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# Water deficiency and its effects on grain yield and some physiological traits during different growth stages in lentil (*Lens culinaris* L.) cultivars

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**ABSTRACT**

*In order to investigate the effect of different Water Deficiency levels on grain yield and some physiological characteristics of lentil cultivars, a pot experiment carried out as complete randomized block design with four replications at Faculty of Agriculture and Natural Resources, Razi University, Kermanshah in 2011. Experimental factors were include, water deficiency in two levels (control: without water deficiency, water deficiency during vegetative and reproductive growth stages from at -1.2 MPa) and four lentil cultivars (Landrace, Gachsaran, Kimia and Qazvin). Results showed that water deficiency had significant effect on grain yield, RWC, stomatal resistance, proline and chlorophyll fluorescence. Highest grain yield obtained in Gachsaran cultivar in control while in drought treatments landrace cultivar had upmost grain yield also this cultivar showed highest RWC, Fv/Fm, proline and least stomatal resistance.*

**Key Words**: Drought stress, Lentil, Chlorophyll Fluorescence, Stomatal Resistance.
***Abbreviations:*** *W.D: Water Deficiency, $S_1$: Control, $S_2$: Drought stress during vegetative growth stage, $S_3$: Drought stress during reproductive growth stage.*

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## INTRODUCTION

Among ordinary plants in arid and semi-arid regions, Pulse are one of the general plants that planted in non-fertilized soils and these plants are often sensitive to water deficit [21]. Lentil is one of the important plants which play a role in human nutrition because of its high leveled protein [14]. Cultivation of lentil in Iran is 220,000 ha and 92% of it planted as rain-fed condition [18].

Among all factors limiting crop productivity, drought remains single one important affecting the world security and sustainability in agricultural production [29]. A 6 to 54 percent decrease related to stress intensity and different regions in lentil yield was reported [16]. Reference [13] reported that beans have corresponding relation with drought stress and as increase in drought intensity, beans yield showed a downward trend. Also Reference [4] reported same results in soybean. Reference [12] said drought stress caused a severe fall in buds so that brings to yield decrease in some plants.

First and highest sensitive reaction in response to drought stress is decrease in cell swelling and its growth, so water stress has several physiological effects on plants including decline in photosynthetic rate with stomatal closing and increase in plant metabolism such as up rise of carbohydrates, proteins and nucleic acids [7].

Relative water content is a good sign for water status in plants and spot it better than water potential [20]. RWC decreased 45-88 percent in drought condition [10] and tolerant cultivars had more RWC in comparison with sensitive cultivars [17].

Stomatal closing is the first sign of defense against drought stress [26]. Stomatal resistance is a key factor in controlling energy and water transmit between plant and atmosphere [24]. Stomatal reaction as main factor for controlling water casualties is appreciable with stomatal resistance determination [25]. Reference [19] reported that drought stress caused a significant decrease in stomatal conductance and increase in stomatal resistance, also Reference [5] reported same results.

Chlorophyll fluorescence is survey for effect of different stress such as drought, heat etc. on leaf photosynthesis efficiency in field and green house conditions [27]. Based on Reference [22] Fv/Fm in crop plants is 0.832 as well as it ordinary is between 0.75 and 0.85. Distribution in photosynthetic system is one of the physiological reasons for decline in growth [22]. Reference [1] said the maximum quantum efficiency of photosystem II (Fv/Fm) shows a significant decrease in drought stress during vegetative and reproductive growth stages in mungbean.

As for above subjects, this experiment carried out to investigate the physiological characteristics in response to drought stress in different growth stages of lentil cultivars and study their relations with grain yield.

## MATERIALS AND METHODS

This experiment was carried out as pot experiment based on complete randomized block design with four replications at Faculty of Agriculture and Natural Resources, Razi University, Kermanshah in 2011. Experimental factors were Water Deficiency (WD) including control (without WD) (S1), WD during vegetative (S2) and reproductive growth stages (S3) until -1.2 MPa (Table 1 and Fig. 1) and four lentil cultivars including Landrace, Gachsaran, Kimia and Qazvin cultivars.

