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Study of Growth indices in lentil at drought stress conditions

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Abstract
Drought stress is one of the most important environmental factors that limit lentil production. In order to evaluate the effect of drought stress at flowering and pod filling stages on growth indices of lentil cultivar Kimiya, an experiment was carried out at the research greenhouse of Higher Educational Complex of Saravan, using a completely randomized design with four replications. Drought stress was applied by lack of irrigation until the soil moisture reached to 20 percent of field capacity at stages of flowering and pod filling stages. In this experiment, growth indices including Plant leaf area (PLA), relative growth rate (RGR), Plant growth rate (PGR), net assimilation rate (NAR) were measured. Results showed that the flowering stage in lentil plant is more sensitive to drought because at flowering stage decreased LAI, RGR, PGR and NAR. Overall, the results indicated that at the end of growing season, PGR declined due to the stopping of vegetative growth, senescence of leaves, the reduction of NAR and the allocation of assimilates to the seeds.

Keywords: allocation, leaf area, moisture, vegetative

Introduction

Lentil is an annual food legume highly valued for grain in the world. The crop has great significance in cereal-based cropping systems because of its nitrogen fixing ability, the high protein and high micronutrients seeds for human diet, and its straw for animal feed. In addition, lentil can play a major role in sustaining soil fertility by symbiotic nitrogen fixation because there are major economic limitations in the use of commercial nitrogen fertilizers (Kumar *et al*., 2012) [7].

In large areas of lentil cultivation that have temperate winter, autumn sowing date is common and in areas with cold winters and Highlands, lentil planted in spring (Oweis *et al*., 2005) [8]. Since the amount and distribution of rainfall is variable in autumn and spring, the occurrence of drought stress at all stages of vegetative and reproductive growth is possible (Kashiwagi., 2006) [6]. Intermittent drought stress occurs due to the intermittent interruption of autumn rainfall and terminal drought stress occurs due to the early stopping of spring rainfall. In Mediterranean regions, lentil grown in autumn or winter, therefore, reproductive growth stage is affected by drought stress. However, the occurrence of drought stress lead to decrease lentil yield (Gangali *et al*., 2008) [1].

On the other hands, evaluation of the growth indices is very important (Gordner *et al*., 1985) [4] to determine the extent of these indices in the final yield. Quantitative growth analysis is a useful method for justifying and interpreting the plant's response to the various environmental conditions that the plant encounters during its growth. By using this method, a better understanding of how the photosynthetic assimilates are allocated to different organs and also accumulation of dry matter produced during the plant growth season (Ghasemigolozani., 1997) [2].

Furthermore, growth analysis is a very important method in quantitative analysis of plant growth and crop production. The major indices in plant growth analysis are included: Crop growth rate (CGR), Relative growth rate (RGR), Net assimilation rate (NAR), Leaf area index (LAI). In this research, the effect of drought stress on growth indices of lentilat flowering and pod filling stage has been evaluated.

Materials and methods

In order to evaluate the effect of drought stress at flowering and pod filling stages of lentil, an experiment was conducted in the greenhouse research of Higher Educational Complex of Saravan. The experiment was conducted in a completely randomized design with four replications. The experiment was carried out in pots containing 5 kg of soil with a diameter of 22 cm and a height of 18 cm. The lentil cultivar was Kimiya and planting depth was 5 cm and also, plant density was three plants in each pot.

The amount of water in the dry soil was measured in base of the field capacity. In order to determine the amount of water treatment in each pot, at first, 4000 g of soil was placed inside the oven at 103 °C and 48 hours later weighed and the dry weight of the soil was determined. Then the dried soil was poured in a pot and water slowly added to reach the saturation point and after full withdrawal of water, the pot was weighed. After subtracting the weight of the pot and the dry soil, the amount of water stored in the field capacity was determined and different treatments were accordingly

calculated. Then, 56 pots were prepared and 5 kg of soil were poured into each pot. 28 pots were considered for control treatment, for flowering and pod filling stages was considered 16 and 12 pots, respectively. Drought stress was applied at flowering stage, 32 days after emergence when 50% of the plants entered flowering stage. Furthermore, drought stress was applied in pod filling stage, 44 days after emergence when 50% of the plants had pods. The stress period for each phenological stage was initiated by stopping irrigation and until the water the soil reached up to 20% of the field capacity that coincided with the emergence of stress symptoms, including the closure of leaflets and the withering of the terminal buds. At this time, a number of pots were destroyed in order to sample and measure the traits and the rest of the stressed pots were irrigated. Four sampling were taken for stress in the flowering stage and three sampling were taken for stress in the pod filling stage, while sampling was done for the control treatment at each phenological stage. The irrigation of the pots was carried out every three days until the soil water reached 70% Field capacity. The leaf area index was calculated using leaf area meter device and for measuring leaf dry weight, samples were placed in an oven at 72°C for 48 hours and then weighted.
Furthermore, Growth indices were calculated based on plant and due to the constant temperature in greenhouse conditions, instead of using the growth degree day, calendar days after emergence was used. To determine the leaf area per plant, plant growth rate, relative growth rate, net assimilation rate, the equations 1, 2, 3 and 4 were used respectively.

