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Influence of Different Irrigation Regimes on Production of Lettuce (*Lactuca sativa* L.)

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Abstract: Lettuce requires frequent irrigation for better growth and development. Growing lettuce plants in dry soil conditions promotes bolting. This experiment was conducted in Horticulture Department at the University of Swaziland to determine the optimal irrigation regime for the production of lettuce under greenhouse conditions. The different irrigation levels used were 25, 40, 50 and 75% moisture content of field capacity. There was no significant ($P > 0.05$) differences in plant height, number of leaves, leaf area, leaf area index and fresh mass of roots of lettuce plants irrigated at 50 and 75% moisture content. However, plant height, number of leaves, leaf area and leaf area index were significantly ($P > 0.05$) reduced at 25 and 40% irrigation levels. The 75% irrigation level induced the highest lettuce plant height (31.5 cm), highest number of leaves (11.6), highest leaf area (2,773.5 cm^2) and highest leaf area index (12.9). The next best results for all these parameters were obtained from lettuce plants irrigated at 50% moisture content. The lowest yield was obtained from lettuce grown at 25% irrigation regime. It is recommended that lettuce grown under similar conditions be irrigated at 50% moisture content.

Key words: Drought stress · Irrigation scheduling · Head mass · Lettuce · Root mass

INTRODUCTION

Most soils are suitable for lettuce (*Lactuca sativa* L.) growing. However, it does best on sandy loams that contain a high proportion of well-rotted organic matter [1]. Optimal yields are obtained in the soil pH range of 6.0-6.7 [2]. Lettuce can be irrigated using furrow system. However, the use of sprinklers helps to reduce the amount of irrigation water needed and the potential for salt accumulation in the soil. Lettuce is moderately sensitive to salinity. It should be free from water and salt stresses throughout the growing cycle. The critical period is during head development. An irrigation threshold of 40% soil water deficit should be targeted to avoid water stress. The soil should never be left to dry since this condition results in bolting. Irrigation should be as generous as possible but water-logging must be avoided. Irrigation is required at frequent intervals, particularly until the seedlings are established. Throughout growth, water should be plentiful but once heads are firm, watering should be reduced, otherwise bottom-rot may cause heavy losses [1].

If plants do not receive adequate rainfall or irrigation, the resulting drought stress can reduce growth more than all other environmental stress combined [3]. A plant responds to water stress by halting growth, reducing photosynthesis and other metabolic processes in order to reduce water requirements [4-6]. According to Loos [7], the time required for drought injury to occur depends on the water-holding capacity of the soil, environmental conditions, stage of growth and plant species. Plants growing in sandy soils with low water-holding capacity are more susceptible to drought stress than those growing in clay soils. A limited root system will accelerate the rate at which drought stress develops. A plant with a large mass of leaves in relation to the root system is prone to drought stress because the leaves may lose water faster than the roots can supply it.

Water deficit can cause serious losses in most crop plants. Many develop morphological and physiological adaptations to water stress like rapid completion of ontogeny, leaf rolling, reduced leaf area, low stomatal conductance and high root: shoot ratio. Sorbitol, glucose

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and fructose concentrations increases, while sucrose and starch levels decreases significantly suggesting that sugar alcohols and monosaccharides are the most important osmotica for adjustment to drought and salt stresses [8]. The most obvious general effects of water deficit are reduction in plant size, leaf area, produce quality and yield [9].

Crop growing environment can be modified to reduce or prevent drought stress by supplementary irrigation, mulching, shading and use of windbreaks [10]. Reducing the overall water requirements of crop plants is best achieved by using efficient irrigation systems, proper watering and use of drought tolerant plants where appropriate [6].

Irrigated agriculture is very important in meeting the food and fibre needs of an increased global population [11]. Estimates of total irrigated land in the world range from 220 to 250 million hectares in 2010 [24, 25]. This covered about 18% of the total cultivated area and contributed about one third of the world's food production. Irrigated agriculture will continue to increase, but water supplies and irrigation costs will become major constraints in the future irrigation development. According to Hoffman *et al.* [12], irrigation management consists of determining when to irrigate (irrigation scheduling), the amount of water to apply at each irrigation and during each stage of plant growth and the operation and maintenance of the irrigation system. Irrigation is the largest water user worldwide [13]. As a large consumer of water, irrigation reduces the quantity of water available for other uses. However, irrigated agriculture is critical to the global food supply.

