

## Study of Variation Trend of Growth Indices in Lentil under Drought Stress

<sup>1</sup>Mehdi Panahyan-e-Kivi and <sup>2</sup>Shahzad Jamaati-e-Somarin

<sup>1</sup>Department of Agronomy, Payam Noor University, Ardabil. Iran.

<sup>2</sup>Young Researchers Club, Islamic Azad University-Ardabil Branch, Ardabil. Iran.

**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 phenological 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, phenology, 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). When 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. With 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.

**Corresponding Author:** Shahzad Jamaati-e-Somarin, Young Researchers Club, Islamic Azad University-Ardabil Branch, Ardabil. Iran.

Email: jamaati\_1361@yahoo.com,

Tel: +989141594490.

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 ( $I_1$ , irrigation based on 60 mm evaporation from basin Class A;  $I_2$ , irrigation based on 80 mm evaporation from basin Class A;  $I_3$ , irrigation based on 100 mm evaporation from basin Class A; and  $I_4$ , 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).

$$\text{Equation (1-3)} \quad CGR = \frac{\Delta DM}{\Delta H}$$

$$\text{Equation (2-3)} \quad RGR = \left( \frac{1}{DM} \right) \left( \frac{\Delta DM}{\Delta H} \right)$$

where

DM = shoot dry matter ( $g/m^2$ ),

H = heat index ( $\Sigma H_i$ ) (GDD).

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

$$\text{Equation (3)} \quad H_i = \left[ \frac{T_{\max} - T_{\min}}{2} \right] - T_b$$

In this equation,  $H_i$  is GDD for the day  $i$ ,  $T_{\max}$  is the maximum daily temperature with the highest threshold of  $40^\circ C$ ,  $T_{\min}$  is the minimum daily temperature with lower threshold of  $10^\circ C$  and  $T_b$  is base temperature (a temperature under which growth is impossible) which was considered as  $5^\circ C$  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. With 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  $R^2$  coefficient for predicting shoot dry matter weight variations in terms of heat index (Emam and Niknejhad, 2004).

$$\text{Equation (4)} \quad DM = a + bH + cH^2 + dH^3$$

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).

$$\text{Equation (5)} \quad CGR = b + 2cH + 3dH^2$$

$$\text{Equation (6)} \quad RGR = \frac{b + 2cH + 3dH^2}{a + bH + cH^2 + dH^3}$$

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

### **Plant Height and Axillary Branch No:**

From the viewpoint of plant height, there was no significant difference among cultivars. Evaluation of phenological stages in lentil and variance analysis results showed significant effect of irrigation and irrigation by cultivar interaction on plant height on the probability level of 1%. Under field condition, with the increase in water deficiency, plant height significantly decreased so that I<sub>1</sub> had the highest plant height (25.56) and I<sub>4</sub> had the lowest one (20.5). With the decrease in irrigation frequency, plant height decreased. According to results, there was a significant difference among cultivars from the viewpoint of axillary branch no. on the probability level of 5%. ILL4400 had the highest axillary branch no. (5.29) and IL6212 had the lowest one. The reason for the latter was shorter canopy coverage of ILL6212. Irrigation treatment significantly affected axillary branch no. on the probability level of 5% so that with more irrigation frequencies, axillary branch no. stood in different groups so that I<sub>1</sub> treatment after 60 mm evaporation had the highest axillary branch no. (5.9) and I<sub>4</sub> had the lowest one (4). With the increase in water supply, canopy extended and axillary branch no. increased so that I<sub>3</sub> and I<sub>4</sub> stood in same group. In I<sub>1</sub> treatment, with irrigation at early vegetative growth period, axillary branch no. increased. The effect of water limitation on axillary branch no. and plant height has been considered in other studies (Fougereux *et al.*, 1997). Cultivar by irrigation interaction (Table 2) was significant on the probability level of 5% so that interaction means comparison showed that axillary branch no./plant of cv. ILL4400 and ILL6212 decreased with the decrease in irrigation level but Ardabil indigenous cultivar did not show significant difference among different irrigation levels.

