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**FULL LENGTH ARTICLE** **OPEN ACCESS**

# Quinoa (*Chenopodium quinoa* willd.) growth and yield attributes and yield as influenced by drip and surface method of irrigation

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**ABSTRACT**

*A field experiment was conducted at college farm, college of Agriculture Rajendranagar Hyderabad, during rabi 2016-17 to study the influence of irrigation methods and irrigation levels on growth and yield of quinoa. The experiment was laid out in randomized block design with three replications and ten treatments. The treatments are combinations of 0.5 and 1.0 $E_{pan}$ in drip and 0.5 and 1.0 IW:CPE ratio in surface method at different crop growth stages. Results revealed that all the growth parameters like plant height, number of branches, leaf area index and dry matter accumulation at harvest and yield attributing characterize., main panicle length, number of panicles plant$^{-1}$, test weight (1000- grain weight) and yield parameters like grain yield, stalk yield and harvest index were significantly higher with 1.0 $E_{pan}$ throughout cropping period under drip irrigated treatment ($T_2$) and 1.0 IW: CPE in surface method of irrigation ($T_{10}$). The highest grain yield stalk yield and harvest index was recorded with 1.0 $E_{pan}$ throughout cropping period ($T_2$). Imposing mild water stress (0.5 $E_{pan}$) at flowering stage ($T_8$) and at vegetative stage ($T_3$) has realized next best yield proving grain filling is the sensitive stage for irrigation in quinoa. The number of branches per plant and number of panicles plant$^{-1}$ of quinoa was higher in surface treatment ($T_{10}$).*
***Key words:*** *Quinoa,Irrigation,growth parameters, Yield attributes.*

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## INTRODUCTION

Quinoa (*Chenopodium quinoa* willd.) is an annual herbaceous plant, belongs to the Chenopodiaceae, is well adapted to poor soil and unfavourable climatic conditions (Garcia *et al*., 2003. Yazer*et al.,* 2015). It has the ability to tolerate low temperatures (8 $^{0}$C) (Jensen *et al*. 2000)and drought (Vacher, 1998). Quinoa is a new crop to India and can be successfully grown in the Himalayas and the plains of Northern India with reasonably high yields (Bhargava*et al*., 2006). The high nutritional value and protein content is one of the important characteristics of this crop. Quinoa grain is the only vegetable food that provides all amino acids essential to the life of humans in optimum quantities and is comparable with milk. To popularize the importance of crop in the world the Untied Nation organization (UNO) declared year 2013 as international year of quinoa (FAO, 2013). Since Independence, India experienced green revolution (rice & wheat), white revolution (milk) and still India tops in malnutrition. Nearly 52 per cent population were suffering with diabetes due to over dependence on few cereal foods (rice or wheat) eroding the gross domestic product of the country by 4 to 6 per cent. Along with food security the nutritional security is also essential for Indian population (APARD, 2013-14). Quinoa can be introduced in India to check malnutrition as well as to increase foreign exchange. In this context, quinoa is considered as strategic crop with potential to contribute to food security and sovereignty due to nutritional quality, genetic variability, adaptability to adverse climate and soil conditions and low production cost. The cultivation of quinoa provides an alternative for countries with limited food production which are therefore forced to import or receive food aid.

Water demand goes on increasing day by day and on other hand the depletion of ground water and insufficient water availability to agriculture has made the irrigation specialists and agronomist to adopt new crops and cropping systems. Quinoa is one such drought tolerant crop that suits in cropping pattern as a short duration rabi crop (105-110 days) and has specific morphological characteristics such as extensive root system and hygroscopic papillae on the leaf cuticle (Jensen *et al*., 2000) Garcia (2003) and

Geerts*et al*. (2009) demonstrated yield optimization in quinoa through deficit irrigation with maximum water productivity in other countries. Hence an experiment was formulated to study response of quinoa to variable water supply in drip and surface method of irrigation in Southern Telangana.

