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Effect of irrigation intervals on growth and chemical composition of some *Curcuma* spp. plants

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Abstract. *Mohamed MA, Wahba HE, Ibrahim ME, Yousef AA. 2014. Effect of irrigation intervals on growth and chemical composition of some* Curcuma *spp. plants. Nusantara Bioscience 6: 140-145.* The Influence of irrigation intervals on the growth, yield of rhizomes and chemical composition of both *Curcuma aromatica* and *Curcuma domestica* plants was investigated. Three irrigation treatments were used in this experiment. The first treatment was irrigated every one week. The second and third treatments were irrigated every two and three weeks. The long irrigation intervals significantly reduced growth parameters and chemical composition. Growth parameters, i.e. plant height, number of leaves, width of the leaf, fresh and dry weight of rhizomes, as well as chemical composition, i.e. total carbohydrate, volatile oil and curcumin in dry rhizomes increased when the plants irrigated every week compared to irrigation treatments every two or three weeks. Also, *C. aromatica* gave the higher values of growth parameter and chemical composition compared to *C. domestica* under all irrigation treatments.

Key words: *Curcuma* plant, irrigation intervals, rhizomes, volatile oil, curcumin

INTRODUCTION

Curcuma plant belongs to the family Zingiberaceae, it is a genus of about 70 species of rhizomatous herbs, about 30 species occur in India, of which a few numbers have economic importance (Keys 1976; Chang and But 1986; Wren 1988). *C. aromatica* and *C. domestica* are a herbaceous perennial plant, which are the most valuable and important spices. The major chemical constituents consist of pale yellow to orange-yellow volatile oil (6%) composed of a number of monoterpenes and sesquiterpenes, including zingeberene, curcumene, α-and-β-turmerone and among others. The coloring principles (5%) are curcuminoids such as curcumin (Bruneton 1995). The uses of *Curcuma* in pharmacopeias and in traditional systems of medicine, treatment of ulcers, pain and inflammation due to rheumatoid arthritis (Prucksunand 1986; Masuda 1993) and of amenorrhea, dysmenorrheal, diarrhea epilepsy, pain and skin diseases (Chang and But 1986).The uses of *Curcuma* plant in folk medicine, described in the treatments of asthma, boils, bruises, coughs, dizziness, epilepsy, hemorrhages, insect bites (Chang and But 1986; Kapoor 1990 and Ghazanfar 1994).Due to increasing importance of such plant, and the data concerning the growth and chemical composition of *Curcuma* is limited under Egyptian conditions as well as *Curcuma* plant is one of the most finest and expensive in the marketing of the world. Therefore, it seemed a great importance of finding the most successful practices to enhance their growth characteristics and active ingredients.

One of the most important factors affecting plant growth and production of secondary metabolites is water supply (Randhawa et al. 1992). Also, Flevas and Medrano (2002) mentioned that moisture deficiency induces various physiological and metabolic responses like stomatal closure and decline in growth rate and photosynthesis. Water supply is an important factor affecting growth and metabolic activities in plant species. It has generally negative effect on plant growth and development. However, there are reports on the positive effect of limited water supply, as far as the biosynthesis of secondary metabolites, enzyme activities and solute accumulation is concerned (Singh-Sangwan et al. 2001). Water deficit is a limiting factor in the production of many field crops, as well as water stress causes different morphological, physiological and biochemical changes including leaf area reduction, leaf senescence and reduction in cell development (Kafi and Damghani 2001). Also, drought led to biochemical disorders and can change plant behaviors regarding the biosynthesis of primary and secondary metabolites, lipids are vital to cell functions, plasma membrane may be the primary site of drought damage and it has been shown that water deficit results in a great modifications of membrane fatty acid composition in many crops In addition, drought influences the essential oil biosynthesis (Laribi et al. 2009; Bettaieb et al. 2011; Bourgou et al. 2011).

