for the Inca Empire and other pre-Columbian Andean farming groups for more than 5,000 years [4,5,6]. It is gluten free, after harvest the seeds are processed to remove the bitter tasting outer seed coat. FAO declared 2013 as international year of Quinoa [7]. While the main producers are Bolivia, Peru and the United States, quinoa production is expanding to other continents and it is currently being cultivated in several countries in Europe and Asia with good yields. The rise in popularity of quinoa has led to a surge in breeding efforts, as well as research in agronomy and food science. These endeavours aim to enhance quinoa production and satisfy the expanding market demand [8,9]. Additionally, investigations into processing characteristics and market classification prospects have been conducted. In the climate change scenario, there is a dire need to study the emerging crops such as quinoa was quite essential. Hence the study on the crop was initiated and conducted at Agricultural Research Station, Ananthapuramu.

2. METHODOLOGY

A field experiment was conducted under rainfed conditions for two years during kharif, 2015 and 2016 to test the feasibility of the quinoa in drylands of scarce rainfall zone of Andhra Pradesh at Agricultural Research Station, Ananthapuramu, Andhra Pradesh.The soil of the experimental site was red sandy loam with shallow depth, low in organic carbon (0.35%) and low in available nitrogen (142 kg ha^{-1}), medium in available P_2O_5 (32 kg ha^{-1}) and K_2O (226 kg ha^{-1}). The crop was grown on 24th standard week and harvested at 40th standard week. To test the performance of 3 varieties viz., EC-5077739, EC-5077738 and IC-411284 under rainfed conditions with direct sowing and transplanting with four replications under Randomised block design with 6 treatments with 45 cm x 10 cm spacing. The characters viz., Plant height, days to maturity, Panicle length, different phenophases were recorded. Physiological parameters viz., Seedling vigour index, Germination Percentage, Germination index etc. were studied. The plots were harvested individually and threshing was done manually and yield parameters were recorded. The data collected for all the parameters were subjected to statistical scrutiny by analysing variance for randomised block design (RBD) as Panse and Sukhatme [10] outlined. Statistical significance was tested with the 'F' test at a 5 percent probability level and compared the treatment means with a critical difference. Non- significant treatment differences were denoted as NS. The physiological parameters were estimated in quinoa under lab conditions with different criteria.

3. RESULTS AND DISCUSSION

The results were analysed in the opstat software through open access internet program and the interpreted here under.

3.1 Seed Yield

Seed yield was recorded in both net plot and per ha was represented in table.1. The pooled seed yield data revealed that higher significant seed yield (2150 kg ha^{-1}) was recorded with IC-411824 with transplanting followed by IC-411824 with direct sowing which were on par with each other among all the six treatments. An adequately established root zone plays a crucial role in the establishment of a robust and expansive root system, hence promoting the growth and development of plants [11,12,13]. Among the six treatments lowest seed yield was recorded with EC-5077339 with direct sowing (1623 kg ha^{-1}). With the treatments tested the variety IC-411824 recorded significantly higher yields than the other varieties. This was contributed due to the better establishment, branching and more grain yield per plant and higher test weight of particular variety. According to Spear and Santos (2005), there is a positive correlation between dry matter production, plant height, and grain yield in quinoa plants. This correlation is reflected in the maturity period of the plants, where genotypes that mature later tend to grow taller compared to those that mature early. Additionally, the later maturing genotypes have been found to exhibit superiority in other yield components. In order to achieve optimal production levels, it is imperative to address the issue of drought stress by the implementation of irrigation practises during critical stages of plant development, including establishment, blooming, and early grain filling. By adopting such measures, it is anticipated that improved yields can be attained [14]. With the two establishment methods there was slight edge of the transplanting treatments than the direct sowing. This might be due to better establishment of seed germination and growth under initial stages in green houses later on sturdy plants were transplanted at 2 weeks leads to better establishment.