### **Days to Flowering (DTF) and to Maturity (DTM):**

Studied cultivars started to flower in different times. According to means comparison (Table 1) DTF of cultivars was significant on the probability level of 1% and there were considerable differences among them so that ILL6212 had the lowest DTF (61.75) and Ardabil indigenous cultivar and ILL4400 were ranked in same group. Cultivars with shorter vegetative growth reached to their reproductive growth stage sooner. Irrigation level significantly affected DTF too. With the increase in irrigation frequency, required time to the flowering commencement increased so that it was 65.44, 64.66, 63.11 and 63.22 days at irrigation levels of I<sub>1</sub>, I<sub>2</sub>, I<sub>3</sub> and I<sub>4</sub>, respectively. DTMs of cultivars were significantly different ( $\alpha = 0.01$ ). ILL6212 had the greatest DTM (93.5 days) and ILL4400 and Ardabil indigenous cultivar stood in next ranks (with DTMs of 96.6 and 97.5 days, respectively).

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

	Auxiliary Branch No	Plant Height (cm)	Days to Flowering	Days to Maturity (DTM)	Yield (kg ha <sup>-1</sup> )
<b>Irrigation levels</b>					
I <sub>1</sub>	5.9a	25.56a	65.44a	98.2a	869c
I <sub>2</sub>	4.7ab	23.9a	64.66b	96.11b	1340a
I <sub>3</sub>	4.27b	21.5b	63.11c	94.88c	1100b
I <sub>4</sub>	4b	20.5b	63.22c	94.44c	893c
<b>Genotypes</b>					
V <sub>1</sub>	4.74a	22.75a	65.5a	97.5a	836b
V <sub>2</sub>	4.18c	22.6a	61.75b	93.5b	1098ab
V <sub>3</sub>	5.29b	23.85a	65a	96.6a	1308a

\*Numbers with same words in each column, have no significant differences to each other.

Means comparison of main effect of irrigation on DTM showed that irrigation significantly affected the trait too, so that with the increase in irrigation frequency, vegetative growth as well as vegetative growth period increased. In addition, under drought stress, plants started to flower sooner and DTM decreased so that in the study, I<sub>1</sub> had the highest DTM (98.22 days) and I<sub>2</sub>, I<sub>3</sub> and I<sub>4</sub> stood in the next ranks (with DTMs of 96.11, 94.88 and 94.44 days, respectively). Emam and Niknejhad (2004) reached to the same results.

**Grain Yield:**

Irrigation significantly affected grain yield and  $I_2$  level produced the highest grain yield (Table 1). In  $I_2$  treatment, plants were irrigated twice from the beginning of seed feeling to the end of flowering. In  $I_1$  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.  $I_2$  treatment produced the highest grain yield (1340 kg) and  $I_3$  treatment by producing a grain yield of 1100 kg stood in the next rank. The treatment  $I_1$  and  $I_4$  with grain yields of 869 and 893 kg/ha had the lowest one. In treatment  $I_4$ , 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.

**Table 2:** Means of traits associated with yield in relation with the interaction between genotype and irrigation level in lentil

Genotype	Irrigation level	Auxiliary Branch No	Yield(kg ha <sup>-1</sup> )
V <sub>1</sub>	I <sub>1</sub>	5.8b	863e
	I <sub>2</sub>	5.26b	1071cd
	I <sub>3</sub>	4.13cd	668f
	I <sub>4</sub>	3.76d	744f
V <sub>2</sub>	I <sub>1</sub>	4.33cd	749f
	I <sub>2</sub>	4.36cd	1459b
	I <sub>3</sub>	4.16cd	1126c
	I <sub>4</sub>	3.76d	658f
V <sub>3</sub>	I <sub>1</sub>	7.6a	996d
	I <sub>2</sub>	5.4b	2921a
	I <sub>3</sub>	4.53c	646f
	I <sub>4</sub>	4.46c	1063cd

\*Numbers with same words 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).

**Plant Total Dry Matter (TDM)**

The trend of variations of TDM and its prediction equation are shown in fig 1, fig 2, fig 3, fig 4, fig 5, fig 6, fig 7. 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. With 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<sup>2</sup> after 25 days with a GDD of 311 and 290 g/m<sup>2</sup> 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<sup>2</sup> due to the less frequent irrigation than  $I_1$  and at  $I_3$  and  $I_4$ , it decreased to 225 and 190 g/m<sup>2</sup>, respectively. ILL6212 with the lowest plant volume accumulated 7.8 g dry matter/m<sup>2</sup> at  $I_1$  at the first sampling and 251 g dry matter/m<sup>2</sup> 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<sup>2</sup> 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<sup>2</sup> at the first sampling and 361 g/m<sup>2</sup> 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<sup>2</sup>, respectively. TDM of ILL4400 at the level of  $I_4$  was equal to that of ILL6212 at  $I_1$ .