Thus, the aim of this work was to evaluate the productivity of two species of *Curcuma* plant (*C. aromatica* and *C. domestica*) under different irrigation intervals. In recent years the effective role of water supply on the growth and production of several medicinal plants was observed by many investigators. Baher et al. (2002) showed that greater soil water stress decreased plant height, total fresh and dry weight of *Satureja hortensis*. In another research, Colom and Vazzana (2002) on *Eragrostis curvula*

plant showed that the number of stem/plant and dry weight was negatively related to water stress. Leithy et al. (2006) found that, exposing rosemary plant to water stress led to a decrease in growth parameters at different cuts, while the volatile oil percentage was improved by water stress, but the volatile oil yield decreased affected by deficit irrigation. Ahmed and Mahmoud (2010) found that frequent irrigation intervals (7 days) improved vegetative growth, i.e. plant height, stem diameter, number of leaves per plant, leaf area index and shoot dry weight of sunflower. Bettaieb et al. (2012) found that cumin plant treated with moderate water deficit (MWD) improved the number of umbels per plant as well as the number of umbellets per umble and the seed yield, in comparison to the control plant, but it decreased under severe water deficit (SWD). El-Mekawy (2013) on *Achillea santolina* L. showed that irrigation every 7 days, highly significant increased number of branches/plant, plant height, fresh and dry weight of herb/plant, fresh and dry weight of roots/plant compared to irrigation every 14 and 21 days. Silva et al. (2010) on *Aloe vera*, Al-Kayssi et al. (2011) on black cumin, Sidika et al. (2012) on purple basil, Rebey et al. (2012) and Vazin (2013) on cumin plant, Lal et al. (2013) on lemon grass found that providing the plants with suitable water amounts resulted in better growth and yield than those grown under drier conditions. Also, Hassan et al. (2013) found that deficit irrigation (60 and 80%) of the field capacity significantly reduced growth parameters and yield of oil of *Rosmarinus officinalis* L. compared to control (100% of field capacity).

The studies about the effect of irrigation on *Curcuma* plants are rare. Therefore, the aim of this study was to evaluate the productivity of two species of *Curcuma* plant (*C. aromatica* and *C. domestica*) under different irrigation intervals in Egypt.

MATERIALS AND METHODS

Plant material and experimental design

Two field experiments were conducted during the two successive seasons of 2010 and 2011 at the Experimental Farm of Faculty of Agriculture, Cairo University, Egypt to study the effect of irrigation intervals on growth and active constituents of two species of *Curcuma* plant (*C. aromatica* and *C. domestica*). There were three treatments of irrigation intervals. The first irrigated every week, the second irrigated every two weeks, while the third treatment irrigated every 3 weeks. Rhizomes of *Curcuma* plant were obtained from the Experimental Farm of Faculty of Agriculture, Cairo University, Egypt. The experiment was randomized in complete block design with three replicates. The soil was prepared and divided into plots with size of 2m x 5m (10 m^2). Each plot included 3 ridges. Rhizomes of weight 15-20 g with 2-3 eyes per piece were planted on a space of 25cm among hills in the ridge which contain about 16-17 plants. The number of plants in each plot was about 57 plants. The rhizomes were cultivated on 1st May in both seasons. The mechanical and chemical analysis of the soil were carried out before planting in Soil Science Department, National Research Center according to the methods of Chapman and Pratt (1978) and data was as follow the soil was sandy loam composing with 55.30% sand, 29.75% silt, 14.93% clay, while chemical analysis of the soil was, pH 8.23, E.C. 2.81 mmohs, organic matter 0.23%, N 480 ppm, P 37.8 ppm and K 35.1 ppm as well as, cations and anions were Meq/L 9.5 Na^+, 0.7 K^+, 14.0 Ca^{++}, 8.2 Mg^{++}, 4.40 HCO_3, 25.0 SO_4 and 13.00 Cr.