3.2 Test Weight

Among the different varieties test significantly higher test weight/1000 grain was recorded in IC-411824 and lowest 1000 grain weight was recorded with EC-5077339 which were different from each other. However, the slight variation on the two methods of establishment transplanting recorded bit higher test weight than the direct sowing due to the well-spaced plant geometry with better growth recorded the higher test weight than the direct sowing. Significant genotypic variation was recorded for 100-seed weight, with seed weight being significantly higher under drought conditions than in the other two environments (rainfed and irrigated). This maybe because quinoa does not require the application of more water during the reproductive stage, which may be the case in irrigated and rainfed environments of this study. However, no significant variation was found between the irrigated and rainfed environments. Our study revealed a positive correlation between grain yield and seed weight, which agrees with earlier findings [15].

3.3 Panicle Length

In the treatments under testing significantly higher panicle weight was attributed in IC-411824 with transplanting and the lowest panicle weight was EC-5077338 with direct sowing. This can be related to the role of ascorbic acid assisted in rise in the number of panicles per plant and panicle number too [16].

3.4 Days to Maturity

Quinoa plants with direct sowing took 2 weeks extra to mature rather than the transplanted plants. Among the different treatments IC-411824 with direct sowing matured at 105 days rather than the other treatments. The transplanted established well in short span and completed all the growth phases and matured earlier than the transplanting. Under transplanting all the varieties matures earlier than direct sowing. Jacobsen et al. [17] also observed a favourable correlation between quinoa grain yield and other plant characteristics, including maturity period (plant cycle), plant height, length of inflorescence, and diameter of inflorescence. The link under consideration is anticipated, as the genotypes that exhibited early flowering also shown increased height at harvest and accumulated the greatest biomass. Consequently, these factors contributed to the largest yield of dry grain per hectare.

3.5 Plant Height

Plant height was measured in the quinoa crop at different pheophases from transplanting, vegetative, flowering and harvesting stages. In the all the phenophases significantly higher plant height was recorded with IC-411824 with transplanting and significantly lowest plant height was recorded with EC-5077338 with direct sowing. This slightly higher variation of the plant height was attributed due to the better establishment in the transplanting compared to direct sowing treatments. The growth of plant height was at fastest rate in the vegetative to flowering stage and later on the difference in the gap from flowering to maturity was bit lower than the earlier phases where plant utilises most of the energy for the conversion of accumulates in to seed rather than the growth of the plant. The vegetative characters viz., plant height increases from vegetative to flowering in all varieties and recorded highest with IC-411824. In this study, a positive association was observed between plant height and grain yield, indicating that taller quinoa plants tended to produce more. Wider space with transplanting exhibited a plant height comparable to control plants and much greater than. This research runs counter to what Pourfarid et al. [18] found.

3.6 Actual depth of water received during crop growth season through rainfall

The water required for the quinoa was same for the different varieties among the different treatments was same. But the water required was significantly higher in the direct sowing treatments (293.6mm) per crop cycle than transplanting (254.3mm). Higher water requirement in direct sowing was due to the more duration to mature the crop took more water for the growth and development of the crop where as in transplanting it took 2 weeks earlier to mature which enables the less water for the crop to complete the life cycle in short span of time.

3.7 Water use efficiency

Water use efficiency was the is direct measure for the yield with the water utilised for the season. Among the different varieties tested highest water use efficiency was recorded with IC-411824 with transplanting due to higher yield produced under lower water requirement and lowest water use efficiency was recorded with EC-5077339 with direct sowing.

3.8 Physiological parameters

Before sowing the experiment, the entries were tested for the different physiological parameters under lab conditions. Among the different varieties tested IC-411824 recorded significantly higher germination percentage in both soil and vermicompost as a bedding material and lowest germination percentage was recorded with EC-5077339. Further highest germination percentage was recorded with the vermicompost when compared with soil when germination was kept under trays. IC-411824 recorded highest germination percentage (98 %) with vermicompost. With respect to days to initiation of germination all the varieties took same days to initiate germination. The observed disparity could perhaps be attributed to the reduction in free radical generation, which was facilitated by the presence of ascorbic acid, hence potentially contributing to the observed outcome.