## MATERIALS AND METHODS

The experiment was conducted at college farm. College of Agriculture Rajendranagar, Hyderabad during *rabi* season 2016-17. Geographically, experimental site is situated at an altitude of 542.3 m above mean sea level at 170 32' 25'' N latitude, 780 41' 01'' E longitude and categorised under the South Agro-climatic region of Telangana. The soil of the experimental site was sandy loam in texture, slightly alkaline in reaction (7.8), non-saline (0.14 $dsm^{-1}$ ), low in organic carbon content (0.43 %), medium in available nitrogen (256.5 kg $ha^{-1}$), medium in available phosphorous (66.68 kg $ha^{-1}$) and high in available potassium (344.61 kg $ha^{-1}$). The experiment was conducted in Randomized block design with three replications. Ten treatment combinations comprised of 0.5 $E_{pan}$throughout cropping period ($T_1$), 1.0$E_{pan}$ throughout cropping period ($T_2$) irrigation with 0.5 $E_{pan}$ at vegetative and 1.0 $E_{pan}$ at both flowering and at grain filling stage ($T_3$), Irrigation with 0.5 Epan at vegetative, 1.0 $E_{pan}$ at flowering and 0.5 $E_{pan}$ at grain filling stage ($T_4$), Irrigation with 0.5 $E_{pan}$ at vegetative, 0.5 $E_{pan}$ at flowering and 1.0 $E_{pan}$at grain filling stage ($T_5$), Irrigation with 1.0 $E_{pan}$ at vegetative, 0.5$E_{pan}$at flowering and 0.5 $E_{pan}$ at grain filling stages ($T_6$), Irrigation with 1.0 $E_{pan}$ at vegetative, 1.0 $E_{pan}$ at flowering and 0.5$E_{pan}$ at grain filling stages($T_7$), Irrigation with 1.0 $E_{pan}$ at vegetative, 0.5 $E_{pan}$ at flowering and 1.0 $E_{pan}$at grain filling stages ($T_8$), Irrigation with 0.5 IW: CPE throughout crop growth by flatbed method ($T_9$) and Irrigation with 1.0 IW:CPE throughout crop growth by flatbed method ($T_{10}$). Spacing followed was 30×10 cm. The field plot size was 3.6 ×10 m, the drip laterals were spaced at 60 cm, forming 12 rows of 10 m length in one plot. Treatments$T_1$ to $T_8$ are drip and $T_9$ and $T_{10}$ are surface irrigated treatments. In Drip treatments, irrigation was scheduled at three days interval. Irrigation water depth of 50 mm was fixed in surface method of irrigation. The total available soil moisture is the difference between - 0.2 MPa and -1.5 MPa in 0-60 cm soil depth amounted to 96.20 mm.The fertilizer dose of 80:50:40 kg $ha^{-1}$ N, $P_2O_5$ and $K_2O$ respectively, was applied to quinoa in the form of urea,single super phosphate and muriate of potash respectively. Total amount of P was applied as basal, K in equal two splits half as basal and other half at 30 DAS. The N was applied in three equal splits at basal, 30 DAS and at flowering stage. Crop was sown on 29thOctober 2016 and necessary agronomic and plant protection operations were taken during crop growth period. Crop was harvested on 10thFebruary 2017. The data on growth, yield attributes and yield was recorded at harvest and statistically analysed.

## RESULTS AND DISCUSSION

Irrigation scheduling brought significant variation on plant height, number of branches $plant^{-1}$,leaf area index (LAI), dry matter accumulation $plant^{-1}$at harvest of quinoa crop. Scheduling of irrigation 0.5$E_{pan}$at vegetative, 1.0 $E_{pan}$ at flowering and 0.5 $E_{pan}$ at grain filling stages ($T_4$) recorded significantly taller plants (135.3 cm). Lower plant height (115.9 cm) was observed in surface irrigated treatment receiving 0.5 IW: CPE throughout cropping period ($T_9$) (Table.1). It might be due to rapid cell division, cell elongation under adequate water supply. Shorter plant height was mainly due to poor growth caused by stress conditions (Singh and Singh, 2014 and Walters *et al.*2016. Higher number of branches was recorded under surface method of irrigations ($T_9$ and $T_{10}$) irrigation scheduled at 0.5 and 1.0 IW: CPE ratio respectively. It might be due to adequate availability of moisture which increased the availability of nutrients and led to more number of branches $plant^{-1}$. The lower number of branches was recorded under irrigation with 1.0 $E_{pan}$ at vegetative, 0.5 $E_{pan}$at flowering and 0.5 E at grain filling stages ($T_6$) due to inadequate availability of moisture at both flowering and at grain filling stages of the crop and also number of irrigations in this treatment was also less.Significantly higher leaf area index (LAI)was recorded with 1.0 $E_{pan}$ throughout cropping period. Increase in LAI under increasing moisture availability might be due to increased nutrient absorption which contributed for more number of green leaves and size of leaves and ultimately led to higher LAI. The lowest LAI was recorded under 0.5 IW/CPE ratio ($T_9$) which could due to reduced cell expansion under moisture stress conditions. (Garcia *et al*. 2000and Vacher.1998). Accumulation of dry matter is directly related to their vigorous plant height, LAI and number of branches $plant^{-1}$. Higher dry matter accumulation at all the stages were recorded under non-stressed treatments of drip and surface $T_2$ and $T_{10}$ (1.0 $E_{pan}$ throughout cropping period and 1.0 IW/CPE). It might be due to taller plants, higher number of branches and LAI under adequate moisture availability which in turn contributed for higher dry matter accumulation as the result of proper cell turgidity and opened leaves which ultimately increased the photosynthetic activity of plants and led to higher dry accumulation under the treatment. Significantly higher dry matter accumulation due to increasing irrigation level was supported by Gonzalez *et al*. (2009) in quinoa and Singh and Singh (2014) in mustard.