An understanding of water relations of plants is central to enabling us to improve the profitability of all horticultural crops [14]. Not only is the maintenance of an adequate water status essential to maintain photosynthesis, production and growth, but also an important factor determining the quality of most horticultural commodities.

Irrigation can be important for vegetable crops because many are shallow rooting and, therefore, sensitive to water shortage. Vegetable production is a high-cost enterprise with high value end products and growers need to have irrigation available as an insurance against drought. There are several potential benefits from irrigating vegetables, e.g. yield increase, improvement in plant establishment, continuity of supply to market or processor and quality [15].

As water supplies become scarcer and the cost of water for irrigation increases, irrigation-scheduling methodologies need to be more precise [16]. One of the options proposed for that purpose is the use of regulated deficit irrigation. This is an optimising strategy, by which crops are deliberately allowed to sustain some degree of water deficit and yield reduction. The objective is to increase water use efficiency, either by reducing irrigation adequacy or by eliminating the least productive irrigation. Therefore, it is used to increase profits when there are constraints on capital, energy, labour, or other essential resources [12]. The aim of the study was to determine the influence of different irrigation regimes on the growth and development of lettuce under greenhouse conditions.

MATERIALS AND METHODS

Experimental Site: The study was carried out in the greenhouse in the Horticulture Department, Faculty of Agriculture, Luyengo Campus of the University of Swaziland. The site is located at Luyengo, Manzini Region in the Middleveld agro-ecological zone. Luyengo is 26° 34' S and 31° 12' E. The average altitude of this area is 750 m above sea level. The mean annual precipitation is 980 mm with most of the rain falling between October and March [17, 18].

Experimental Design: The experiments were laid out in a randomised complete block design. Four irrigation treatments, i.e., irrigating at 25, 40, 50 and 75% moisture content from field capacity were used.

Plant Materials: Five-week-old lettuce seedlings were obtained from Vickery Seedlings Ltd, Malkerns, Swaziland. They were planted in 9,147.5 cm^3 black polyethylene bags filled with a mixture of garden soil, compost and sand at the ratio of 1:1:1.

Crop Management: After planting, cutworm bait was applied. Irrigation was done uniformly for the first two weeks to allow the seedlings to establish. Thereafter, the different irrigation regimes were applied until harvesting time. Compound fertiliser NPK (2:3:2 [22]) was applied at the rate of 10g per pot.

Determination of Soil Moisture Content: To determine the irrigation schedule, the soil moisture content was determined using the soil mass method. Four pots containing the growing medium were used. A tensiometer

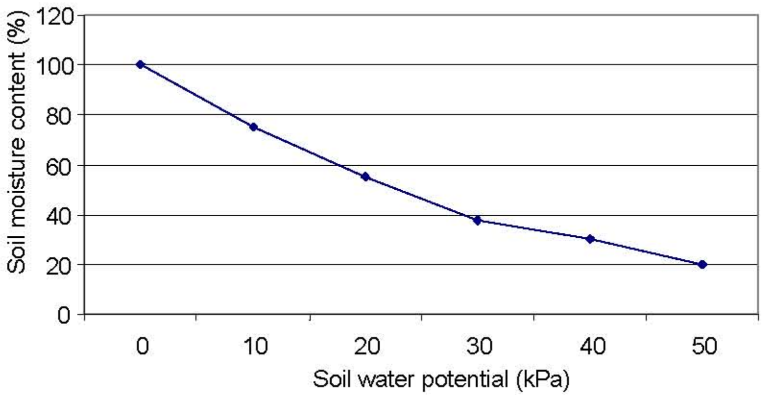

Fig. 1: Irrigation scheduling by determination of soil moisture content at different tensiometer readings (soil water potential)

was placed in each pot. The pots were irrigated to field capacity and the medium allowed to dry. Tensiometer reading were recorded daily and thereafter, soil samples taken from each pot and their fresh and dry masses determined. Soil water content at each tensiometer reading was determined from field capacity to 50 kPa (Figure 1). Extrapolation using the graph (Figure 1) was used to determine the tensiometer reading when soil moisture content reached 25, 40, 50 and 75% of field capacity. Two tensiometers placed in different polyethylene bags for each treatment were used. Irrigation was performed when the tensiometer readings showed 8 kPa (75% moisture content), 23 kPa (50% moisture content), 27 kPa (40% moisture content) and 45 kPa (25% moisture content).

