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Research Communication

Effect of land configuration and irrigation scheduling on productivity and water use of quinoa (*Chenopodium quinoa*) under south-eastern ecologies of Rajasthan

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) season of 2019–20, at Agricultural Research Station, Agriculture University, Ummedganj, Kota, Rajasthan, to evaluate the land configuration and irrigation scheduling on yield and water use (water use efficiency and water productivity) of 'White Type' quinoa [*Chenopodium quinoa* C.L. willdenow (Willd.)]. In main plot, 9 treatment combinations of land configuration techniques (flat bed, ridge and furrow and broad bed and furrow technique) were replicated 4 times, with 3 irrigation scheduling [1 irrigation at 20–25 days after sowing (DAS), 2 irrigation at 20–25 and 55–60 DAS and 3 irrigation at 20–25, 55–60 and 90–95 DAS] in subplot. Amongst the land-configuration techniques, maximum yields, *viz.* grain, stover and biological yield, obtained under broad bed and furrow techniques, were significantly higher over ridge and furrow and flat bed techniques. Broad bed and furrow technique significantly increased the water-use efficiency (23.40 kg/ha-mm) and water productivity (₹106.26/m^3) over rest of the land-configuration techniques. It also recorded the maximum moisture extracted at lower layers, *i.e* 30–60 and 60–90 cm depth, but flat-bed technique extracted maximum moisture in upper layer of soil, *i.e.* 0–30 cm. Application of 3 irrigation level resulted in significantly highest yields, *viz.* grain, stover and biological yield, compared to rest of irrigation scheduling. With 1 irrigation level, the maximum water-consumption efficiency (26.77 kg/ha-mm) and water productivity (₹112.70/m^3) were significantly lower than with higher levels of irrigation. The maximum moisture extracted at 0–30 cm depth was recorded at 3 irrigation level (20–25, 55–60 and 90–95 DAS), and the maximum moisture extracted in lower layers of soil (30–60 and 60–90 cm) was recorded at 1 irrigation level (20–25 DAS). In terms of grain yield, biological yield, water-use efficiency and water productivity interactions between land layout strategies and irrigation schedule were also found significant.

Key words: Irrigation scheduling, Land configuration, Moisture extraction pattern, Quinoa, Water-use efficiency, Water productivity, Yield,

In World, quinoa [*Chenopodium quinoa* C.L. Willdenow (Willd.)] is cultivated in an area of 184,585 ha, with an average production of 161,415 tonnes (FAO, 2019), while in India, it is cultivated in an area of 440 ha with an average production of 1,053 tonnes (Srinivasa, 2015). Quinoa is a dicotyledonous annual plant of Amaranthaceae family. It is a natural food resource of high nutritive value, which is increasingly being recognized as significant in food security for present and future generations. Given its importance, the Food and Agriculture Organization (FAO) has designated quinoa as the most important crop for ensuring food security in the 21st century. The year 2013 has been designated as the International Year of Quinoa by the United Nations. The sustainable cultivation of neglected crops can assist in meeting the issues of the modern world by tapping on the accumulated expertize of our ancestors and small-household farmers, who are today the largest crop producers (FAO, United Nations, 2013). The crop of quinoa has the potential to survive in the events of droughts, cold, saline conditions and can be easily cultivated in low rainfall-areas. It is an annual broad-leaf, fast-growing plant, 1–2 m tall with deep penetrating roots (up to 150 cm). It is a winter (*rabi*) season crop and grown well under soils having *p*H value between 6.0 and 8.5 and it matures in 95 to 120 days. It is considered to be a super food and mother grain owing to abundance of nutrients with full of carbohydrates, fat, protein, vitamin, fibre, anti-oxidants and other minerals. The raw (uncooked)