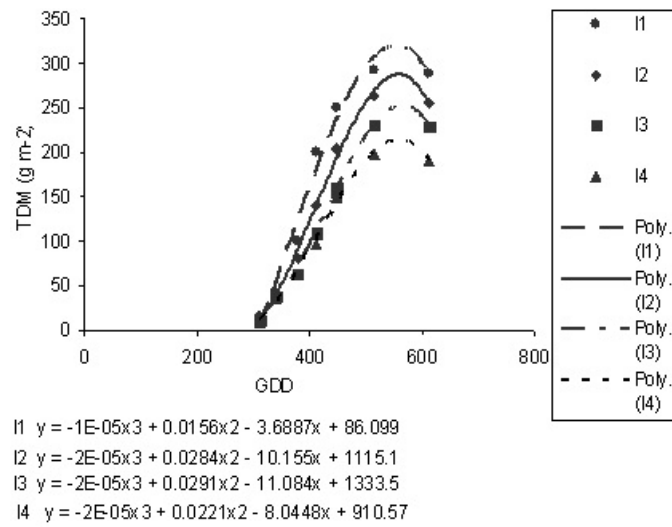


Fig. 1: Variation curve of DM per GDD in Ardabil indigenous cultivar.

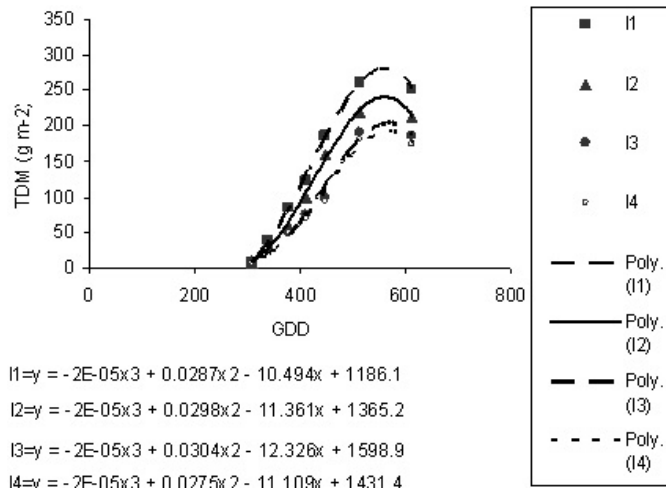


Fig. 2: Variation curve of DM per GDD in ILL6212.

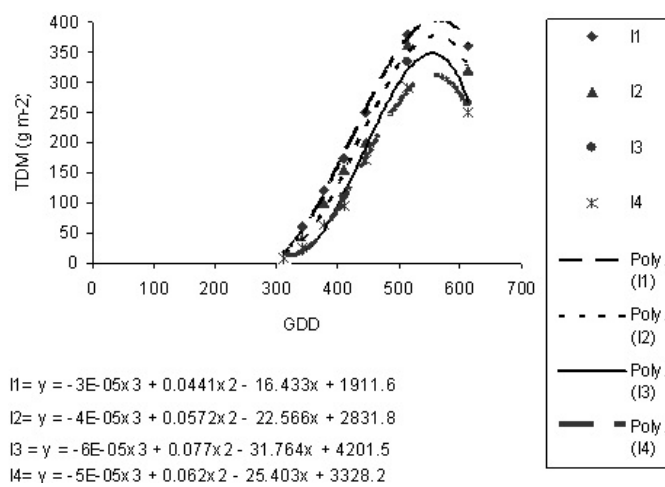
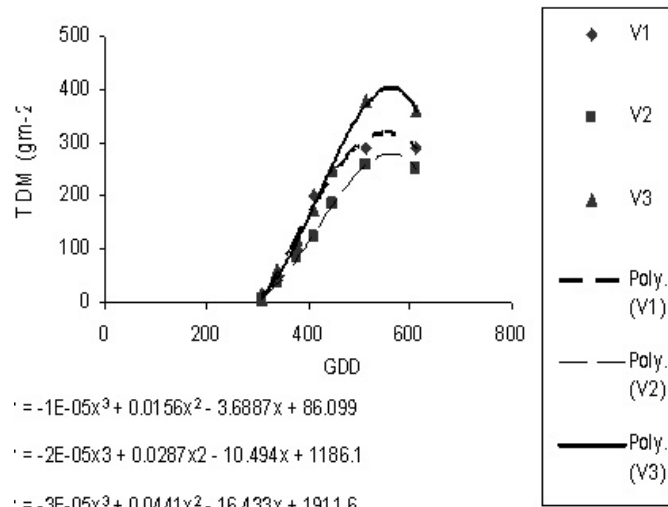
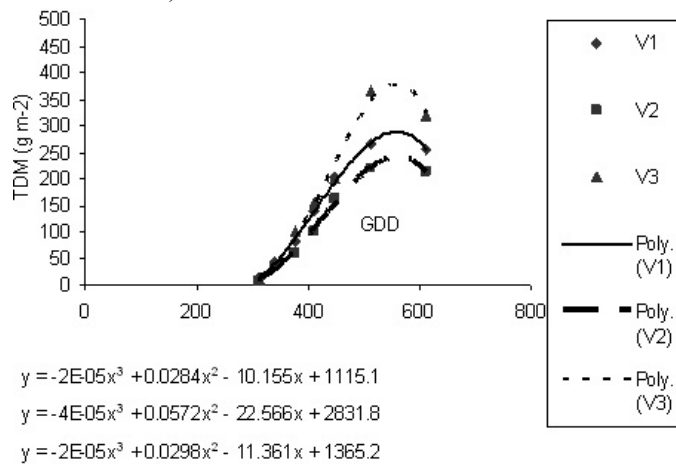