Data Collection and Analysis: Data collection was performed from 3 to 7 weeks after transplanting (WAT). Five randomly selected plants were used in each replication and treatment. Data collected included: number of leaves per plant, plant height, leaf length and leaf width. Fresh and dry mass of lettuce heads were determined after harvesting (7 WAT). Fresh and dry root mass were also determined at the end of the experiment (7 WAT). Collected data was subjected to analysis of variance (ANOVA) using M Stat-C statistical package. Means that were significant were separated using Duncan's New Multiple Range Test (DNMRT) at P = 0.05.

RESULTS AND DISCUSSION

Plant Height: The highest lettuce plant height (31.5 cm) measured 7 WAT was observed in plants irrigated at 75% moisture content (Table 1). The lowest plant height (27.3 cm) was obtained from plants irrigated at 25% moisture content. The second highest plant height at all determination dates (3, 4, 5, 6 and 7 WAT) was obtained from plants irrigated at 50% moisture content.

From 3 to 7 WAT, there was no significant ($P > 0.05$) difference in plant height between lettuce irrigated at 50 and 75% soil moisture content. Similarly, Mesbah [19] observed no appreciable differences in plant height, number of tillers, spike length, leaf area index and grain yield between wheat plants irrigated at 1,600 and 1,850 m^3 of water. However, in this investigation, irrigating lettuce at 25 and 40% moisture content reduced the plant height significantly ($P > 0.05$) compared with 50 and 75% moisture content. According to Thompson *et al.* [20], insufficient irrigation reduced growth in most plants. The lowest plant height was observed in lettuce plants irrigated at 25 and 40% moisture content could probably be attributed to the observed reduction in number of leaves formed in these plants (Table 1).

Number of Leaves: The highest number of leaves (11.6) was observed in lettuce plants irrigated at 75% moisture content at 7 WAT (Table 1). The lowest number of leaves (8.0) was obtained with plants irrigated at 25% moisture content. There was no significant ($P > 0.05$) difference in the number of leaves formed between the lettuce plants irrigated at 50 and 75% moisture content from 3 to 7 WAT. The plants irrigated at 25 and 40% moisture content had significantly ($P > 0.05$) lower number of leaves as compared to plants irrigated at 50 and 75% moisture content. However, Thompson *et al.* [20] observed no appreciable reduction in number of leaves of *Miscanthus* grass irrigated at different irrigation regimes. Lettuce plants irrigated at 25 and 40% moisture content exhibited drying of lower leaves which could probably be attributed to reduced soil moisture availability.

Table 1: Effect of different irrigation regimes on plant height, number of leaves, leaf area and leaf area index of lettuce determined 3, 4, 5, 6 and 7 WAT

	Weeks after transplanting (WAT)				
Soil moisture content (%)	3	4	5	6	7
Plant height (cm)					
25	16.7b*	20.9b	25.0b	25.4c	27.3c
40	18.8a	22.3b	25.1b	26.6b	28.7b
50	18.7a	23.6a	26.6a	29.4a	31.4a
75	19.4a	24.6a	27.9a	30.5a	31.5a
Number of leaves					
25	5.3b	6.8c	7.1b	7.3c	8.0c
40	6.1a	7.3b	8.0a	8.2b	9.5b
50	6.5a	7.8ab	8.6a	9.0a	12.9a
75	6.9a	8.3a	8.8a	9.5a	11.6a
Leaf area (cm^2)					
25	218.7d	393.4c	632.9c	1,078.3c	1,505.0c
40	294.9c	575.1b	894.3b	1,461.5b	2,007.0b
50	338.3b	682.1a	1,153.9a	1,687.4a	2,601.8a
75	437.0a	765.1a	1,195.7a	1,935.4a	2,773.5a
Leaf area index					
25	5.3b	6.8b	7.1b	7.3b	8.0c
40	6.1a	7.3a	8.0a	8.2a	9.5b
50	6.5a	7.8a	8.6a	9.0a	11.6a
75	6.9a	8.3a	8.8a	9.5a	12.9a

*Means followed by same letter along columns not significantly different. Mean separation by DNMRT at P = 0.05

Table 2: Effect of different irrigation regimes on head fresh mass, head dry mass, root fresh mass and root dry mass of lettuce determined 7 WAT

