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Effects of Water Supply and Plant Density on Leaf Characteristics of Amaranth (*Amaranthus Caudatus* L.)

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Abstract. In order to evaluate the effects of water supply and plant density on leaf characteristics of amaranth (*Amaranthus caudatus* L.), a split plot experiment was conducted based on randomized complete block design with three replications at the University of Tabriz in 2013. Treatments were irrigation intervals (I_1 and I_2: irrigations after 70 and 140 mm evaporation from class A pan, respectively) as main plots and plant densities (4, 8 and 12 plants/m^2) as sub plots. The results showed significant interaction of irrigation × plant density for leaf area index (LAI), leaf area ratio (LAR), and specific leaf area (SLA) and leaf weight ratio (LWR). All these traits decreased with decreasing water availability. The difference between well irrigation and water deficit for LAI, LAR and LWR decreased, but for SLA increased as plant density increased. The highest LAI, LAR and LWR under both irrigation treatments were observed at 8 plants/m^2. It was concluded that optimum density for improving leaf area index, leaf area ratio and leaf weight ratio of amaranth under well and limited irrigations is 8 plants/m^2.

Keywords: Amaranth, Leaf Area Index, Water Supply.

1. Introduction

Amaranth (*Amaranthus caudatus)* is an annual herbaceous plant or shrub from Amaranthaceae family that at maturity can reach to 3 meters or more. Amaranth is an extraordinary plant, due to its rapid growth and ultra-efficient photosynthesis. This plant requires less than two-third of current plant moisture, which makes it a valuable plant in those parts of the world where lack of water limits agricultural production. Plant growth is controlled by several factors, of which water plays a vital role.

Drought stress is a permanent constraint to agricultural production in many regions, and an occasional cause of losses of agricultural production [1], [2]. Many researchers believe that amount of crop water use control plant growth, development and field crops production. Meanwhile plants may injure under non optimal access of water at any stage [3]. Reduction in crop yield as a result of water stress has also been reported for soybean [4]. Abortion of flowers and pods due to water stress in flowering and pod set stages are the main reasons for reducing number of pods and grains per plant [5], [6]. A small decrease in the availability of water to a growing plant immediately reduces its metabolic and physiological functions. On the other hand, plant density is an important agent that affects yield and yield components in crops. Bruin and Pederson [7] observed that soybean planted in 38 cm row spacing yielded 248 Kg ha^{-1} greater than soybean planted in 76 cm rows. Gan *et al* [8] have also shown increase of grain yield at higher plant density in chickpea. High plant density may increase relative humidity within the canopy and increase the duration of leaf wetness by reducing air movement and sun light penetration [9], [10]. Irrigation and planting density

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are the most important environmental factors that affect the plants yield. So, the present work is an attempt to study the effects of different irrigation intervals and plant densities on leaf characteristics of amaranth.

2. Materials and Methods

A field experiment was conducted in 2013 at the Research Farm of Tabriz university (Latitude 38°5´N, Longitude 46°17´E, Altitude 1360 m above sea level), to investigate the response of amaranth to water supply and plant density. Irrigation treatments (I_1 and I_2: irrigation after 70 and 140 mm evaporation from class A pan) and plant densities (4, 8 and 12 plant per m^2) were assigned to main and sub-plots, respectively. All plots were irrigated immediately after sowing. Irrigation treatments were applied after seedling establishment. Weeds were controlled by hand weeding during crop growth and development. Leaf area index (LAI) was measured by LAI meter (model: ADC-AM300). Leaf area ratio (LAR), Specific leaf area (SLA) and Leaf weight ratio (LWR) were calculated as:

LAR (cm^2/g) = total leaf area / total dry weight

SLA (cm^2/g) =total leaf area / leaf dry weight

LWR (g/g) =leaf dry weight/total dry weight

The data were analyzed by MSTATC software and the means were compared using Duncan multiple range test at $P\leq0.05$.

3. Results and Discussions

Results of ANOVA showed significant interaction of irrigation × plant density ($P\leq0.01$) for leaf area index, leaf area ratio, specific leaf area and leaf weight ratio (Table. 1). Leaf area index, leaf area ratio, specific leaf area and leaf weight ratio at different densities under well irrigation were higher than those under deficit irrigation. The difference between well irrigation and water deficit for LAI, LAR and LWR decreased (Fig. 1. A.B.D), but for SLA increased (Fig. 1.C) with increasing plant density. The highest LAI, LAR and LWR under both irrigation treatments and SLA under limited irrigation (I_2) were observed at 8 plants/m^2 (Fig. 1. A.B.D.C), but the highest SLA under well watering (I_1) was recorded at 12 plants/m^2. Cell growth and development are the most important processes affected by water stress. Plant size is indicated by a decrease in height or smaller size of leaves when there is a decrease in the growth of cells **[**11**]**. Small cells can withstand turgor pressure better than large cells, and can contribute to turgor maintenance more effectively under drought conditions **[**12], [13**]**.

