ISSN: 0975-766X
CODEN: IJPTFI
Available Online through ***Research Article***
www.ijptonline.com

THE EFFECT OF DROUGHT STRESS ON THE PROCESS OF LENTIL GENOTYPES GROWTH INDEXES

Mehdi Panahyan-e-Kivi
Department of Agriculther, Payame Noor University, Tehran, Iran.

Received on: 18.10.2016 *Accepted on: 11.11.2016*

Abstract

To study variation trend of growth indices in lentil under drought stress, an experiment was conducted in Ardabil Agricultural Research Station in 2007. The experiment was a split-plot design based on Completely Randomized Block Design (CRBD) with four replications. Treatments included three lentil genotypes (Ardabil indigenous genotype, ILL4400 and ILL6212) and four irrigation levels [irrigation on the basis of 60 mm evaporation from basin class A (I_1), irrigation on the basis of 80 mm evaporation from basin class A (I_2), irrigation on the basis of 100 mm evaporation from basin class A (I_3) and no-irrigation (I_4)]. Irrigation levels were considered as the main plots and genotypes as the sub-plots. Results showed that among different irrigation levels, ILL4400 had the highest dry weight. ILL6212 had the highest dry matter at irrigation level of I_4 . At irrigation level of I_4 , ILL6212 had the highest growth rate and at irrigation level of I_1 , ILL4400 had the best growth. ILL4400 had higher relative growth rate than other cultivars and it started to decrease with a slow gradient in other cultivars. In the case of phonological traits, Ardabil indigenous genotype had the highest plant height and axillary branch no. at irrigation level of I_1 . The highest days to flowering and days to maturity was achieved at irrigation level of I_1 (i.e. the most frequent irrigation) and among cultivars, Ardabil Indigenous genotype and ILL4400 stood in a same group and ILL6212 flowered in a shorter time so that genotype ILL4400 had the highest yield at irrigation level of I_2 and genotype ILL6212 and Ardabil indigenous cultivar stood in the next ranks. And irrigation level of I_4 had the lowest yield.

Key words: crop growth rate, relative growth rate, dry matter, phonology, lentil, drought

Introduction

Lentil is well adapted to low-precipitated areas where annual precipitation is less than 400 ml and wheat cultivation is popular (Koochaki and Sarmadnia, 2001). W hen a plant starts its reproductive growth and proceeds towards maturity, providing its required water through complementary irrigation increases its yield (Sarker et al., 2003). Plant growth consists of a series of biochemical and physiological process which are in interaction and are affected by environmental factors. Produced dry matter of a plant can be studied by such indices as growth rate and relative growth rate, both are two most important and perhaps most meaningful growth indices (Gordner et al., 1985; Karimi and Siddique, 1991). The most meaningful term in analyzing the growth of plants is crop growth rate which shows the amount of dry matter accumulation in a plant during a given period of time in unit area. Moisture deficiency can limit crop cover and decrease crop growth rate by negatively affecting various morph-physiological processes (Emam and Niknejhad, 2004). In a study on to lentil cultivars, Kafi et al. (2005) showed that crop growth rate was over 40% greater in all steps of complete irrigation than in one-step irrigation. They showed that in most studied varieties, relative growth rate reached to its peak shortly before flowering. W ith the commencement of reproductive growth, relation growth rate starts to decline and reaches negative amount at the end of this stage due to leaf shedding and the decrease in dry matter. Studies show that at the end of growth season, accumulated dry matter decreases in sunflowers and groundnuts (Chimenti et al., 2002) all due to leaf shedding (Sarker et al., 2003). Relative growth rate decreases with time which is caused by the increase in leaf area index and the increase in leaf number which shade the previous leaves. The senescence of lower leaves decreases photosynthesis, too. On one hand, relative growth rate is, by definition, the ratio of added dry matter to previous one and since this ratio increases over time it was lower than dry matter accumulation; and on the other hand, most dry matter is used in making tissues and structure, and photosynthetic activities are not involved and therefore, relative growth rate linearly decreases over the time.The objective of the experiment was to study the trend of growth indices variation in lentil cultivars under drought stress and to determine the best irrigation level and lentil genotype for Ardabil Region.