Preparation of soil

Cattle manure at the rate of 15m^3/fed and calcium super phosphate (15%) at the rate of 26 units/fed. were added pre cultivation, ammonium nitrate (33.5%) at the rate of 50 units/fed. as nitrogen source and potassium sulfate (48% K_2O) at the rate of 38 units/fed. were added into two equal doses, the first half was added on the first of June and the second half was added at the end of July in both seasons. All agricultural practices were followed as recommended.

Growth parameters

The following parameters measured were, plant height in cm, number of leaves/plant, width of leaf in cm they were measured during the most active period of growth while, fresh and dry weight of rhizomes, g/plant, g/unit area and kg/fed. were measured (at the end of growth period).

Chemical composition

Total carbohydrates. Total carbohydrates in the dried rhizomes were determined by using a colorimetric method of Herbert et al. (1971).

Essential oil. Essential oil in dry rhizomes was isolated by hydrodistillation for 3h in order to extract the essential oil according to Guenther (1961).

Curcumin content. Curcumin percentage was determined by HPLC and the yield g/plant, g/unit area (15m^2) and kg/fed. was calculated.

Statistical analysis

Data subjected to statistical analysis according to Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Vegetative parameters

Data tabulated in Table 1 and 2 showed that the vegetative growth, including plant height in cm, number of leaves/plant and width of leaf in cm as well as fresh and dry weight of rhizomes (g/plant, g/unit area and kg/fed.) were determined. It was clear that these parameters were higher with the irrigation every one week compared to the irrigation every two or three weeks. In other words, the maximum mean values of these parameters were resulted from irrigation every one week, followed by two weeks and then three weeks. The values of plant height cm/plant, number of leaves/plant and width of the leaf under the irrigation every one week were higher than the irrigation every two weeks by 11.87%, 6.54% and 16.42%,

respectively. While the values of these parameters under irrigation every two weeks were higher by 4.85%, 11.45% and 44.32% than the irrigation every three weeks. On the other hand, the irrigation every one week increased the fresh and dry weight of rhizome (g/plant) by 23.34% and 36.01% than every two and three weeks, respectively. The differences between the irrigation intervals were significant in most cases.

As for, the response of *Curcuma* species to the different irrigation intervals, the same parameters of vegetative growth showed that *C. aromatica* produced the tallest plant, maximum values of leaves and fresh and dry weight of rhizomes when compared to *C. domestica*. On the other words, these parameters of *C. aromatica* such as plant height, number of leaves/plant, width of the leaf as well as fresh and dry weight of rhizome g/plant increased by 3.47%, 11.4%, 44.67%, 23.69% and 12.85%, respectively, than *C. domestica*. The fresh and dry yield of rhizomes g/unit area and kg/fed had showed a similar trend of results as the dry yield /plant. The differences between these parameters of both *C. aromatica* and *C. domestica* were significant.

Concerning the combination between irrigation and the two species of *Curcuma* plants it can be noticed that there were no significant effect on the vegetative parameters. The maximum values of these parameters were at *Curcuma aromatica* under all treatments of irrigation, but the best treatment was with the irrigation every one week (Table 1 and 2). The trend of results agreed with those obtained by Leithy et al. 2006 on rosemary plant, Bettaieb et al. 2012 on cumin plant and El-Mekawy (2013) on *Achillea santolina* L. El-Tahir et al. (2011) who reported that, this may be due to vital roles of water supply at adequate amount of different physiological processes such as photosynthesis, respiration, transpiration, translocation, enzyme reaction and cell turgidity occurs simultaneously. Moreover, increasing levels of water stress reduce growth and yield due to reduction in photosynthesis by low CO_2 availability due to reduced stomata and mesophyll conductance.