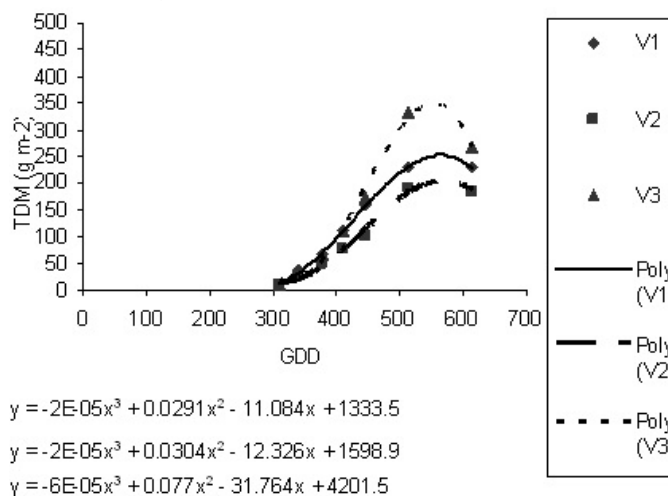
Fig. 3: Variation curve of DM per GDD in ILL4400.



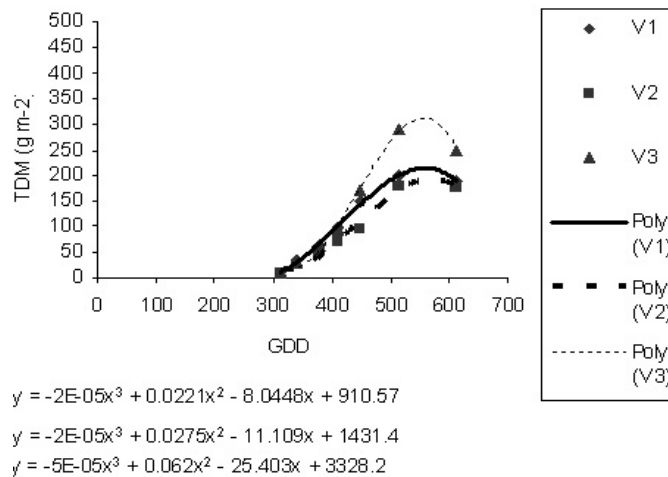
**Fig. 4:** Variation curve of DM per GDD from planting date in studied cultivars at irrigation level of I<sub>1</sub> (60 mm evaporation from basin)



**Fig. 5:** Variation curve of DM per GDD from planting date in studied cultivars at irrigation level of I<sub>2</sub> (80 mm evaporation from basin)



**Fig. 6:** Variation curve of DM per GDD from planting date in studied cultivars at irrigation level of I<sub>3</sub> (100 mm evaporation from basin)