Materials and Methods

To evaluate the variation trend of growth indices of lentil genotypes under drought stress, an experiment was conducted in Ardabil Agricultural Research Station with four replications in 2007 based on split-plot with Completely Randomized Block Design. Treatments included three lentil genotypes (Ardabil indigenous, ILL4400 and ILL6212) and four irrigation levels (I1 , irrigation based on 60 mm evaporation from basin Class A; I2 , irrigation based on 80 mm evaporation from basin Class A; I3 , irrigation based on 100 mm evaporation from basin Class A; and I4, no-irrigation). Irrigation levels constituted main plots and cultivars constituted sub-plots. Ardabil has a semi-arid climate with very cold winters and moderate springs and summers. Located at the altitude of 1350 m from sea level and with a mean annual precipitation of about 400 mm, it has a favorable condition for lentil cultivation. After planting lentil at April 17, evaporation was started to be measured and after recording evaporation level equivalent to each treatment, they were irrigated. The amount of water at each irrigation was 80% of evaporated water from basin. Samples were taken five times once seven days started from week 4. Each time, from each plot 6 samples were randomly taken from rows 2 and 3 and after recording their axillary and main branch number as well as measuring plant height, they were put in oven for 48 hours and then their dry matter was weighed. Finally, growth index curve was drawn using gathered data. To calculate CGR and RGR in terms of GDD, equations 1-3 and 2-3 were used (Russel et al., 1984).

Equation (1-3)

$$CGR = \frac{\Delta DM}{\Delta H}$$

Equation (2-3)

$$RGR = \left(\frac{1}{DM}\right)\left(\frac{\Delta DM}{\Delta H}\right)$$

where

DM = shoot dry matter (g/m2), H = heat index (ÓHi) (GDD).

Hi was calculated by equation 3 for each day from planting to sampling date (Russel et al., 1984).

$$H_i = \left[\frac{T_{max} - T_{min}}{2}\right] - T_b$$

Equation (3)

In this equation, Hi is GDD for the day i, Tm a x is the maximum daily temperature with the highest threshold of 40°C, Tm in is the minimum daily temperature with lower threshold of 10°C and Tb is base temperature (a temperature under which growth is impossible) which was considered as 5°C for lentil. To determine a mathematical equation with the capability of expressing the variations of dry matter weight in terms of head index, Software Excel was used. W ith this software, different polynomial equations were examined to find the equation best fitted to observed data. Among examined equation, equation 4-2 had the best R2 coefficient for predicting shoot dry matter weight variations in terms of heat index (Emam and Niknejhad, 2004).

$$DM = a + bH + cH^2 + dH^3$$

Equation (4)

where, DM is shoot dry matter, H is heat index in terms of GDD and a, b, c, and d are the constants. CGR and RGR were calculated by equations 5 and 6 (Emam and Niknejhad, 2004).

$$CGR = b + 2cH + 3dH^2$$

Equation (5)

Equation (6)

$$RGR = \frac{b + 2cH + 3dH^2}{a + bH + cH + dH^3}$$

Data was analyzed by Software SAS and means comparison was carried out by Duncan Test on the probability level of 5% and Software Excel was used for drawing the diagrams

Results and Discussion

Grain Yield:

Irrigation significantly affected grain yield and I2 level produced the highest grain yield (Table 1). In I2 treatment, plants were irrigated twice from the beginning of seed feeling to the end of flowering. In I1 treatment, plants were irrigated five times which led to the supply of enough water at early stages of vegetative growth and as a result, axillary branch no. and husk no. increased, but deficient irrigation led to the shedding of most husks and producing unfilled grains and finally, decrease in yield.

I2 treatment produced the highest grain yield (1340 kg) and I3 treatment by producing a grain yield of 1100 kg stood in the next rank. The treatment I1 and I4 with grain yields of 869 and 893 kg/ha had the lowest one. In treatment I4 , due to the coincidence of grain filling period with early summer hotness, reproductive growth was disrupted and flowers shed and then, fewer grains were filled.