Chemical composition

Total carbohydrate in rhizomes

Data in Table 2 demonstrated that total carbohydrate in rhizomes of *C. aromatica* and *Curcuma domestica* (g/plant, g/unit area and kg/fed) were affected by irrigation interval treatments. The irrigation every two weeks gave the highest percentage value of total carbohydrate, followed by irrigation every three weeks, while, the least value was at the irrigation every one week. The mean content of irrigation every one week was 11.54 g/plant, 751.88 g/unit and 263.03 kg/fed. against 8.97, 512.34 and 204.94 with irrigation every two weeks and 6.02, 342.76 and 137.11 at irrigation every three weeks. This is due to the differences in the dry weight of rhizomes for the three treatments. The differences between irrigation treatments were significant in all cases. As for the response of both *C. aromatica* and *C. domestica* to irrigation intervals, the data presented in Table 2, showed that *C. aromatica* produced the highest carbohydrate yield than *C. domestica* plant. These enhancement were 19.35%, 19.15% and 19.11% for the yield of one plant, unit area and feddan, respectively. Concerning the combination effect between irrigation treatments and different *Curcuma* species, it was apparent that application of irrigation every one week with *C. aromatica* gave promising effect on the accumulation of total carbohydrate in rhizomes during the mean of two seasons. The differences between irrigation treatments and both *C. aromatica* and *C. domestica* were not significant.

These results agreed with those of El Mekawy (2012) who mentioned that the effect of irrigation intervals on carbohydrates percentage of black cumin was reduced significantly by decreasing the soil moisture content as a result of increasing the period of irrigation from 2 up to 6 days intervals. Hassan et al. (2013) used three irrigation treatments on *Rosmarinus officinalis* L. The treatments were 100%, 80% and 60% of the field capacity. They found that Chlorophyll content was gradually increased with increasing irrigation frequency however, carbohydrate percentage increased by deficit irrigation treatments. Rabia et al. (2013) found that the carbohydrates percentage of *Echinacea purpurea* L. significantly decreased as a response to the decrease in irrigation water quantity and reached their minimum value under the lowest irrigation.

Volatile oil yield in rhizomes

The percentage of volatile oil and oil yield in rhizomes of *Curcuma* plants are different are presented in (Table 3). The irrigation every one week gave the maximum values of volatile oil yield (0.551 g/plant 31.416 g/unit area and 12.57 kg/fed.). As compared to the irrigation every three weeks, which gave the least value (0.257 g/plant, 14.639 g/unit area and 5.85 kg/fed.). According to the response of *Curcuma* species to irrigation treatments, it was clear that *C. aromatica* plant was more affective in accumulating oil in rhizomes than *C. domestica*. The enhancements in this concern were 21.22%, 21.25% and 21.17% than *C. domestica* for the yield of one plant, unit area and per fed., respectively. For the effect of interaction between the irrigation intervals and *Curcuma* species, the data in the same Table 3 showed that irrigation every one week with *C. aromatica* resulted in the highest oil percentage and yield in rhizomes, followed by irrigation every two weeks, then three weeks.

The obtained results agreed with those found by Simon et al. (1992) who reported that moderate water stress imposed on sweet basil resulted in higher oil percent and greater oil yield. Also, Farahani et al (2009**)** indicated that drought stress motivated a significant reduction in all growth parameters of *Mentha piperita* L and essential oil yield and percentage. The highest values of menthol were obtained under 70% field capacity by using (GC-MS). Hassan et al. (2013) found that deficit irrigation 60 and 80% of the field capacity significantly reduced growth parameters and yield of oil in *Rosmarinus officinalis* L. compared to control (100%) of field capacity. Also, Hassan and Ali (2013) found that increasing the irrigation level from 40% to 120% of the potential evapotranspiration increased the volatile oil percentage as well as fruit and volatile oil yields/hill and per fed. of coriander plant.

Table 1. Effect of irrigation intervals on growth parameters and fresh weight of *Curcuma aromatica* and *Curcuma domestica* (means of two seasons 2010 and 2011).