	Parameter/mean value (g)			
Soil moisture content (%)	Head fresh mass	Head dry mass	Root fresh mass	Root dry mass
25	85.1d*	5.4c	2.4c	0.2c
40	115.6c	6.7c	2.7c	0.3c
50	152.6b	8.9b	6.0b	1.1b
75	224.2a	15.0a	8.7a	2.1a

*Means followed by same letter along columns not significantly different. Mean separation by DNMRT at P = 0.05

Leaf Area and Leaf Area Index: The highest leaf area (2,773.5 cm^2) was obtained in lettuce plants irrigated at 75% moisture content at 7 WAT, while the lowest leaf area (1,505.0 cm^2) was observed in plants irrigated at 25% moisture content (Table 1). At all determination dates, lettuce plants irrigated at 75% moisture content had the highest leaf area followed by those irrigated at 50% moisture content (Table 1). The highest leaf area index (12.9) was observed in lettuce plants irrigated at 75% moisture content followed by 11.6 at 50% moisture content and the lowest 8.0 in plants irrigated at 25% moisture content. From 3 to 7 WAT, the leaf area of lettuce plants irrigated at 75% moisture content was almost double that of the plants irrigated at 25% moisture content (Table 1).

There was no significant ($P > 0.05$) difference in leaf area and leaf area index between lettuce plants irrigated at 50 and 75% moisture content from 3 to 7 WAT. Irrigating plants at 25 and 40% moisture contents significantly ($P > 0.05$) reduced the leaf area and leaf area index when compared to plants irrigated at 50 and 75% moisture contents. Thompson *et al.* [20] also observed a reduction in leaf area index of *Miscanthus* grass upon reduction in soil moisture content. They attributed the reduction in leaf area index to shoot dieback and senescence of lower leaves. Lower leaf senescence was also observed in this investigation especially in lettuce plants irrigated at 25 and 40% moisture content.

Fresh and Dry Mass of Lettuce Heads: The highest lettuce fresh mass (224.2g) was obtained in plants irrigated at 75% moisture content followed by 152.6g in plants irrigated at 50% moisture content at 7 WAT (Table 2). Plants irrigated at 25% moisture content had the lowest fresh mass (85.1g). The dry mass of lettuce heads followed a similar trend to that of fresh mass (Table 2). The highest lettuce head dry mass (15.0g) determined 7 WAT was obtained in plants irrigated at 75% moisture content followed by 8.9g in plants irrigated at 50% moisture content. The lowest head dry mass of 5.4g was obtained in plants irrigated at 25% moisture content. Irrigating the lettuce plants at 25 and 40% moisture content resulted in a significant ($P > 0.05$) reduction in head fresh and dry mass when compared to plants irrigated at 50 and 75% moisture content. Similar observations have been reported by Karam *et al.* [21] in lettuce, El-Boraie *et al.* [22] in *Hibiscus sabdariffa* L. and Nazeer [23] in maize grown under different irrigation regimes. Thompson *et al.* [20] stated that dry matter yields in crop plants are highly influenced by irrigation rates. The reduction in head fresh and dry mass of the plants supplied with reduced irrigation water in this study could probably be attributed to drying of lower leaves and reduction in number of leaves formed.

Fresh and Dry Mass of Lettuce Roots: The highest lettuce root fresh mass of 8.7g was obtained from plants irrigated at 75% moisture content followed by 6.0g obtained in plants irrigated at 50% moisture content (Table 2). The lowest root fresh mass (2.4g) was obtained in plants irrigated at 25% moisture content. The lettuce root dry mass followed a similar trend to that of the fresh mass (Table 2). The highest root dry mass (2.1g) was obtained at 75% irrigation regime and the lowest (0.2g) at 25% irrigation regime. At 7 WAT, there was more than ten fold increase in lettuce root dry mass between plants irrigated at 25 and those irrigated at 75% moisture content.

At 7 WAT, lettuce plants irrigated at 50 and 75% showed no significant difference ($P > 0.05$) in root fresh and dry mass. Irrigating the lettuce plants at 25 and 40% moisture contents resulted in significant ($P > 0.05$) reduction in root fresh and dry mass. The reduction in root fresh and dry mass of plant provided with reducing irrigation water could probably be attributed to reduction in assimilate formation and translocation from the leaves to the roots.

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