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Growth and Root Yield Response of Radish, *Raphanus Satisvus* L. to Different Irrigation Regimes

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Abstract:

To assess the growth and root yield response of radish to various irrigation regimes, an experiment was conducted during 2014-15. The radish crop was irrigated 2, 3, 4, 5 and 6 times; using first irrigation 7 days after sowing (DAS) and subsequent irrigations at 15, 20, 15, 10 and 7 days interval, respectively. The results revealed that leaves plant^{-1}, leaves length, root length, root diameter, single root

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weight, root + leaves weight, root yield plot^{-1} and root yield ha^{-1} were significantly influenced by irrigation frequency (P<0.05). The radish crop given six irrigations (first irrigation 7 DAS and subsequent at 7 days interval) resulted in maximum values for almost all the traits studied with 6.60 leaves plant^{-1}, 39.35 cm leaves length, 43.28 cm root length, 6.18 cm root diameter, 680.17 g single root weight, 769.52 g root + leaves weight, 62.13 kg root yield plot^{-1} and 39449.67 kg root yield ha^{-1}. The crop receiving five irrigations (first irrigation 7 DAS and subsequent at 10 days interval) produced 6.40 leaves plant^{-1}, 39.07 cm leaves length, 42.48 cm root length, 6.10 cm root diameter, 671.21 g single root weight, 760.28 g root + leaves weight, 60.26 kg root yield plot^{-1} and 38258.94 kg root yield ha^{-1}. The crop irrigated given 4, 3 or 2 irrigations, regardless their application schedule, showed a simultaneous decline in growth and yield traits. It was concluded that there was linear effect (P<0.05) of irrigation frequencies on the growth and root yield of radish and the radish crop given six irrigations throughout the radish growing period (first irrigation 7 DAS and subsequent at 7 days interval) or 5 irrigations (first irrigation 7 DAS and subsequent at 10 days interval) produced almost similar results because of insignificant (P>0.05) difference in growth and yield traits between 6 and 5 irrigations. Hence, 5 irrigations (first irrigation 7 DAS and subsequent at 10 days interval) would be an optimum level for achieving economical yields in radish.

Key words: Radish, irrigation regimes, growth, root yield

INTRODUCTION

Radish, *Raphanus sativus* a member of Brassicaceae family is a vegetable liked by rich and poor alike for its taste and being nutritious; as its roots are eaten raw, cooked and used in a diversified forms and its numerous varieties varying in size, color and duration of required cultivation time (Cecílio Filho and May, 2002). Radishes have a very short vegetative cycle, which provides for a rapid return of capital. Garden radishes

can be grown wherever there is sun and moist, fertile soil. Early varieties usually grow best in the cool days of early spring, but some later-maturing varieties can be planted for summer use.

Irregular and inadequate water supply reduces growth, yield, and quality of the crop produce. The plant response to irrigation greatly varied due to amount and the stage of the crop being irrigated; however crop varieties respond differently to irrigation regimes (Tan, 1990; Bokhtiar *et al*., 2005). With an extensive, deep root system, the plants hold up better during dry spells; when watering is done, soil may be soaked to a depth of at least 15-20 cm (6-8 inches). Radishes like moisture, but over-watering is harmful; over watering is not only a waste of water, but soggy soil prevents the roots from getting the air they need (Isaac *et al.,* 2009). If plants look a little wilted on a hot, summer afternoon that may be considered normal. A thorough soaking every four to five days on light, sandy soils and every seven to ten days on heavy soils is a good general guide for irrigating if no enough rains. Early watering in the day to cut down on evaporation losses and also to give your plants plenty of time to dry out is suggestible (Wan and Kang, 2005).