Ta b le 2: Means of yield in relation with the interaction between genotype and irrigation level in lentil

Genotype	Irrigation level	Y yield(kg ha- 1)
V 1	I1	863e
	I2	1071cd
	I3	668f
	I4	744f
V 2	I1	749f
	I2	1459b
	I3	1126c
	I4	658f
V 3	I1	996d
	I2	2921a
	I3	646f
	I4	1063cd

***N umbers w with same w ords in each column, have no significant differences to each other.**

Among cultivars, genotype ILL4400 had the highest grain yield (1308 kg) and ILL6212 and Ardabil indigenous cultivar were stood in the next ranks (with grain yields of 1098 and 836 kg). The interaction of ILL4400 × I_2 produced the highest yield (2921 kg/ha) and I_3 × ILL4400 and I_4 , I_1 × ILL6212 stood in same group and produced the lowest yield (668 and 744 kg/ha, respectively) (Table 2).

Among different levels of irrigation, I_2 produced higher yield due to foregoing reasons including higher filled husk, higher husk no. and greater grain weight/plant. The decrease in grain yield due to water deficiency has been reported by others for groundnut, beans and corn (Koochaki and Sarmadnia, 2001) and for lentil (Hudak and Patterson, 1995).

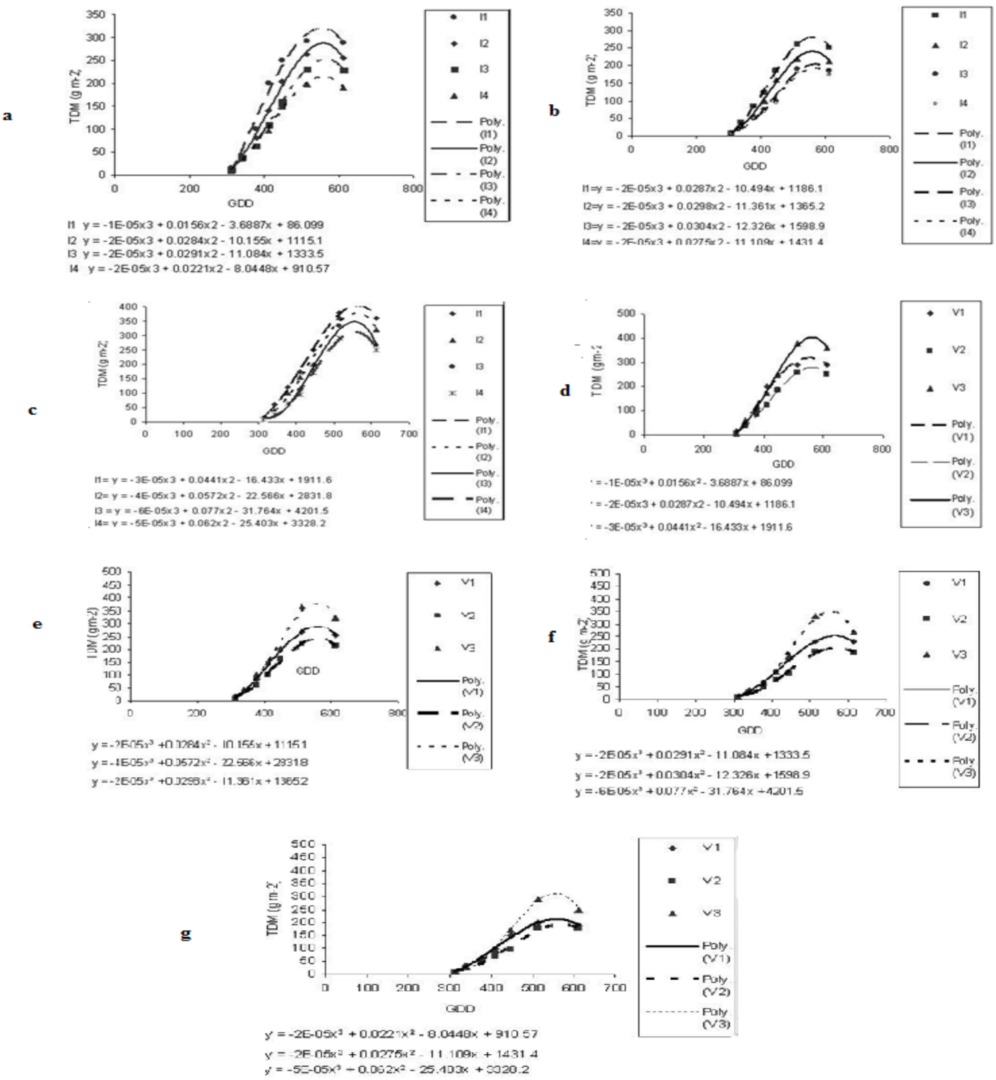
Table-1: Effect of irrigation and genotype on means of traits associated with the yield of lentil.