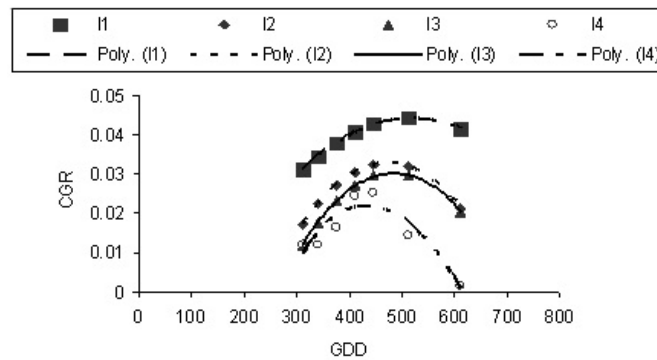
**Fig. 7:** Variation curve of DM per GDD from planting date in studied cultivars without irrigation.

The comparison of studied cultivars at different irrigation levels showed that ILL4400 had higher DM ( $380 \text{ g/m}^2$ ) than other cultivars and its DM accumulation started to fall with the increase in irrigation frequency and had the highest DM because of having higher foliage area. It has the highest DM at late stages because it was late-maturity cultivar and the falling of curve at these stages was due to the shedding of leaves and their rapid searing. Ardabil indigenous cultivar which was ranked after ILL4400 had the maximum DM of  $292 \text{ g/m}^2$ . ILL6212 had the lowest plant volume and even at irrigation level of  $I_1$  in spite of accessing to enough water just produced  $260 \text{ g DM/m}^2$ . ILL4400 produced the highest DM at irrigation level of  $I_4$  which had positive correlation with its yield, as ILL4400 had the highest yield among the cultivars. In different irrigation treatments of  $I_1$ ,  $I_2$ ,  $I_3$  and  $I_4$ , similar trend has been reported for peas (Kafi *et al.*, 2005).

**Crop Growth Rate (CGR):**

The trend of variations of CGR and its prediction equation are shown in fig 8, fig 9, fig 10, fig 11, fig 12, fig 13, fig 14. 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. With 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.



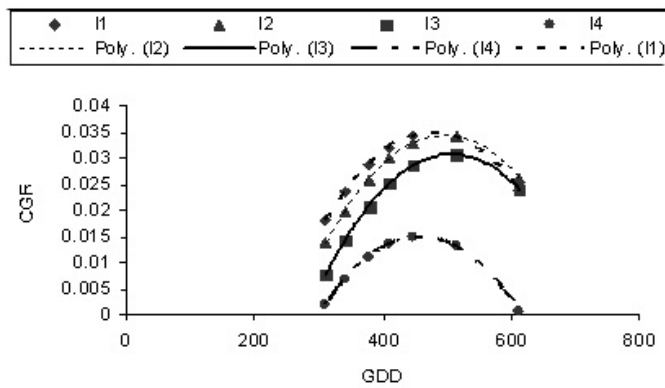
$$I1 = y = -8E-23x^3 - 3E-07x^2 + 0.0003x - 0.0369$$

$$I2 = y = 3E-10x^3 - 8E-07x^2 + 0.0006x - 0.0986$$

$$I3 = y = 4E-10x^3 - 9E-07x^2 + 0.0007x - 0.1186$$

$$I4 = y = 6E-10x^3 - 1E-06x^2 + 0.0009x - 0.1484$$

Fig. 8: CGR at different treatment levels in Ardabil indigenous cultivar



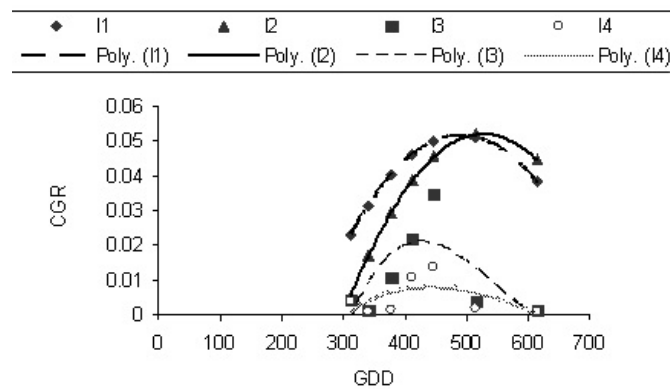
$$I1 = y = -6E-07x^2 + 0.0006x - 0.1025$$