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quinoa contains about 13% water, 64% carbohydrates, 16% protein and 6% fat. It is a rich source of calcium, magnesium, phosphate, potassium, iron, manganese and omega-3-fatty acid. It can be consumed in the form of grains, flakes, pasta, breads, biscuits, beverages and meals etc. The seed of quinoa used in preparing various kinds of dishes, soups and chapattis. The sprouted quinoa can be used as salads and sandwiches added to cookies and muffin recipes. Quinoa starch having small grains and high viscosity, it can be exploited for various industrial cut crossing rates (Bhargava *et al*., 2006). From nutritional point of view, quinoa grains contain a relatively higher amount of fats, proteins, phosphorus, potassium, calcium, magnesium, iron, copper, zinc, and Vitamin-B than other cereals (Jancurova *et al.,* 2009). Land-configuration methods decide the effectiveness of the crop-management practices regarding efficiency of nutrients, irrigation and weed management. The major land-configuration practices include raised beds, ridge and furrow, broad bed and furrow (Deshmukh *et al*., 2016). Land management system plays an important role in minimizing soil erosion and improving water use efficiency of field crops. Easy and uniform germination as well as growth and development of plant are provided by manipulation of sowing method (Chirome *et al.,* 2008). In broad bed and furrow technique, field is divided into narrow strips broad beds separated by furrows. The seed is sown on the broad bed surface. When it rains or when it is irrigated, the water collects in the furrow, and lateral water movement meets the crop's water needs. When there is too much rain or irrigation water, the water flows through the furrows, preventing water stagnation. Broad bed and furrow and ridge and furrow land configuration techniques can help overcome soil-related challenges in sodic soil by allowing for easy and uniform germination as well as good plant growth and development (Ramesh and Rathika, 2009). The continuous increase in India's population and alternate uses of finite water resources for domestic, industrial, environmental, recreation besides agriculture forced optimization of water resources and selection of efficient crops in agriculture.

Under water-scarce condition, farmers experiment with cropping pattern changes (shifting towards efficient crops) and adjustment in irrigation scheduling. Quinoa is one such drought-tolerant crop that suits in cropping-pattern and has specific morphological characteristics such as extensive root-system and hygroscopic papillae on the leaf cuticle (Jensen *et al*., 2000). In quinoa crop, the growth and early grain-filling stages are the critical stages, water is required on these stages for its potential productivity. Quinoa seed yields respond positively to irrigation. The amount of consumed water was 100–250 mm in case of complete irrigation, while 30–125 mm in deficit irrigation reported in a study, carried out in Bolivia (Geerts *et al*., 2008). Riccardi *et al*., (2014) reported threshold level for a positive response to irrigation is 55% of ETc for quinoa. Deficit irrigation (25% of full irrigation) caused a significant increase in water productivity of quinoa. In agriculture, water productivity is a useful indicator for quantifying the impact of irrigation-scheduling decisions with regard to water management. This experiment, therefore, investigated the consequences of sowing in different land configuration techniques and application of different irrigation amount on yield, water-use efficiency, water productivity and moisture-extraction pattern.

The study was conducted during the winter (*rabi*) season (November to March) 2019–20 at Agricultural Research Station, Agriculture University, Ummedganj, Kota, Rajasthan (25°13'N, 75° 25' E, 258 m above mean sea-level). The soil was clay loam in texture, slightly alkaline in reaction, medium in available nitrogen and phosphorus, high in available potassium and low in organic carbon. The region falls under the V^{th} Agro Climatic Zone of Rajasthan, i.e. Humid South-Eastern Plain Zone. Climate of Kota region, the wet season is oppressive and mostly cloudy, the dry season is mostly clear, and classified as hot round the year. The rainfall ranges during experimentation from 650 mm to 1,000 mm, most of which (80–85%) is received through south-west monsoon during the last week of June to the first week of September, whereas winter showers occur occasionally. The mean annual maximum and minimum temperatures are 40.16°C and 18.5°C, respectively. The summer months are hot and May is the hottest month having a maximum temperature up to 43.52°C. Winter month, experienced mild cold with an average temperature from 8.74-16.56°C. January is the coldest month, as temperature goes down up to 4°C. Quinoa variety 'White Type' was used as test crop in the study.