Yield attributes like number of panicle plant$^{-1,}$ length of panicle and 1000-seed weight were higher in crop irrigated at1.0 E throughout cropping period ($T_2$) followed by irrigation with 1.0 E at vegetative, 0.5 E at flowering and 1.0 E at grain filling stages (Geren and Geren 2015). Better vegetative growth was ultimately associatedwith higher yield attributing characters due to increased absorption of mineral nutrients under adequate available soil moisture (Yazar*et al*., 2015 and Singh and Singh. 2014).
Grain and stalk yield of quinoa were significantly influenced by different irrigation scheduling (Table 2). Higher grain and stalk yields (2911.5 and 3426.9 kg ha$^{-1}$) were recorded under irrigation given at 1.0 E throughout cropping period ($T_2$) which might be due to better translocation of photosynthates from source to sink as the result of moisture availability led to higher yields. Higher grain yield of quinoa with optimum irrigation schedule was supported by Geerts*et al.* (2009 a), Walter *et al* (2016) and Geren and Geren (2015). Irrigation of 1.0 E at vegetative, 0.5 E at flowering and 1.0 E at grain filling ($T_8$) obtained next higher grain and stalk yield (2481.5 and 2998.0 kg ha$^{-1}$) and was found at par with treatment receiving 0.5 E at vegetative and 1.0 E both at flowering and grain filling stage ($T_3$). It might be due to no water stress during grain filling stage (72 to 105 DAS) and mild stress at flowering stage in these treatment ($T_8$) and mild stress at vegetative stage ($T_3$) (60-72 DAS).An increment of 10.7 and 29.0 % in grain yield was observed in surface methods (1.0 IW: CPE through surface method of irrigation ($T_{10}$) and 0.5 IW: CPE ratio ($T_9$) respectively. The highest stalk yield of quinoa (3426.9 kg ha$^{-1}$) was obtained with 1.0 E throughout the cropping period. This could be attributed to better vegetative growth, optimum plant stand, more dry matter production and biological yield under favoured soil moisture availability especially at grain filling stages of the crop, as compared to less frequent irrigation scheduling treatments ($T_1$ and $T_9$). The harvest index in drip irrigation at 1.0 E throughout the cropping period was higher (45.9%). The range of harvest index was higher among the treatments but was found insignificant. Lower harvest index was observed in continuous stress (0.5 IW: CPE) imposed in surface method of irrigation in ($T_9$) (38.5 %).

Table 1. Influence of irrigation treatments on growth characters of quinoa at harvest

| | Treatments | Plant height (cm) | Number of branches plant$^{-1}$ | Leaf area index | Dry matter accumulation (g m$^{-2}$) |
|---|---|---|---|---|---|
| $T_1$ | 0.5 E throughout cropping period | 120.7 | 11.2 | 1.3 | 597.3 |
| $T_2$ | 1.0 E throughout cropping period | 133.0 | 16.0 | 1.7 | 982.8 |
| $T_3$ | Irrigation with 0.5 E at vegetative and 1.0 E at both flowering and at grain filling stage | 134.3 | 15.0 | 1.4 | 781.8 |
| $T_4$ | Irrigation with 0.5 E at vegetative, 1.0 E at flowering and 0.5 E at grain filling stage | 135.3 | 13.4 | 1.3 | 763.7 |
| $T_5$ | Irrigation with 0.5 E at vegetative, 0.5 at flowering and 1.0 at grain filling stage | 128.3 | 13.8 | 1.3 | 740.3 |
| $T_6$ | Irrigation with 1.0 E at vegetative, 0.50 E at flowering and 0.5 E at grain filling stages | 132.8 | 9.4 | 1.3 | 701 |
| $T_7$ | Irrigation with 1.0 E at vegetative, 1.0 E at flowering and 0.5 at grain filling stages | 123.7 | 14.8 | 1.4 | 709.5 |
| $T_8$ | Irrigation with 1.0 E at vegetative, 0.5 E at flowering and 1.0 E at grain filling stages | 130.8 | 16.1 | 1.5 | 875.8 |
| $T_9$ | Irrigation with 0.5 IW: CPE throughout crop growth by flatbed surface method | 115.9 | 17.8 | 1.2 | 733.5 |
| $T_{10}$ | Irrigation with 1.0 IW: CPE throughout crop growth by flatbed surface method | 118.3 | 20.3 | 1.2 | 900.1 |
| | SEm ± | 4.05 | 1.18 | 0.1 | 47.4 |
| | CD (P=0.05) | 12.1 | 3.5 | 0.3 | 141 |