The preservation of the integrity of the cell membrane is crucical. Amal et al. [19]. The seed vigour and viability characters viz., germination index, seedling length and seed vigour index was highest with IC-411824 and the lowest was recorded with EC-5077339. Total phenolic content increased by ascorbic acid results in increasing seedling growth, because phenolic compounds act as a major role in lignification and also helps in structural development throughout the growth period which further leads to increasing the seed vigour in faba bean as reported by Randhir and Shetty [20]. The increased length of the seedlings could be the result of a combination of factors, including the existence of a greater amount of stored food materials and the role of ascorbic acid in cell elongation. Naheif [21] found analogous outcomes in wheat. The seed vigour and viability characters viz., germination index, seedling length and seed vigour index was highest with IC-411824.

Table 1. Pooled yield and yield attributes of quinoa under rainfed *alfisols*

Treatment	Seed yield/ Plot (kg)	Seed yield (kg/ha)	Panicle length (cm)	Test weight (g)	Days to maturity
EC-5077339 with transplanting	11.37	1776	31.2	17.21	86
EC-5077338 with transplanting	12.60	1970	31.8	17.23	87
IC-411824 with transplanting	13.76	2150	32.3	17.41	89
EC-5077339 with direct sowing	10.32	1623	29.6	17.20	102
EC-5077338 with direct sowing	11.34	1850	30.4	17.19	100
IC-411824 with direct sowing	12.96	1981	31.1	17.30	105
CD @ 5 %	1.41	105	1.32	0.05	9
CV	10.32	12.45	9.87	3.20	3.56
SEm±	4.21	294	3.89	0.15	26

Table 2. Pooled plant height (cm) of quinoa under rainfed *alfisols*

Treatment	Plant height at different phases (cm)			
	Transplanting	**Vegetative**	**Flowering**	**Harvesting**
EC-5077339 with transplanting	11.29	17.72	66.4	69.2
EC-5077338 with transplanting	11.69	18.22	69.3	70.8
IC-411824 with transplanting	11.97	20.19	71.1	73.4
EC-5077339 with direct sowing	10.32	14.52	54.1	57.8
EC-5077338 with direct sowing	9.81	15.43	58.6	62.1
IC-411824 with direct sowing	10.4	17.12	62.3	64.1
CD @ 5 %	0.36	0.52	2.89	3.01
CV	**10.56**	**11.75**	**10.97**	**9.89**
SEm±	**1.08**	**1.58**	**8.95**	**9.41**

Table 3. Pooled yield, water requirement and water use efficiency of quinoa under rainfed *alfisols*

Treatment	Actual depth of water received during crop growth season through rainfall (mm)	Seed Yield (kg/ha)	Water use efficiency (kg-hamm^{-1})
EC-5077339 with transplanting	254.8	1776	7.10
EC-5077338 with transplanting	254.8	1970	7.89
IC-411824 with transplanting	254.8	2150	8.63
EC-5077339 with direct sowing	293.6	1623	6.05
EC-5077338 with direct sowing	293.6	1850	6.71
IC-411824 with direct sowing	293.6	1981	7.32
CD @ 5 %	38.9	105	0.91
CV	**5.76**	**12.45**	**10.34**
SEm±	**115.8**	**294**	**2.91**

Table 4. Physiological parameters of quinoa under rainfed *alfisols*

Treatment	Germination percentage (%)		Days to germination	Germination index	Seed ling length @ 5 DAS	Seed vigour index
	Soil	**Vermi compost**				
EC-5077339	56	97	3	26	6.6	640
EC-5077338	57	97	3	27	6.8	660
IC-411824	62	98	3	30	7.4	725

4. CONCLUSION

Based on the above experimentation it can be concluded that significantly higher seed yield, plant height, panicle weight, days to maturity, higher water use efficiency was recorded with with IC-411824 with transplanting.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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