1/plant) (1)= $\left[(LA2 + LA1)/2\right]$ (PLA

PGR= (W2-W1)/(T2-T1) plant (2)

RGR= (Ln W2- Ln W1)/ (T2-T1) (3)

NAR = [(LnW2.LnW1)/ (T2-T1)] [(LnLA2 – LnLA1)/(LA2-LA1)] (4)

In the above equations, LA was the leaf area (cm^2), W was dry weight of the plant (g), T and p were sampling time and per plant, respectively. In this study, Excel software was also used to draw charts.

Results and Discussion

Leaf area

The results showed that in all treatments the leaf area increased days after emergence. At the end of growing season, the control treatment had the highest leaf area, so that after 25 to 71 days after emergence, this trend was followed neatly and remained almost constant afterwards (Fig. 1).The lowest amount of leaf area was obtained for drought stress at flowering and pod filling stages, respectively, because drought stress in this stage led to senescence leaves and also accelerated the aging plant (Tavakoli *et al*, 1989) [12].
The results also indicated that the development of leaves decreased after the lentil plant was exposed to drought stress, and this reduction trend continued until irrigation. Finally, when the speed of senescence leaves was more than the speed of development of leaves, leaf area and consequently photosynthetic production reduced. The higher leaf area index in chickpea in non-stress conditions is also confirmed by other researchers (Goldani & Rezvani., 2007; Shabiri *et al*., 2007) [3, 10]. By reducing the soil water content, leaf area index showed a decreasing trend. The leaf area index is one of the most important growth indices which have significant correlation with biological and grain yield (Singh, 1997) [11].

Net assimilation rate (NAR)

Curve of NAR is presented in Fig. 2 over growing season. Control treatment decreased with steady slope. NAR is an estimate of the average photosynthetic intensity of leaves in a plant canopy and its maximum occurred when all leaves are exposed to sunlight, this condition happened when the lentil is at early stages of growth and leaves are so large that none of them is in the shade (Gordner *et al*., 1985) [4].
The drought stress at flowering and pod filling stages caused a dramatic decrease in NAR because the lentil in the reproductive stage had an active growth and drought stress caused decreasing trend of NAR. At the end of growing season, NAR in all treatments increased slightly due to falling leaves and decrease shading of leaves on each other and also photosynthesis of pods. Rezaeyanzadeh (2008) [9] concluded that if it can be prevented from occurring drought stress at flowering stage with supplemental irrigation, NAR increased and the slope of NAR rate smoothly decreased. Since the onset of flowering stage coincided with a high rate of photosynthesis and plant growth, so irrigation at this stage improved photosynthetic activity and thus increased the NAR.
According to findings of Gordner *et al*., (1985) [4], the amount of NAR didn't remain constant over time, and as the age of the plant increased, a declining trend observed in growth and development, and this trend was also accelerated in an inappropriate environment and drought stress conditions. Moreover, the new leaves are overlapped on each other which led to decrease dry weight per unit leaf area.

Plant growth rate (PGR)

In all treatments, plant growth rate initially increased and then decreased and finally, its trend became negative at the end of growing season. This trend was observed due to increased absorption of solar radiation along with the increase leaf area during growing season which led to increase the rate of dry matter accumulation in lentil. As shown in Fig. 3, PGR increased in the control treatment with a steady slope up to 61 days after emergence and subsequently decreased. It seems that by increasing the leaf area in non-drought stress condition, a higher light was received by the lentil, which led to improve PGR due to increase photosynthesis. Under drought stress, PGR decreased due to reduction in leaf area, the amount of photosynthesis and the occurrence of leaf senescence.
Goldani and Rezvani (2007) [3] concluded that, PGR decreased due to increased respiration and reduction of photosynthesis in drought stress condition. The drought stress at flowering and pod filling stages was caused a Sharp decline in PGR up to 51 days after emergence and then after this time up to 61 days after emergence, an amount of increase of this treatment was as much as the half of the control and at the end of growing season had decreasing trend. On the other hands, the yellowing and falling of leaves that occurred under drought stress period did not recover.
According the curves of PGR and leaf area, it can be approved that the maximum PGR was obtained before the maximum leaf area was occurred, when the PGR reached its maximum, the leaf area still had an increasing trend. PGR

was directly dependent on the leaf area and NAR. On the other hand, with the progress of time, NAR had a decreasing trend, which can decrease the PGR. At the end of growing season, PGR declined due to the stopping of vegetative growth, senescence of leaves, the reduction of NAR and also the allocation of assimilates to the seeds.

Relative growth rate (RGR)

As shown in Fig. 4, in all treatments, the RGR decreased with aging of the plant, because the parts that were added to the plant were structural tissues that were not metabolically active and did not have a role in photosynthesis (Karimi & Siddique, 1991) [5]. At the beginning of the growing season, the amount of RGR is boosted due to greater light penetration, less leaf shading, and higher NAR.