$$I2 = y = 1E-22x^3 - 6E-07x^2 + 0.0006x - 0.1136$$

$$I3 = y = 5E-23x^3 - 6E-07x^2 + 0.0006x - 0.1233$$

$$I4 = y = 9E-23x^3 - 6E-07x^2 + 0.0006x - 0.1111$$

Fig. 9: CGR at different levels of irrigation treatments in cv. ILL6212



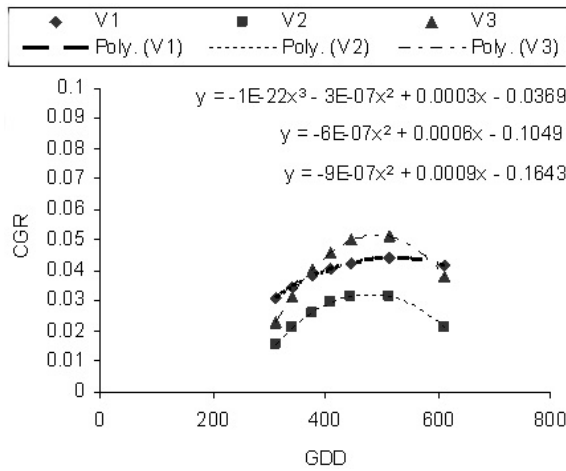
$$I1 = y = -9E-07x^2 + 0.0009x - 0.1643$$

$$I2 = y = 1E-22x^3 - 1E-06x^2 + 0.0011x - 0.2257$$

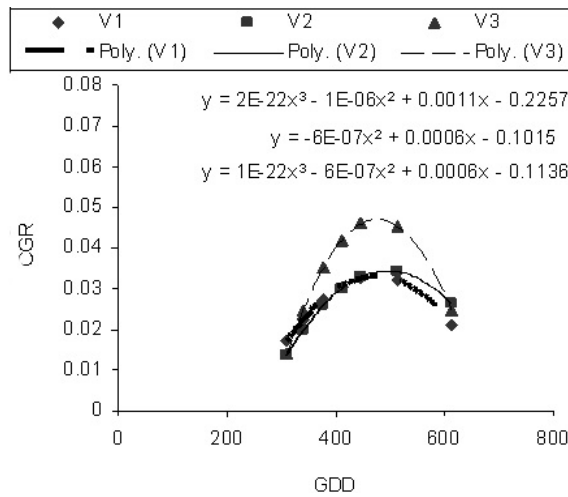
$$I3 = y = 4E-09x^3 - 6E-06x^2 + 0.0031x - 0.4986$$

$$I4 = y = 5E-10x^3 - 1E-06x^2 + 0.0006x - 0.1025$$

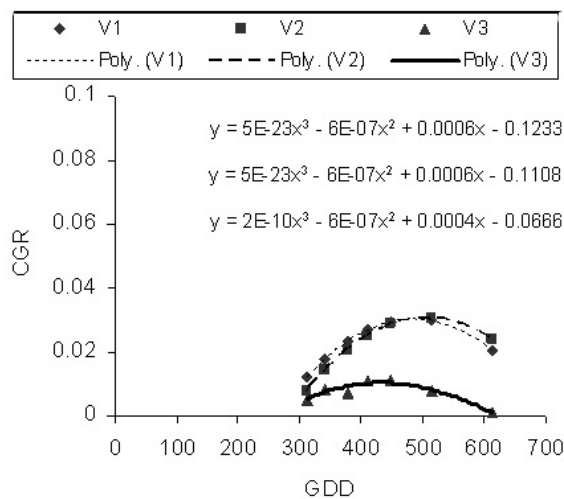
Fig. 10: CGR at different levels of irrigation treatments in cv. ILL4400