The experiment was conducted in a split-plot design with 4 replication, consisted of 9 treatment combinations of 3 land-configuration techniques (flat bed, ridge and furrow and broad bed and furrow technique) in main plot and 3 irrigation scheduling [1 irrigation at 20–25 days after sowing (DAS), 2 irrigations at 20–25 and 55–60 DAS and 3 irrigations at 20–25, 55–60 and 90–95 DAS] in subplot. Quinoa seeds were sown @ 8 kg/ha on 17 November 2019 and gross plot size was 5.7 m × 3.8 m. Recommended dose of nitrogen, phosphorus and potassium 120 : 75 : 75 N, P_2O_5 and K_2O kg/ha, respectively, was applied to quinoa through urea, single superphosphate and muriate of potash, respectively. Fertilizers were applied as nitrogen in 3 split (half, one-fourth and one-fourth) doses and entire phosphorus and potassium applied basal through band placement. Nitrogen fertilizer was applied in 3 split doses: basal, after the first irrigation and after the second irrigation. Grain yield obtained from each plot including the tagged plants was sun-dried and recorded treatment-wise and expressed as kg/ha. Stover yield was calculated by subtracting grain yield from respective biological yield of each plot and expressed as kg/ha. The unthreshed produce from net plot area after thorough sun-drying was weighed for recording the biological yield and expressed as kg/ha. Crop water-use efficiency (CWUE) is the ratio between grain yield to the amount of water used in evapo-transpiration by the crop. It was worked out by using the following formula and expressed as kg/ha-mm.

$$\text{CWUE} = \frac{\text{Yield (kg/ha)}}{\text{Evapotranspiration (mm)}}$$

Water productivity is a ratio between net returns and total water applied in the field. Water productivity (₹m^3) was computed as:

$$\text{Water produtivity} = \frac{\text{Net returns (₹/ha)}}{\text{Total water applied (m}^3\text{)}}$$

Soil-moisture extraction pattern from the three layers, viz. 0–30, 30–60 and 60–90 cm depths, was calculated by using the formula given below.

$$Moisture\ extration\ from\ i^{th}\ layer = \frac{Mai - Mbi}{100} \times ASi \times Di$$

Where, Mai, moisture percentage after irrigation in ith layer; Mbi, moisture percentage before irrigation in ith layer; ASi, Apparent specific gravity of ith layer (Mg/m^3); Di, Depth of ith layer (cm)

Soil-moisture determination was done from the soil samples taken from 0–90 cm soil profile at 0–30, 30–60 and 60–90 cm depth intervals with the help of screw auger, at the time of sowing, 1 day before each irrigation, 2-3 days after each irrigation and finally at the time of harvesting. These samples were collected in aluminium moisture boxes and their fresh weight was recorded. The samples were dried in electric oven at 105 ± 5°C for 48 hours. The moisture percentage was expressed on oven dry-weight basis. The moisture extraction (per cent) from each layer was calculated. Soil-moisture extraction from each layer was expressed in terms of per cent of total moisture extraction from 90 cm depth to have an understanding of soil-moisture extraction pattern of the crop from different layers of root zone.

Maximum and significantly higher yields, viz. grain (2,593 kg/ha), stover (2,891 kg/ha) and biological yield (5,484 kg/ha), of quinoa under broad bed and furrow technique were observed, registering 42.00, 41.65 and 41.82% higher than ridge and furrow and flat bed land-configuration techniques respectively. The final yield of quinoa not only depends on yield-attributing parameters but also influenced by growth parameters. This might be owing to maximum exposure to sunlight by quinoa plant which enhanced the photosynthetic activity. Broad bed and furrow technique also improves the plant vigour, resulting in higher number and weight of panicles, ultimately enhanced the yields. Ali *et al.* (2020) observed maximum grain yield (1.8 t/ha) of quinoa under bed system planting, might be due to less logging and shattering losses under this planting system. The results of present investigation are in line with those of Ramesh *et al.* (2020) in quinoa. Maximum water-use efficiency (23.40 kg/ha-mm) and water productivity (₹106.26/m^3) was recorded under broad bed and furrow technique followed by ridge and furrow and flat bed techniques during experimentation. The water-use efficiency and water productivity were increased with the increment in conserve soil moisture and maximum grain yield. This might be owing to higher grain yield obtain under broad bed and furrow with same amount of water used in other treatments. Our results support the findings of Sodavadiya *et al.* (2017) in Indian bean and Halli and Angadi (2017) in cowpea. Among land-configuration techniques, at 0–30 cm soil depth, the highest soil moisture was extracted under flat-bed technique, this might be due to less developed rooting zone of crop and less moisture conservation under this technique. At deeper layer, *viz.* 30–60 and 60–90 cm soil depth, the highest soil moisture extracted under broad bed and furrow technique, owing to well-developed rooting zone of crop and higher moisture conservation throughout cropping period. These results are in close conformity with the findings of Meena (2015) in maize.