	Days to Maturity (D TM)		Yield (kg ha^{-1})
Irrigation			
I_1	98	.2a	869c
I_2	96	.11b	1340a
I_3	94	.88c	1100b
I_4	94	.44c	893c
V_1	97	.5a	836b
V_2	93	.5b	1098ab
V_3	96	.6a	1308a

***N umbers with same words in each column, have no significant differences to each other.**

Plant Total Dry Matter (TDM)

The trend of variations of TDM and its prediction equation are shown in fig a to g. Prediction curves of shoot dry matter per GDD of Ardabil indigenous cultivar from planting to harvest showed that the relation of dry matter accumulation with GDD was a kind of polynomial. Since sampling was started 25 days after planting, at early stages rapid growth started due to favorable climatic condition and curve slope increased. In this stage, great photosynthesis due to greater leaf area sharply increased dry matter and approaching husk formation stage, dry matter was roughly settled and at final stages, it started to fall due to leaf senescence and their shedding. W ith a close look at growth curve it can be seen that I_1 lead to the production of more dry matter but besides had more severe fall at final stages. Since in this treatment, irrigation was more frequent, vegetative growth was greater at first stages and therefore more dry matter was produced, but it had more severe decrease at final stages. Source limitation caused husk shedding, seed abortion as well as leaf shedding and finally the decrease in TDM . Variation trend of dry matter was indifferent among different cultivars, but its amount was affected by plant volume and early-maturity of genotypes so that dry matter accumulation comparison in Ardabil indigenous cultivar at different irrigation levels showed that at I_1 , dry matter was 15 g/m ^{2} after 25 days with a GDD of 311 and 290 g/m^2 after 95 days with a GDD of 613; at I_2 , there was no considerable difference at the first sampling and it decreased to 255 g/m^2 due to the less frequent irrigation than I_1 and at I_3 and I_4 , it decreased to 225 and 190 g/m^2 , respectively. ILL6212 with the lowest plant volume accumulated 7.8 g dry matter/m^2 at I_1 at the first sampling and 251 g dry matter/m^2 at the last one. I_2 , I_3 and I_4 which did not have a considerable difference, accumulated 212, 185 and 175 g dry matter/m^2 95 days after planting, respectively. At I_1 irrigation level, ILL4400 had higher dry matter due to greater foliage and higher plant volume. Its TDM was 8.7 g/m^2 at the first sampling and 361 g/m^2 at 95 days after planting which was higher than other cultivars. The amount of accumulated dry matter at irrigation levels of I_2 , I_3 and I_4 was 320, 266 and 250 g/m^2 , respectively. TDM of ILL4400 at the level of I_4 was equal to that of ILL6212 at I_1 .



a: Variation curve of DM per GDD in Ardabil indigenous cultivar.

b: Variation curve of DM per GDD in ILL6212.

c Variation curve of DM per GDD in ILL4400.

d: Variation curve of DM per GDD from planting date in studied cultivars at irrigation level of I1 (60 mm evaporation from basin)