**Fig. 11:** CGR of studied cultivars at treatment of irrigation after 60 mm evaporation from basin (I<sub>1</sub>)



**Fig. 12:** CGR of studied cultivars at treatment of irrigation after 80 mm evaporation from basin (I<sub>2</sub>)



**Fig. 13:** CGR of studied cultivars at treatment of irrigation after 100 mm evaporation from basin (I<sub>3</sub>)

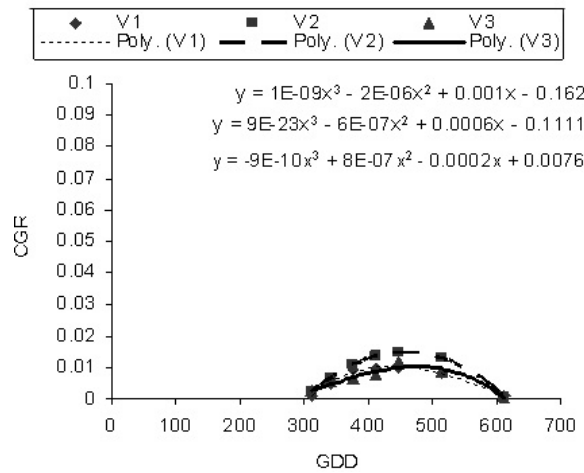


Fig. 14: CGR of studied cultivars at treatment of no-irrigation ( $I_4$ )

**4-4-3. Relative Growth Rate (RGR):**

The trend of variations of RGR and its prediction equation are shown in fig 15, fig 16, fig 17, fig 18, fig 19, fig 20, fig 21. 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, CGR, 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.

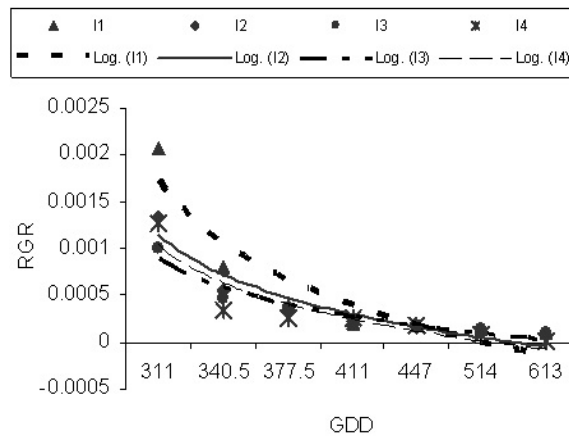
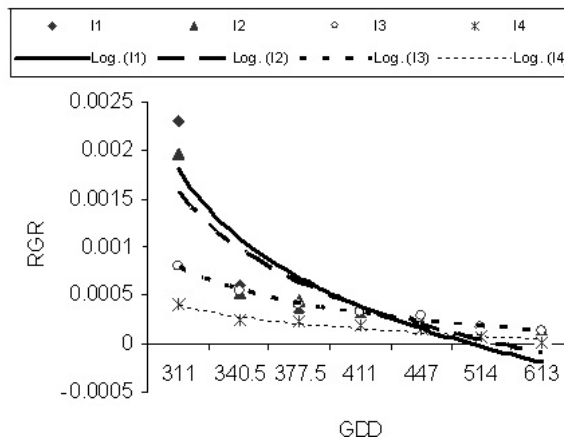


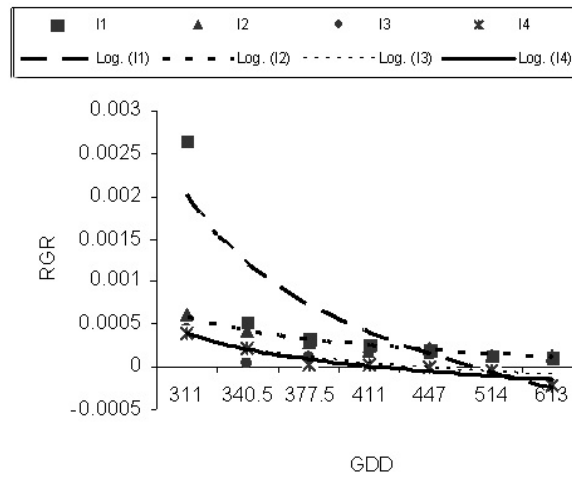
Fig. 15: RGR of Ardabil indigenous cultivar at different irrigation levels