Scarcity of water resources is a worldwide issue due to their increasing demand, as a result of world's growing population and social-economic development (Zapata and Segura, 1995). The pressure on water resources is expected to increase as the requirements for food production and industrial needs go up in parallel with rapidly growing population (Webber *et al*., 2006). Water resources are limited worldwide and there is an urgent need to identify and adopt efficient irrigation management strategies since irrigation of agricultural lands accounts for over 85% of worldwide water usage (Zegbee *et al*., 2006). Richards *et al*. (2002) indicate that crop water use efficiency can be increased either by improving the irrigation scheduling and the crops may be saved from

water stress at its critical growth stages. At leaf level, the increase in transpiration efficiency may result both from an increase in photosynthetic rate and a decrease in stomatal conductance (Wayne, 2002). There is varying agreement over the effect of irrigation frequency on crop water use. The high irrigation frequency could reduce evaporation and deep percolation, and establish a favorable soil moisture and oxygen condition in the root zone throughout the crop period. For minimizing deep percolation and to maintain nearly constant high soil water potential, high frequency irrigations is needed. An excessively high irrigation frequency could cause the soil surface to remain wet and the first stage of evaporation to persist most of the time, and resulted in more water loss (Richards *et al.* (2002). Bokhtiar *et al.* (2005) reported that under water stress the splitting in radish is observed. Wan and Kang (2005) reported that radish needs higher amounts of water, but the frequency of irrigation may be determined according to the type of the soil and moisture content. Wan and Kang (2005) suggested that radish may be irrigated after every 3 days for achieving higher yields in the area of study. Rolbiecki and Rolbiecki (2009) suggested that irrigation frequency may be adjusted according to the soil moisture availability. Liang *et al.* (2014) suggested that optimal irrigation frequency improves the crop productivity but better to irrigate crop with fertilizer through fertigation technique. Considering the significance of irrigation water scheduling and its effects on the growth and productivity of radishes, the present experiment was conducted to examine the growth and root yield response of radish to different irrigation regimes.

MATERIALS AND METHODS

The present experiment was laid out in a RCB Design replicated three times at Horticulture Orchard, Sindh

Agriculture University Tandojam using plot size of 3.15m x 5.0m (15.75m^2). After selection of experimental site, the soil was analyzed for various physico-chemical characteristics and soil texture was determined as well. The composite soil samples were collected up zCdto 30 cm soil depth and sent to the laboratory for analysis. The soil analysis report indicates silty clay loam texture of the experimental site with 17.10 percent sand, 47.12 percent silt and 35.78 percent clay; while the soil pH was 8.05. After soil analysis, the plowing was done using disc plow to remove the hard pan and disc harrow was operated. When the land was ploughed up, the clods were crushed, and leveling was done to eradicate the weeds and to make the soil surface leveled for uniform distribution of irrigation water. After soaking dose, when the soil came in condition, cultivator was operated and ridges were developed with prepared keeping 45 cm distance between rows.

The seed of variety "Mino early long white" was obtained from the local market of Hyderabad. The seeds were dibbled on both sides of the ridges on 16th October, 2014 keeping plant to plant distance of 10 cm. The irrigation was applied as per the treatment plan. In case of fertilizers, 100 kg ha^{-1} N in the form of DAP and urea, while 80 kg P ha^{-1} in the form of DAP and SSP were applied. All P along with half N was applied at the time of preparation of ridges by mixing in the soil; while remaining N was divided into two equal splits were applied at flowering initiation and fruit development stages. The crop was kept clean, and a periodical weeds removal practice was carried out. All the cultural practices were performed uniformly in all the plots, keeping in view the crop requirement. The observations were recorded on the basis of randomly selected five plants in each plot on the following parameters:

The observations were recorded as below:
Number of leaves plant^{-1}, Length of leaves (cm), Root length (cm),Root diameter (cm), Single root weight (g) Weight of leaves + root (g), Root yield plot^{-1} (kg), Root yield (kg ha^{-1})

Statistical Analysis

To analyze the treatment variation, LSD (Least Significant Difference) test was applied to observe the statistical difference within treatments according to the method developed by Steel and Torrie (1980).