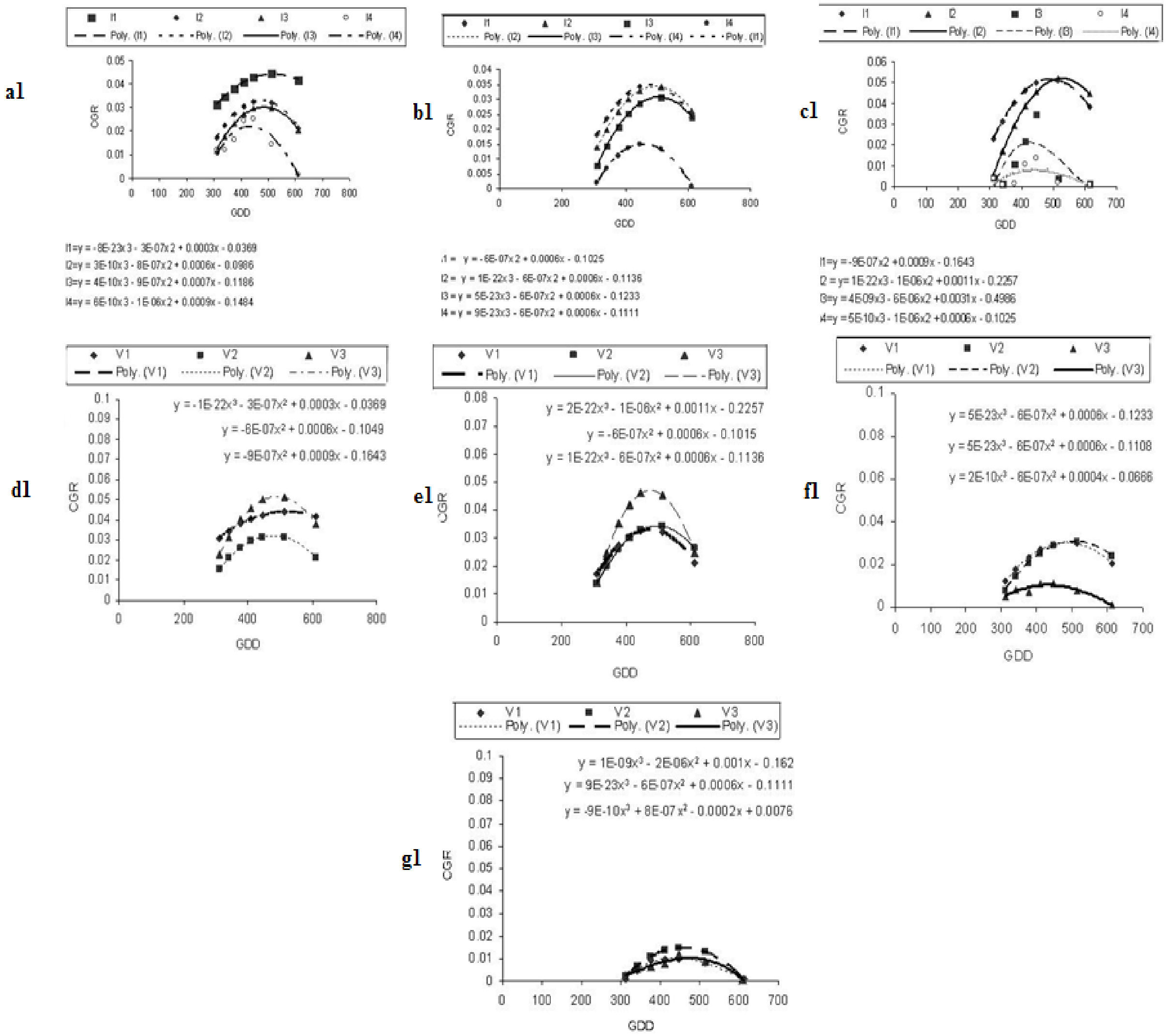
e: Variation curve of DM per GDD from planting date in studied cultivars at irrigation level of I2 (80 mm evaporation from basin)

f: Variation curve of DM per GDD from planting date in studied cultivars at irrigation level of I3 (100 mm evaporation from basin)

g:Variation curve Of DM per GDD from Planting date in studied cultivars without irrigation.