Irrigation intervals	Species	Plant height cm/plant	No. of leaves/plant	Width of leaf	Fresh weight of rhizomes g/plant	Fresh weight of rhizomes kg/unit area ($15m^{2U}$)	Fresh weight of rhizomes kg/fed.
One week	*C. aromatica*	91.70	5.70	18.30	95.47	5.46	2182.67
	C. domestica	81.70	5.70	14.30	65.57	4.88	1952.00
Means		**86.70**	**5.70**	**16.30**	**80.52**	**5.17**	**2067.73**
Two weeks	*C. aromatica*	88.30	5.70	16.30	66.87	3.81	1524.00
	C. domestica	66.70	5.00	11.70	63.70	3.63	1453.33
Means		**77.50**	**5.35**	**14.00**	**65.28**	**3.72**	**1488.66**
Three weeks	*C. aromatica*	60.30	5.30	12.70	48.90	2.79	1114.67
	C. domestica	46.70	4.30	6.70	41.50	2.39	958.67
Means		**53.50**	**4.80**	**9.70**	**45.20**	**2.59**	**1036.67**
Means of	*C. aromatica*	88.10	5.57	15.77	70.41	4.02	1607.4
species	*C. domestica*	65.03	5.00	10.90	56.42	3.63	1454.67
LSD at 0.05							
Irrigation I		5.66	0.45	1.35	4.71	0.27	107.40
Species S		4.63	0.37	1.10	3.84	0.22	87.68
I X S		N.S	N.S	N.S	N.S	N.S	N.S

Table 2. Effect of irrigation intervals on yield of dry weight and total carbohydrate in rhizomes of *Curcuma aromatica* and *C. domestica*. plants (means of two seasons 2010 and 2011).

Irrigation intervals	Species	Dry weight of rhizomes g/plant	Dry weight of rhizomes g/unit area	Dry weight of rhizomes kg/fed.	Total carbohydrate in rhizomes %	Total carbohydrate in rhizomes g/plant	Total carbohydrate in rhizomes g/unit area	Total carbohydrate in rhizomes kg/fed
One week	*C. aromatica*	28.25	1610.06	644.13	44.59	12.60	718.20	287.02
	C. domestica	25.04	1417.40	566.93	42.15	10.48	597.55	239.03
Means		**26.25**	**1513.73**	**605.53**	**43.37**	**11.54**	**757.88**	**263.03**
Two weeks	*C. aromatica*	20.06	1143.42	453.33	48.88	9.80	558.79	223.52
	C. domestica	18.55	1057.35	422.93	44.07	8.14	465.88	186.35
Means		**19.30**	**1100.38**	**438.13**	**46.48**	**8.97**	**512.34**	**204.94**
Three weeks	*C. aromatica*	14.63	833.34	333.33	45.66	6.46	368.22	147.29
	C. domestica	12.19	694.64	277.87	44.18	5.57	317.30	126.92
Means		**13.41**	**763.99**	**305.60**	**44.92**	**6.02**	**342.76**	**137.11**
Means of	*C. aromatica*	20.98	1195.61	511.86	46.38	9.62	548.40	219.28
Species	*C. domestica*	18.59	1056.46	422.58	43.47	8.06	460.24	184.10
LSD at 0.05								
Irrigation (I)		1.39	79.07	31.55	-	0.61	108.49	13.80
Species (S)		1.13	64.56	25.76	-	0.50	88.58	11.27
I x S		0.53	90.94	12.10	-	N.S	N.S	N.S

Table 3. Effect of irrigation intervals on volatile oil and curcumin yield in rhizomes of *Curcuma aromatica* and *C. domestica* plants (means of two seasons 2010 and 2011).