RESULTS

Number of leaves plant^{-1}

The analysis of variance described significant ($P<0.05$) effect of various irrigation regimes on the number of leaves plant^{-1} of radish. The results (Table-1) indicated that the number of leaves plant^{-1} was maximum (6.60) when the crop was irrigated six times throughout the radish growing season (first irrigation 7 DAS and subsequent at 7 days interval), followed by 6.40 and 5.40 leaves plant^{-1} recorded in radish crop given 5 irrigations (first irrigation 7 DAS and subsequent at 10 days interval) and 4 irrigations (first irrigation 7 DAS and subsequent at 15 days interval), respectively. With further decrease in the number of irrigations, the plant growth was adversely affected and radish crop that received 3 irrigations during the entire cropping season (first irrigation 7 DAS and subsequent at 20 days interval) produced 4.80 leaves plant^{-1}. However, the minimum number of leaves (4.80 plant^{-1}) was observed in plots given 2 irrigations (first irrigation 7 DAS and the second 15 days later). There was a linear increase in the number of leaves plant^{-1} of radish with each increment in the number of irrigations. This suggested that the irrigation is the key factor to influence the plant growth.

Length of leaves (cm)

The mean squares suggested significant (P<0.05) effect of various irrigation regimes on the length of leaves of radish. The results (Table 1) depicted that the leaves length was maximum (39.35 cm) when the radish crop was given six irrigations (first irrigation 7 DAS and subsequent at 7 days interval), closely followed by the radish crop given 5 irrigations (first irrigation 7 DAS and subsequent at 10 days interval) with 37.07 cm length of leaves. The leaves length followed a declining trend with reducing the number of irrigations and the crop receiving 4 irrigations (first irrigation 7 DAS and subsequent at 15 days interval) and 3 irrigations during the entire cropping season (first irrigation 7 DAS and subsequent at 20 days interval) produced 34.47 cm and 31.66 cm leaves length, respectively. However, the minimum leaves length (29.82 cm) was recorded in radish crop that received only 2 irrigations (first irrigation 7 DAS and the second 15 days later). The leaves length in radish increased linearly with increasing the number of irrigations. However, the differences in the leaves length were non-significant (P>0.05) between 6 and 5 irrigations. Hence, 5 irrigations (first irrigation 7 DAS and subsequent at 10 days interval) would be an optimum level for leaves length trait in radish.

Root length (cm)

The data indicated that root length of radish was significantly (P<0.50) affected by various irrigation regimes. It is obvious from the results that root length was highest (43.28 cm) when the radish crop was supplied with six irrigations (first irrigation 7 DAS and subsequent at 7 days interval), closely followed by the radish crop supplied with 5 irrigations (first irrigation 7 DAS and subsequent at 10 days interval) with 42.48 cm root length. The root length followed a decreasing trend with lower irrigation regimes and the crop receiving 4

irrigations (first irrigation 7 DAS and subsequent at 15 days interval) and 3 irrigations (first irrigation 7 DAS and subsequent at 20 days interval) resulted in 36.52 cm and 34.59 cm root length, respectively. However, the lowest root length (29.85 cm) was recorded in crop receiving only 2 irrigations (first irrigation 7 DAS and the second 15 days later). There was a successive improvement in root length of radish with increasing the irrigation frequency. However, the differences in the root length were non-significant ($P>0.05$) between 6 and 5 irrigations. Hence, 5 irrigations (first irrigation 7 DAS and subsequent at 10 days interval) would be an optimum irrigation frequency for this trait.

Root diameter (cm)

The results demonstrated significant influence ($P<0.50$) of various irrigation regimes on the root diameter of radish. The root diameter was maximum (6.18 cm) in crop irrigated six times during entire cropping season (first irrigation 7 DAS and subsequent at 7 days interval), closely followed by the crop supplied with 5 irrigations (first irrigation 7 DAS and subsequent at 10 days interval) with 6.10 cm root diameter. The root diameter decreased considerably with lowering the irrigation frequency and the crop irrigated 4 times (first irrigation 7 DAS and subsequent at 15 days interval) and 3 times (first irrigation 7 DAS and subsequent at 20 days interval) resulted in 5.22 cm and 4.94 cm root diameter, respectively. However, the minimum root diameter (3.95 cm) was noted in crop receiving only 2 irrigations (first irrigation 7 DAS and the second 15 days later). There was a consecutive increase in the root diameter of radish with increasing the irrigation frequency. However, similarity ($P>0.05$) in the root diameter was observed with 6 or 5 irrigations were applied. Hence, the optimum irrigation frequency for root diameter was

5 irrigations (first irrigation 7 DAS and subsequent at 10 days interval) during entire growing season.