Crop Growth Rate (CGR):

The trend of variations of CGR and its prediction equation are shown in fig a1 to f1. CGR rose with the increase in GDD and at irrigation level of I_1, reached to its maximum level in the range of 514 GDD i.e. 75 days after planting and then started to decrease. At irrigation treatment of I_2, CGR reached to its maximum level at 447 GDD which can be due to water and resource deficiency compared to treatment I_1. At irrigation levels of I_3 and I_4, the maximum CGR was gained at 447 GDD and then started to decrease. Cv. ILL6212 had the highest CGR at irrigation level of I_1 and started to sharply decrease at 514 GDD likely because of resource deficiency regarding the rapid vegetative growth which led to senescence and shedding of leaves. CGR at treatment of I_2 slowly decreased at final stages after irrigation and thus its curve stood over the others. CGR of ILL4400 at treatment of I_2 after 514 GDD outreached that at irrigation level of I_1 and its decrease trend had slack gradient compared to I_1 . As said, it could be due to resource limitation and extensive vegetative tissues. At initial stages of growth due to gradual increase in light absorption which is escalated by the increase in LAI, CGR increases and after reaching to its maximum level starts to decrease until reaching to a negative level due to the shadowing of lower leaves by upper ones and organs and acceleration of leaves senescence and decrease in photosynthetic capacity. This result is consistent with the findings of other researches about peas (Teran and Singh, 2002). At irrigation level of I_1 , at initial growth stages CGR of Ardabil indigenous cultivar was higher than that of other cultivars, but as the growth continued, the CGR of cv. ILL4400 sharply increased so that at 514 GDD, it outreached the other cultivars and then started to decrease. Hence, CGR of cv. ILL4400 was higher than that of other cultivars at optimum moisture condition. At irrigation level of I_2 , cv. ILL4400 had higher CGR and regardless of the high CGR that Ardabil indigenous cultivar had at initial stages, cv. ILL6212 outreached at subsequent stages. W ith the decrease in irrigation frequency (I_3), Ardabil indigenous cultivar had higher CGR at initial growth stages but at late stages, CGR of ILL6212 was higher so that it had the highest CGR at 514 GDD. And cv. ILL4400 had lower CGR from the beginning until the sampling than other cultivars. At treatment of no-irrigation (I_4), cv. ILL6212 had higher CGR followed by Ardabil indigenous cultivar and cv. ILL4400. Therefore, it can be concluded that in dry farming, that is when there is no available water, among the studied cultivars, cv. ILL6212 had better CGR and at irrigation level of I_1 , i.e. 5 times of irrigation, cv. ILL4400 had better growth.



A1: CGR at different treatment levels in Ardabil indigenous cultivar

B1: CGR at different levels of irrigation treatments in cv. ILL6212

C1: CGR at different levels of irrigation treatments in cv. ILL4400

D1: CGR of studied cultivars at treatment of irrigation after 60 mm evaporation from basin (I_1**)**