Drought stress is one of the limiting factors in crop growth which reduces dry matter production through decreasing leaf area and accelerating leaf senescence [14]. Lowering LAR under water stress (Fig. 1.B) was facilitated by the reduction of total leaf area. Because a decreased LAR is commonly associated with a high tissue density and total non-structural carbohydrate content in leaves under drought conditions **[**15**].** Decreasing the difference between well watering and water limitation for LAI, LAR and LWR, and increasing it for SLA with increasing plant density (Fig. 1) suggest that low water availability at high densities increases leaf thickness. Thicker leaves were the result of an increment in the size of palisade cells and also due to a major number of spongy parenchyma layers. The opposite behavior was the result of thinner leaves. Changes in mesophyll thickness as a result of alteration of palisade/spongy parenchyma cells ratio were observed in three ornamental species [16] and soybean [17].

Plant density is one of the most important cultural practices determining plant growth, as well as other important agronomic attributes of the crops. Density affects plant architecture, alters growth and developmental patterns and influences carbohydrate production and partitioning [18]. Increasing plant density increases leaf area index and consequently water consumption [19]. Therefore, the use of high plant populations under limited water supply may increase plant water stress and dramatically reduce growth and grain yield [20]. Consequently, it is extremely important to consider water supply to define the optimum plant population for any particular region and cropping system. Optimum plant density of amaranth for improving leaf area index, leaf area ratio and leaf weight ratio under well and limited irrigations was 8 plants/m^2 (Fig. 1).

Table 1: Analyses of variance of the effect of irrigation and plant density on some morpho-physiological characteristics of amaranth.

Source of Variation	df	MS			
		LAI	LAR	SLA	LWR
Replication	2	0.02^{ns}	0.042^{**}	0.07^{ns}	0.0001^{ns}
Irrigation(I)	1	1.13^{*}	174.62^{**}	133.91^{**}	0.013^{**}
Error	2	0.02	0.053	0.03	0.0001
Density(D)	2	3.16^{**}	89.48^{**}	57.50^{**}	0.006^{**}
I×D	2	0.29^{**}	1963.18^{**}	571.21^{**}	0.008^{**}
Error	8	0.01	0.055	0.526	0.0001
CV (%)		4.92	0.35	0.72	1.17

ns, * and **: non-significant and significant at $P \leq 0.05$ and $P \leq 0.01$, respectively

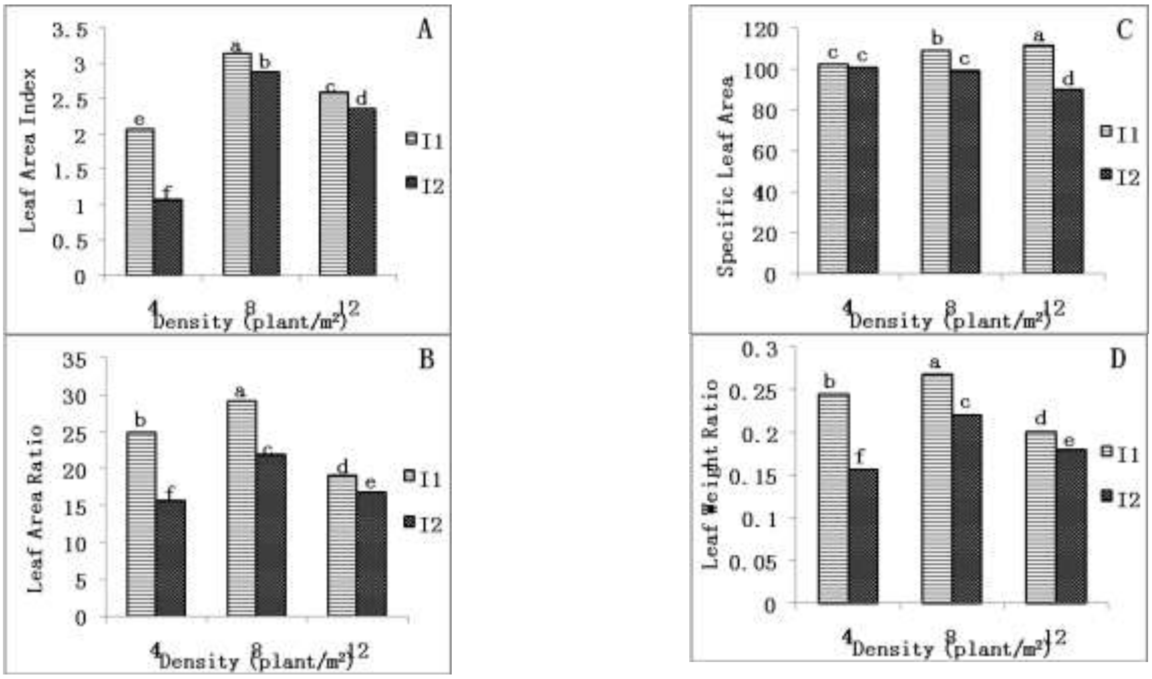

Fig. 1: Means of LAI (A), LAR (B), SLA (C) and LWR (D) under different irrigation levels and plant densities in amaranth.

Different letters indicate significant difference at $P \leq 0.05$.

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