Table 1. Number of leave splant^{-1}, length of leaves, root length and root diameter of carrot as affected by different irrigation regimes

Sowing patterns	Number of leave splant^{-1}	Length of leaves (cm)	Root length (cm)	Root diameter (cm)
T1=Two Irrigations (1st irrigation 7 DAS and subsequent irrigation after 15 days later)	4.20 e	29.82 d	29.85 c	3.95 d
T2=Three Irrigations (1st irrigation 7 DAS and subsequent irrigations at 20 days interval)	4.80 d	31.66 c	34.59 b	4.94 c
T3=Four Irrigations (1st irrigation 7 DAS and subsequent irrigations at 15 days interval)	5.40 c	34.47 b	36.52 b	5.22 b
T4=Five Irrigations (1st irrigation 7 DAS and subsequent irrigations at 10 days interval)	6.40 b	39.07 a	42.48 a	6.10 a
T5=Six Irrigations (1st irrigation 7 DAS and subsequent irrigations at 7 days interval)	6.60 a	39.35 a	43.28 a	6.18 a
S.E.±	0.0730	0.6153	0.9059	0.1170
LSD 0.05	0.1684	1.4188	2.0889	0.2698
LSD 0.01	0.2450	2.0645	3.0396	0.3936

Means followed by same letters are not significantly different at P=0.05 as suggested by LSD test.

Table 2. Mean squares corresponding to number of leave splant^{-1}, length of leaves, root length and root diameter of carrot as affected by different irrigation regimes

Source	Degrees of freedom	No. of leaves plant^{-1}	Length of leaves	Root length (cm)	Root diameter (cm)
Replications	2	0.288	4.2497	2.332	0.01261
Treatments	4	3.156**	55.2451**	94.5743**	2.53511**
Error	8	0.008	0.5679	1.2309	0.02053

Single root weight (g)

The radish crop given six irrigations (first irrigation 7 DAS and subsequent at 7 days interval) produced highest single root weight of 680.17 g, closely followed by the crop given 5 irrigations (first irrigation 7 DAS and subsequent at 10 days interval) with 671.21 g single root weight. The single root weight declined with decrease in the irrigation frequency and radish given 4 irrigations (first irrigation 7 DAS and subsequent at 15 days interval) and 3 irrigations (first irrigation 7 DAS and subsequent at 20 days interval) produced 573.83 g and 543.61 g single root weight, respectively. However, the lowest single root weight (371.21 g) was observed in crop given 2 irrigations (first irrigation 7 DAS and the second 15 days later). The single root weight of radish was simultaneously influenced with increase or decrease in the irrigation regimes. However, the single root weight did not show pronounced difference ($P>0.05$) when 6 or 5 irrigations were given. Thus, 5 irrigations (first irrigation 7 DAS and subsequent at 10 days interval) was an optimum irrigation frequency for single root weight of radish.

Weight of root + leaves (g)

The data suggested that root + leaves weight in radish was significantly affected by irrigation regimes. The radish crop given irrigation five times (first irrigation 7 DAS and subsequent at 7 days interval) resulted in a maximum weight of root + leaves (769.52 g), closely followed by 5 irrigations (first irrigation 7 DAS and subsequent at 10 days interval) with 760.28 g weight of root + leaves plant^{-1}. The root + leaves weight plant^{-1} adversely affected with reducing the irrigation frequency and crop receiving 4 irrigations (first irrigation 7 DAS and subsequent at 15 days interval) and 3 irrigations (first irrigation 7 DAS and subsequent at 20 days interval) produced 658.30 g and 625.28 g root + leaves weight, respectively.