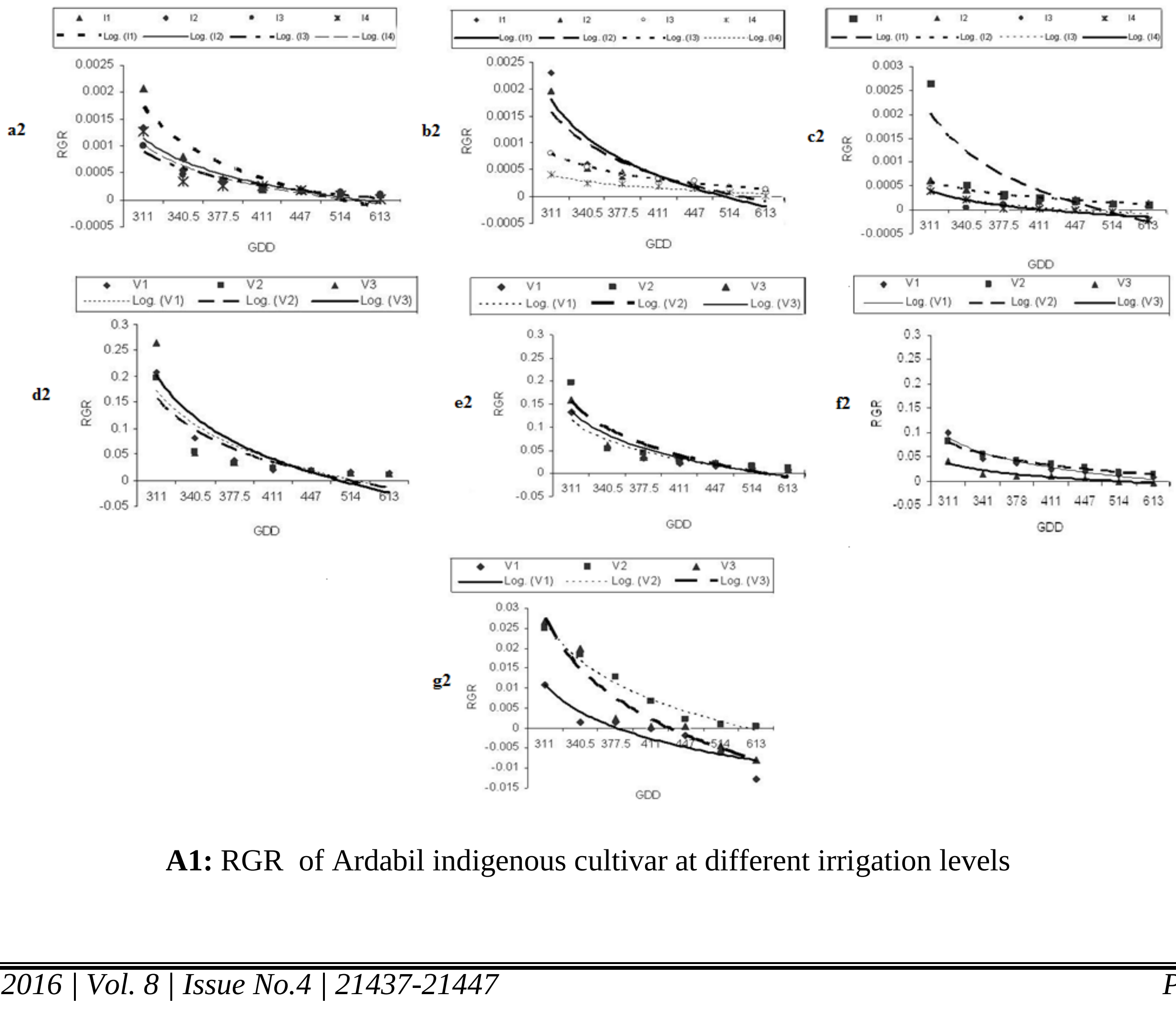
E1: CGR of studied cultivars at treatment of irrigation after 80 Mm Evaporation from basin (I_2)

F1: CGR of studied cultivars at treatment of irrigation after 100 mm evaporation from basin (I_3)

G1: CGR of studied cultivars at treatment of no-irrigation (I_4**)**

Relative Growth Rate (RGR):

The trend of variations of RGR and its prediction equation are shown in fig a2 to f2. Linear trend of the variations of RGR showed that it reached to its maximum level at 310 GDD and then decreased with a constant rate until the last sampling to zero at 550 GDD and then became negative. Some reasons of the decrease in RGR are the aging of lower leaves, their shadowing and the increase in tissues which are ineffective in photosynthesis. Other researchers observed the similar trend in corn (Emam and Niknejhad, 2004; Oweis *et al*., 2004) and peas. The irrigation level of I_1 increased vegetative growth of plants and their foliage. The curves of TDM and RGR at this treatment level stood over the other irrigation levels. Vegetative growth increase in this irrigation treatment may increase flowers and husks. At the same time, moisture deficiency at late growth stages led to a steep gradient of growth index curves due to the increased water demand by plants and lower availability of water at each irrigation. In an experiment, drought stress decreased pure photosynthesis level, CG R, seed yield and harvest index (Biarnes*et al*., 1996). The study of RGR trend in studied cultivars showed that despite of having a high RGR, RGR of cv. ILL4400 decreased with a slower gradient at late stages. At irrigation level of I_4 , the RGR of cv. ILL6212 started to decrease with slower gradient than that of Ardabil indigenous cultivar and ILL4400. Therefore, it appears that with the increase in the gradient of RGR curve which means faster decrease in dividable and active tissues can decrease the yield.