Irrigation intervals	Species	Oil yield in rhizomes %	Oil yield in rhizomes g/plant	Oil yield in rhizomes g/unit area	Oil yield in rhizomes kg/fed	Curcumin yield in rhizomes %	Curcumin yield in rhizomes g/plant	Curcumin yield in rhizomes g/unit area	Curcumin yield in rhizomes kg/fed
One week	*C. aromatica*	2.08	0.588	33.497	13.40	0.522	0.14	8.55	3.42
	C. domestica	2.07	0.515	29.336	11.74	0.425	0.11	6.08	2.43
Means		**2.08**	**0.551**	**31.416**	**12.57**	**0.473**	**0.13**	**7.32**	**2.93**
Two weeks	*C. aromatica*	2.02	0.405	23.104	9.24	0.527	0.10	6.08	2.43
	C. domestica	1.92	0.356	20.307	8.12	0.411	0.08	4.37	1.75
Means		**1.97**	**0.381**	**21.705**	**8.68**	**0.469**	**0.09**	**5.23**	**2.09**
Three weeks	*C. aromatica*	2.12	0.310	17.670	7.07	0.445	0.07	3.80	1.52
	C. domestica	1.67	0.204	11.609	4.64	0.392	0.05	2.85	1.14
Means		**1.89**	**0.257**	**14.639**	**5.85**	**0.418**	**0.06**	**3.33**	**1.33**
Means of	*C. aromatica*	2.07	0.434	24.757	9.90	0.498	0.10	6.14	2.46
Species	*C. domestica*	1.89	0.358	20.417	8.17	0.409	0.08	4.43	1.77
LSD at 0.05									
Irrigation (I)		-	0.028	1.16	0.64	-	0.009	0.49	0.20
Species (S)		-	0.023	1.31	0.53	-	0.007	0.40	0.16
I x S		-	0.003	N.S	N.S	-	0.011	0.19	0.08

Curcumin yield in rhizomes

The effect of irrigation intervals on curcumin percentage and content in rhizomes was shown in (Table, 3). Irrigation every one week produced the maximum value of curcumin, followed by irrigation every two weeks, then the irrigation every three weeks. The maximum values of curcumin were 0.13 g/plant, 7.32 g/unit area and 2.93 kg/fed., under the irrigation every one week, and 0.09 g/plant, 5.23 g/unit area and 2.09 kg/fed under the irrigation every two weeks while, irrigation every three weeks produced the least values in this concern, (0.06 g/plant, 3.3 g/unit area and 1.33 kg/fed (Table, 3). Most of these differences were significant. As for *Curcuma* species, *C. aromatica* gave the highest curcumin yield in rhizomes as compared to *C. domestica*. The mean values of curcumin in rhizomes of *C. aromatica* were 0.10 g/plant, 6.14g/unit area and 2.46 kg/fed., while they were0.08g/plant, 4.43g/unit area, and 1.77 kg/fed. for *C. domestica.* As for the interaction between irrigation intervals treatments and *Curcuma* species, it was noticed that *C. aromatica* under irrigation every one week gave the maximum value of curcumin in rhizomes comparing to *C. domestica.* Generally the curcumin content in the two species was gradually decreased with increasing irrigation intervals.

The mentioned results are in harmony with those of Farooq (2009) who reported that Drought stress reduces plant growth by affecting various physiological and biochemical processes, such as photosynthesis, respiration, translocation, ion uptake, carbohydrates, nutrient metabolism and growth promoters. El-Azim (2009) on *Peganum harmala* L. mentioned that prolonging the irrigation interval from 10 to 30 days, the percentage of crude protein, total ash, potassium and total flavonoids in plant tissues decreased (Ekren et al. 2012). Exposing rosemary plant to water stress led to a decrease in N, P, K, and protein contents. Amirjani (2013) stated that seedlings of *Catharanthus roseus* subjected to 4 different water-regimes. The first irrigated every one week, the second treatment every two weeks, the third treatment irrigated every three weeks, while control plants irrigated every day. The photosynthetic activity and transpiration rate significantly decreased with increasing drought level. Total protein decreased to 77% and total chlorophyll decreased by 27%.

CONCLUSION

The irrigation intervals every one week improved growth characteristics and chemical composition of *Curcuma* sp. Also, *Curcuma aromatica* produced the higher values as compared to *C. domestica*.

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