However, the minimum root + leaves weight (416.65 g) was noted in crop given 2 irrigations (first irrigation 7 DAS and the second 15 days later). The root + leaves weight plant^{-1} showed a simultaneous decrease under decreased irrigation regimes. However, irrigation the crop more than 5 times in a season was uneconomical, because the differences in the root + leaves weight between 5 and 6 irrigations were non-significant; suggesting 5 irrigations (first irrigation 7 DAS and subsequent at 10 days interval) as an optimum irrigation frequency for root + leaves trait.

Root yield plot^{-1}

The effect of irrigation regimes on the root yield plot^{-1} of radish were significant ($P<0.05$). The root yield plot^{-1} was highest (62.13 kg) under six irrigations throughout the radish growing period (first irrigation 7 DAS and subsequent at 7 days interval), while the root yields were 60.26 kg and 46.09 kg plot^{-1} when the radish crop received 5 irrigations (first irrigation 7 DAS and subsequent at 10 days interval) and 4 irrigations (first irrigation 7 DAS and subsequent at 15 days interval), respectively. With further decrease in the number of irrigations, the root yield was severely affected in negative direction and in plots given 3 irrigations (first irrigation 7 DAS and subsequent at 20 days interval) the crop produced 38.53 kg root yield plot^{-1}. However, the lowest root yield plot^{-1} (25.69 kg) was obtained in plots given 2 irrigations (first irrigation 7 DAS and the second 15 days later). There was a linear increase in the root yield plot^{-1} of radish with each increment in the number of irrigations. This suggested that the irrigation is the major factor to increase radish root yields. However, the increase in root yield was insignificant ($P>0.05$) for the plots given 5 and 6 irrigations. So, the optimum irrigation frequency for economically maximum root yield was 5 irrigations (first irrigation 7 DAS and subsequent at 10 days interval).

Root yield (kg ha^{-1})

The results related to root yield ha^{-1} of radish variety "Mino early long white" as affected by different irrigation regimes demonstrated significant ($P<0.05$) effect on root yield. The root yield ha^{-1} was highest (39449.67 kg) when the crop was given six irrigations (first irrigation 7 DAS and subsequent at 7 days interval), followed by 5 irrigations (first irrigation 7 DAS and subsequent at 10 days interval) and 4 irrigations (first irrigation 7 DAS and subsequent at 15 days interval) with average root yields of 38258.94 kg and 29265.50 kg ha^{-1}, respectively. The root yield was badly affected when the crop received only 3 irrigations (first irrigation 7 DAS and subsequent at 20 days interval) producing root yield of 24462.43 kg ha^{-1}. However, the lowest root yield ha^{-1} (16309.50 kg) was obtained in crop given 2 irrigations (first irrigation 7 DAS and the second 15 days later). It was observed that there was a linear increase in the root yield ha^{-1} of radish with each increment in the number of irrigations. This suggested that the irrigation plays major role in achieving the higher root yields. However, the increase in root yield was insignificant ($P>0.05$) for the crops given 5 and 6 irrigations. Hence, 5 irrigations (first irrigation 7 DAS and subsequent at 10 days interval) was an optimum irrigation frequency for achieving higher root yield.

Table 3. Single root weight, weight of root + leaves, root yield plot^{-1} and root yield ha^{-1} of carrot as affected by different irrigation regimes

Sowing patterns	Single root weight (g)	Weight of root+ leaves plant^{-1} (g)	Root yield plot^{-1}(kg)	Root yield (kg ha^{-1})
T1=Two Irrigations (1st irrigation 7 DAS and subsequent irrigation after 15 days later)	371.21 c	416.65 d	25.69 e	16309.50d
T2=Three Irrigations (1st irrigation 7 DAS and	543.61 b	625.28 c	38.53 d	24462.43c

subsequent irrigations at 20 days interval)				
T3=Four Irrigations (1st irrigation 7 DAS and subsequent irrigations at 15 days interval)	573.83 b	658.30 b	46.09 c	29265.50b
T4=Five Irrigations (1st irrigation 7 DAS and subsequent irrigations at 10 days interval)	671.21 a	760.28 a	60.26 a	38258.94a
T5=Six Irrigations (1st irrigation 7 DAS and subsequent irrigations at 7 days interval)	680.17 a	769.52 a	62.13 a	39449.67a
S.E.±	20.479	12.660	0.8972	569.68
LSD 0.05	47.225	29.193	2.0691	1313.7
LSD 0.01	68.716	42.478	3.0106	1911.5

In a column, means followed by same letters are not significantly different at P=0.05 as suggested by LSD test.