The drought stress in the flowering and pod filling stages greatly reduced the RGR by 51 days after emergence, and then remained constant. As the results approved in Fig. 1, drought stress in these stages reduced the leaf area and did not compensate it until the end of the growth period, and furthermore, the exacerbation of leaf loss caused a decrease trend in the RGR. How evere, the RGR at the end of the growing season had negative trend due to physiological ripening and increased respiration of the seeds as well as aging and leaf loss and the reduction of the current photosynthesis of the lentil canopy (Gordner *et al*., 1985) [4]. Rezaeyanzade (2008) [9] reported that supplemental irrigation at the flowering stage increased the RGR and also decreased the slope of the curve. This reduction is somewhat related to the shading and the aging of the lower leaves of the lentil canopy.

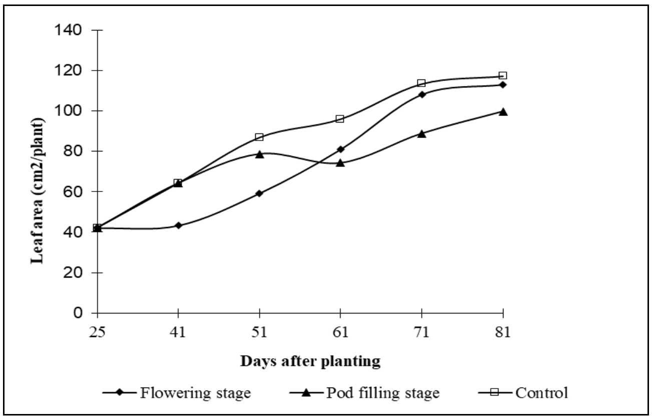

Fig 1: The effect of drought stress at flowering and pod filling stages on leaf area at days after emergence.

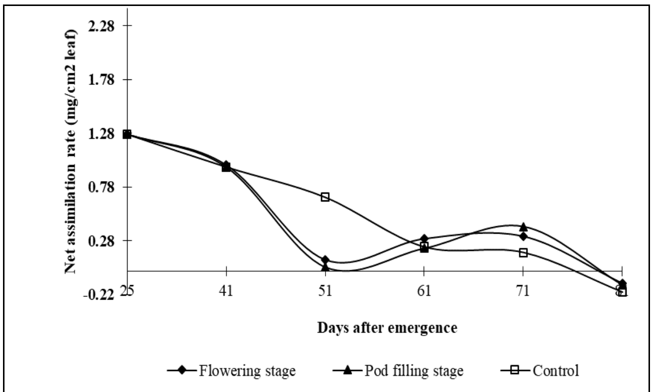

Fig 2: The effect of drought stress at flowering and pod filling stages on net assimilation rate at days after emergence.

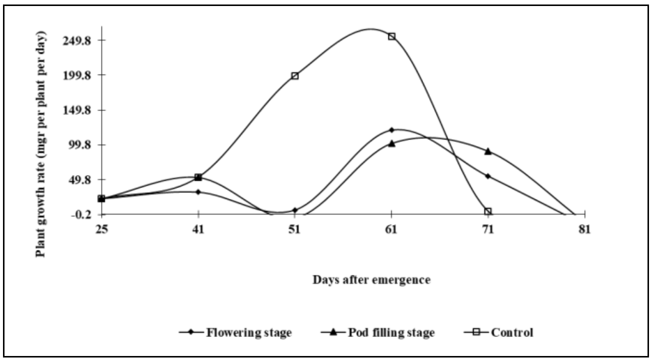

Fig 3: The effect of drought stress at flowering and pod filling stages on plant growth rate at days after emergence.

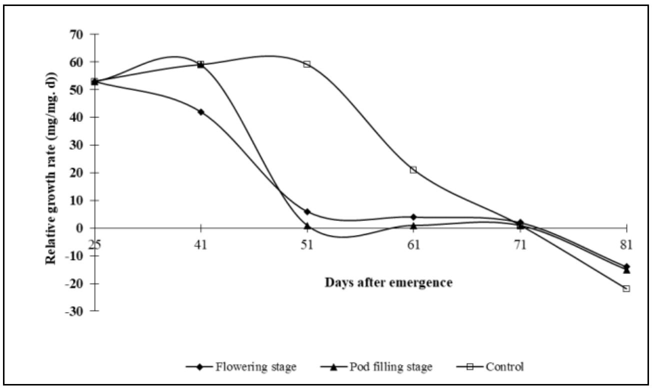

Fig 4: The effect of drought stress at flowering and pod filling stages on relative growth rate at days after emergence.

Conclusion

The results showed that flowering stage was the most sensitive stage of lentil growth to drought stress. Drought stress at this critical stage decreased the flowering period, number of flowers, pale and leaf loss, resulting in reduced photosynthetic dry matter to support the seeds and finally, decrease the growth indices such as LAI, RGR, PGR and NAR. It was recommended to avoid drought stress at the onset of flowering stage because coincided with a high rate of photosynthesis and plant growth, therefore irrigation at this stage boosted photosynthetic activity and consequently increased the NAR.

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