A1: RGR of Ardabil indigenous cultivar at different irrigation levels

B1: RGR of ILL6212 at different irrigation levels

C1: RGR of ILL4400 at different irrigation levels

D1: RGR of cultivars at irrigation level of I_1

E1: RGR of cultivars at irrigation level of I_2

F1: RGR of cultivars at irrigation level of I_3

G1: RGR of cultivars at irrigation level of I_4

Conclusion:

Growth indices including dry matter accumulation, relative growth rate and crop growth rate was different among different studied cultivars of lentil. Cv. ILL4400 and Ardabil indigenous cultivar had the highest TDM, RGR and CGR, respectively and dry matter increased with the increase in irrigation frequency. But the trend of CGR was various so that at irrigation level of I_1 , cv. ILL4400 had the highest CGR and with the decrease in irrigation frequency and applying more severe stress, cv. ILL6212 reached to the highest CGR. Therefore, in regions with the possibility of irrigating lentil, using irrigation during grain filling period can increase grain yield which under this condition, the genotype ILL4400 will had the highest yield but in the regions where irrigation is impossible, genotype ILL4400 can be used which has stronger resistance against stress that other cultivars and will produce the highest yield under dry farming.

References

1. Biarnes Dumoilin, V., J.B. Denis, I. Lejeune Henaut and G. Eteve, 1996. Interperting yield instability in Pausing genotype can denvironmetalco variates. Crop Science, 36: 115-120 , http://cat.inist.fr/?aM odele=afficheN & cpsidt=2958381
2. Chimenti, C., A. Pearson, and J. Hall, 2002. Osmotic adjustment and yield main teance under drought in *sunflower*. Field Crop Research. 75:235-246.
3. Emam, Y., M . Niknejhad, 2004. An Introduction to the physiology of crop yield (translation). Shiraz university press. Shiraz. Iran. Edition Number: 2. ISBN: 964-462-218-9.
4. Gordner, F., R. Pearce and R.L. Mitchell, 1985. Physiology of crop plants. Iowa state university press, Ames USA.Ames 1985. 327 pp. http://www.springerlink.com/content/6kp87386481p7751/. DOI:10.1007/BF02902309
5. Hudak, C.M . and R.P. Patterson, 1995. Vegetative growth analysis of a drought-resistant soybean plant introduction. Crop Science, 35: 464-471. http://crop.scijournals.org/cgi/content/abstract/35/2/464

6. Kafi, M ., M . Lahooti, E. Zand, H.R. Sharifi and M. Gholdani, 2005. Plant physiology (translation). Jehad Daneshgahi Mashhad press. Mashhad. Iran. Edition Number: 5. ISBN: 964-324-005-3
7. Karimi, M .M . and M . Siddique, 1991. Crop growth and relative growth rate of old modern *wheat* cultivars. Aust. J. Agric. Res., 42: 13-20. http://www .publish.csiro.au/paper/AR9910013.htm
8. Koochaki, A., G.H. Sarmadnia, 2001. Physiology of crop plants (translation). Jehad Daneshgahi Mashhad press. Mashhad. Iran. Edition Number: 9. ISBN: 964-6023-92-4.
9. Oweis, T., A. Hachum, M . Pala, 2004. lentil production under supplemental irrigation in a Mediterrance environment. Agri W ater Manegment. 68: 251-265. http://www.sciencedirect.com/science/article/B6T3X-4CS4ND5-2/2/1b0e88959221ea18fefe1d7be0aa8a82
10. Russel, M .A., W .W . W ilhelm, R.A. Olson and J.F. Power, 1984. Growth analysis based on degree-days. Crop. Science, 24: 28-32. http://crop.scijournals.org/cgi/content/abstract/24/1/28
11. Sarker, A ., W . Erskin, M . Singh, 2003. Regrasion models for lentil seed and straw yield in Near East. Agric forest Meteor .116:61-72. DOI:10. 1016/S0168-1923 (02) 00247 -2
12. Teran, H. and S.P. Singh, 2002. Comparison of sources and lines selected for drought resistance in *common bean*. Crop Sci. 42: 64-70. http://crop.scijournals.org/cgi/content/full/42/1/64.