Table 4. Mean squares corresponding to single root weight, weight of leaves, root length and root diameter of carrot as affected by different irrigation regimes

Source	Degrees of freedom	Weight of single root (g)	Weight of root + leaves (g)	Root yield (kg ha^{-1})
Replications	2	1248.0	507.9	635160
Treatments	4	46942.5**	61125.0**	2813008**
Error	8	629.1	240.4	486806

DISCUSSION

Effective management of irrigation water is essential for proper utilization of available water resources. The purpose of proper irrigation scheduling is to determine the exact amount of water to apply to the field and the exact timing for application. The amount of water applied is determined by using a criterion to determine irrigation need and a strategy to prescribe how much water to apply in any situation. The present experiment was conducted to examine the effect of various irrigation regimes on

the growth and root yield of radish and the crop was irrigated 2, 3, 4, 5 and 6 times (first irrigation 7 days after sowing and subsequent irrigations at 15, 20, 15, 10 and 7 days interval, respectively).

The study showed that radish crop given six irrigations throughout the radish growing period (first irrigation 7 DAS and subsequent at 7 days interval) or 5 irrigations (first irrigation 7 DAS and subsequent at 10 days interval) produced almost similar results because of insignificant ($P>0.05$) difference in growth and yield traits between 6 and 5 irrigations. Hence, 5 irrigations (first irrigation 7 DAS and subsequent at 10 days interval) would be an optimum level for achieving economical yields in radish. These results are in agreement with those of Bokhtiar et al. (2005) who reported that under water stress the splitting in radish is observed and the water scheduling may be managed in such a way that water stress may be avoided at critical periods of high temperature. Wan and Kang (2005) reported that radish needs higher amounts of water, but the frequency of irrigation may be determined according to the type of the soil and moisture content. Wan and Kang (2005) suggested that radish may be irrigated weekly for achieving higher yields in the area of study. The consumptive use of water for radish seed production was found to be 54.40 cm/ha and it required irrigation after 30 per cent moisture depletion from the soil. Isaac et al. (2009) reported that frequent application of irrigation water in conjunction with the sewage water showed significant impact on the radish growth and root yield. Rolbiecki and Rolbiecki (2009) reported that irrigation significantly increased marketable yields of lettuce and radish cultivated in loose sandy soil. Water use efficiency was higher in case of drip irrigation in comparison to micro-sprinkler irrigation. The results obtained show the usefulness of drip irrigation in vegetable growing which considerably decreased water

consumption and maintained proper moisture conditions for lettuce and radish growth and yielding. Josef (2009) found that the radish yield increased with weekly irrigation scheduling and decreasing the irrigation frequency showed adverse effects on the crop growth and root yield. Rolbiecki and Rolbiecki (2009) suggested that irrigation frequency may be adjusted according to the soil moisture availability. Liang et al. (2014) suggested that optimal irrigation frequency improves the crop productivity but better to irrigate crop with fertilizer through fertigation technique. Caser (2014) concluded that radish cultivars may respond differently to varying irrigation scheduling.

CONCLUSION

It was concluded that there was linear effect ($P<0.05$) of irrigation regimes on the growth and root yield of radish and the radish crop given six irrigations throughout the radish growing period (first irrigation 7 DAS and subsequent at 7 days interval) or 5 irrigations (first irrigation 7 DAS and subsequent at 10 days interval) produced almost similar results because of insignificant ($P>0.05$) difference in growth and yield traits between 6 and 5 irrigations. Hence, 5 irrigations (first irrigation 7 DAS and subsequent at 10 days interval) would be an optimum level for achieving economical yields in radish.

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