Table 2. Influence of irrigation treatments on yield attributes and yield of quinoa

| | Treatments | Number of panicles plant$^{-1}$ | Main panicle length (cm) | Test weight (g) | Grain yield (kg ha$^{-1}$) | Stalk yield (kg ha$^{-1}$) | Harvest index (%) |
|---|---|---|---|---|---|---|---|
| $T_1$ | 0.5 E throughout cropping period | 5.3 | 32.5 | 2.1 | 1736.4 | 2465.4 | 41.4 |
| $T_2$ | 1.0 E throughout cropping period | 8.1 | 35.8 | 2.4 | 2911.5 | 3426.9 | 45.9 |
| $T_3$ | Irrigation with 0.5 E at vegetative and 1.0 E at both flowering and at grain filling stage | 6.1 | 35.3 | 2.3 | 2332.0 | 2892.3 | 44.6 |
| $T_4$ | Irrigation with 0.5 E at vegetative, 1.0 E at flowering and 0.5 E at grain filling stage | 5.3 | 34.6 | 2.0 | 1823.0 | 2397.6 | 43.2 |
| $T_5$ | Irrigation with 0.5 E at vegetative, 0.5 at flowering and 1.0 at grain filling stage | 5.7 | 32.7 | 2.1 | 1961.9 | 2513.3 | 44.8 |
| $T_6$ | Irrigation with 1.0 E at vegetative, 0.50 E at flowering and 0.5 E at grain filling stages | 4.7 | 33.5 | 2.0 | 1868.5 | 2641 | 41.5 |
| $T_7$ | Irrigation with 1.0 E at vegetative, 1.0 E at flowering and 0.5 at grain filling stages | 5.1 | 32.3 | 2.2 | 1884.8 | 2577.1 | 42.2 |
| $T_8$ | Irrigation with 1.0 E at vegetative, 0.5 E at flowering and 1.0 E at grain filling stages | 5.3 | 36.2 | 2.2 | 2481.5 | 2998.0 | 45.3 |
| $T_9$ | Irrigation with 0.5 IW: CPE throughout crop growth by flatbed surface method | 6.7 | 30.6 | 2.3 | 1555.3 | 2493.4 | 38.5 |
| $T_{10}$ | Irrigation with 1.0 IW: CPE throughout crop growth by flatbed surface method | 8.4 | 33.4 | 2.0 | 2088.6 | 2952.1 | 41.4 |
| | SEm ± | 0.4 | 1.25 | 0.1 | 114.6 | 145.8 | 2.4 |
| | CD (P=0.05) | 1.2 | 3.7 | NS | 340.4 | 433.0 | 7.2 |

## CONCLUSIONS

Drip irrigation scheduled at 1.0 E throughout cropping period ($T_2$) recorded higher growth, yield attributes and yield compared to other surface and drip irrigation treatments. Our results suggestunder deficit water supply, drip irrigation with 0.5 E at vegetative and 1.0 E at both flowering and at grain filling stage ($T_3$) and drip irrigations at 1.0 E at vegetative, 0.5 E at flowering and 1.0 E at grain filling stages ($T_8$) can be recommended. Deficit irrigation should be avoided at grain filling stage in order to obtain higher growth, yield attributes and yield.With the application of equal amount of irrigation water to drip and surface irrigation treatments, drip irrigated treatments recorded higher values of growth, yield attributes and yield. In the scenario of adequate water supply, scheduling of surface method of irrigation at 1.0 IW: CPE ratio ($T_{10}$) can be recommended for higher growth, yield attributes and yield.

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