Amongst the irrigation scheduling, maximum grain (2,592 kg/ha), stover (2,894 kg/ha) and biological (5,486 kg/ha) yields were recorded with 3 irrigation level at 20–25, 55–60 and 90–95 DAS and significantly increased the yield 36.78, 36.77 and 36.77% owing to higher crop growth and yield-attributing characters. Grain and stover yields of quinoa depend upon source-sink relationship (sink components, *viz.* panicles/plant, weight of panicle and 1,000-grain weight, and source components, *viz.* branches/plant, dry-matter accumulation and leaf area) Yazar *et al.*, (2017). Our results confirm the findings of Geren and Geren (2015), Walter *et al.* (2016), Algosaibi *et al.* (2017) and Salim *et al.* (2019) in quinoa. Different irrigation scheduling treatments affected the water-use efficiency and water productivity and these were observed maximum with 1 irrigation level at 20–25 DAS, (26.77 kg/ha-mm and ₹112.70/m^3, respectively). Decreased water-use efficiency and water productivity with 3 irrigation level was based on the fact that the proportionate increase in grain yield less than increase in the amount of water applied. The reduced evapo-transpiration enhanced water-use efficiency. Playan and Mateos (2006) reported higher water productivity for maize with deficit irrigation than with

Table 1. Effect of land-configuration techniques and irrigation scheduling on yields, water-use efficiency (WUE) and water productivity of quino

Treatment	Grain yield (kg/ha)	Stover yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)	WUE (kg/ha-mm)	Water productivity (₹m^3)	Moisture-extraction pattern (%)		
							0–30 cm	30–60 cm	60–90 cm
Land-configuration techniques									
Flat bed technique	1826	2041	3867	47.23	10.92	44.15	57.05	28.00	14.95
Ridge and furrow technique	2322	2597	4919	47.20	20.85	91.42	52.22	32.00	15.78
Broad bed and furrow technique	2593	2891	5484	47.27	23.40	106.26	48.26	35.15	16.59
Sem±	64	49	110	0.46	0.58	3.49	1.13	0.72	0.37
CD (P=0.05)	223	171	379	NS	2.00	12.08	3.92	2.49	1.29
CV (%)	9.94	6.82	7.98	3.34	10.86	15.01	7.48	7.86	8.16
Irrigation-scheduling									
One irrigation level at 20–25 DAS	1895	2116	4011	47.24	26.77	112.70	48.93	34.47	16.60
Two irrigation levels at 20–25 and 55–60 DAS	2253	2521	4774	47.20	16.00	71.49	52.13	31.88	15.99
Three irrigation levels at 20–25, 55–60 and 90–95 DAS	2592	2894	5486	47.26	12.40	57.64	56.48	28.80	14.72
Sem±	53	72	117	0.57	0.51	3.09	1.01	0.66	0.44
CD (P=0.05)	158	213	346	NS	1.51	9.17	3.01	1.95	1.32
CV (%)	8.22	9.91	8.49	4.19	9.56	13.26	6.68	7.17	9.74

full irrigation. Yazar *et al.* (2017) and Salim *et al.* (2019) reported similar findings in quinoa crop. The moisture extracted by quinoa crop was 48.93, 34.47 and 16.60% at 0–30, 30–60 and 60–90 cm soil depth, respectively, with 1 irrigation schedule. This might be due to upper portion of root zone is kept dry, root system well-developed, most of water used consumptively by the plant will be removed from the soil near the surface. Salim *et al.* (2019) reported that, increasing of PEF (pan factor) coefficient from 0.8, 1.0, 1.2 and 1.4 increased the moisture-extraction pattern by the quinoa plant corresponding to depth of 0.0–0.15 m, 35.50, 39.75, 41.25 and 50% and depth 0.15–0.30 m, 27.00, 29.75, 29.75 and 33.75% respectively. These findings are agreed with the results of quinoa in Maize Meena (2015).

Thus, it can be concluded that the growing of quinoa in broadbed and furrow technique is most efficient preposition, when judged in terms of productivity, water-use efficiency and water productivity. Among the irrigation scheduling, maximum and significantly higher productivity of quinoa was recorded with 3 irrigation level, but significantly higher water-use efficiency water productivity were recorded with 1 irrigation level.

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