**Conclusion:**

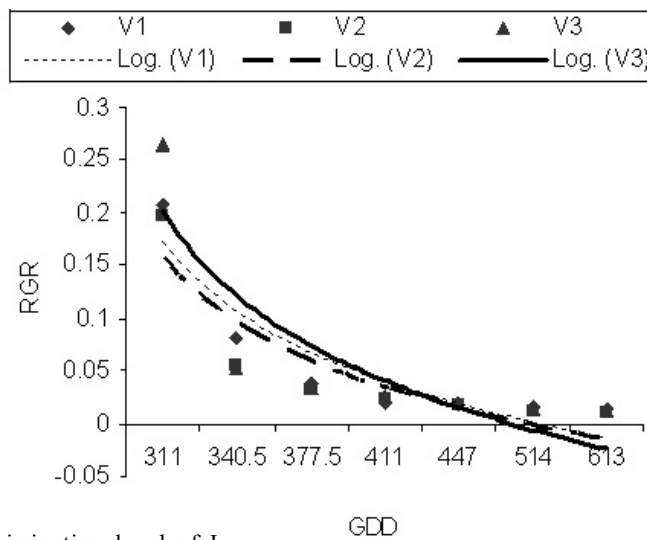
Growth indices including dry matter accumulation, relative growth rate and crop growth rate was different among different studied cultivars of lentil. Cv. ILL4400 and Ardabil indigenous cultivar had the highest TDM, RGR and CGR, respectively and dry matter increased with the increase in irrigation frequency. But the trend



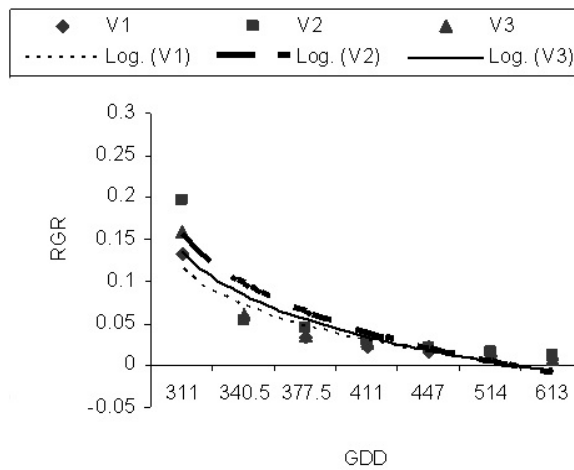
**Fig. 16:** RGR of ILL6212 at different irrigation levels



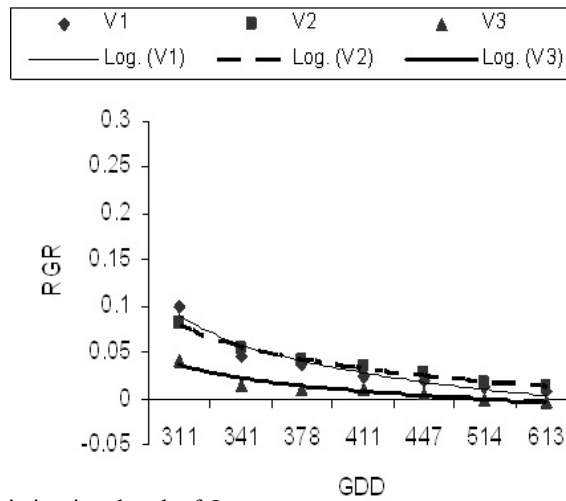
**Fig. 17:** RGR of ILL4400 at different irrigation levels



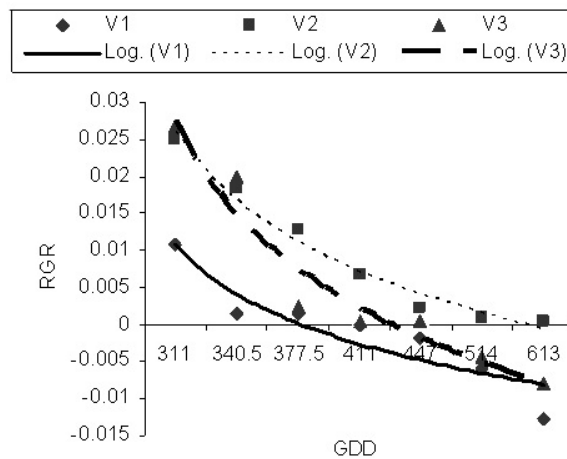
**Fig. 18:** RGR of cultivars at irrigation level of I<sub>1</sub>



**Fig. 19:** RGR of cultivars at irrigation level of  $I_2$



**Fig. 20:** RGR of cultivars at irrigation level of  $I_3$



**Fig. 21:** RGR of cultivars at irrigation level of  $I_4$

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.

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