**Table 1. Soil characteristics in this experiment**

| Sand (%) | Silt (%) | Clay (%) | $Ca^{2+}$ (ppm) | $Mg^{+2}$ (ppm) | $Na^{+1}$ (ppm) | $K^{+1}$ (ppm) | N (%) | Organic matter (%) | Lime (%) | pH of saturated extract | ECe (ds/m) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 83 | 9 | 8 | 3.2 | 1.4 | 2.1 | 230 | 0.059 | 0.56 | 9 | 8 | 0.98 |

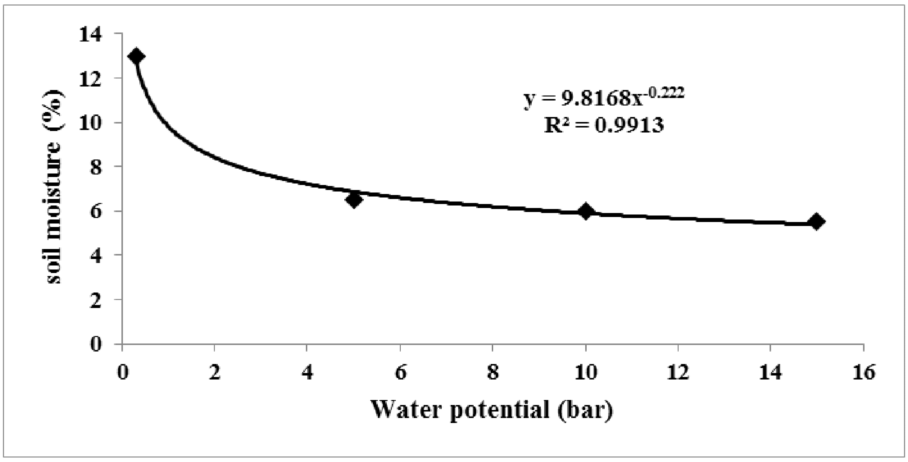


**Figure 1. The relationships between different levels of water potential and soil moisture (%) in tested soil in this experiment.**

Relative water content (RWC) was estimated according to the method of Reference [5] and calculated in the leaves for each drought period. Samples (0.5 g) were saturated in 100 ml distilled water for 24 h at 4° C in dark and their turgid weights were recorded. Then they were oven-dried at 65° C for 48 h and their dry weights were recorded. RWC calculated as follows:

$$\%RWC = (((Fw - Dw))/((Tw - Dw))) \times 100$$

Fw, Dw and Tw are fresh weight, dry weight and turgid weight, respectively.

Stomatal resistance calculated for each drought period with porometer (Decagon Devices INC. version 1.06). Chlorophyll fluorescence was measured by Pocket PEA chlorophyll fluorimeters (Hansatech Instruments, V 1.02) for each drought treatments.

Proline was determined as described by Bates et al., [2]. Leaf tissues (0.25 g) were rinsed three times with distilled water and the stoppered tubes with 10 ml water placed in a boiling water bath for 10 min to extract the hot water-soluble compounds. An aliquot of water extract was treated with ninehydrine reagent. Toluene phase was decanted and the absorbance was recorded at 520 nm by Elisa (Model: Power wave XS, made by Bio Tek, USA). Different concentrations of L-proline were used as standard.

Analysis of variance performed by using SAS 9.1 and MSTAT-C soft wars, also means comparison between was performed with the Least Significant Differences method (LSD) at p<0.05.

ANOVA of the means of four replicates was performed with the Least Significant Difference test, and significance was determined at p < 0.05.

## RESULTS AND DISCUSSION

**Grain Yield:** WD and cultivar treatments had significant effect on grain yield (p<0.01) (Table 2). The highest grain yield was seen in control ($S_1$) with 39.87 mg/plant and the least one was belonged to WD during vegetative growth stage ($S_2$) with 17 mg/plant (Fig. 2).

Landrace cultivar with 33.66 mg/plant had higher grain yield than the others. The lowest grain yield was belonged to Kimia and Qazvin cultivars with 25.88 and 25.49 mg/plant, respectively (Fig. 3).

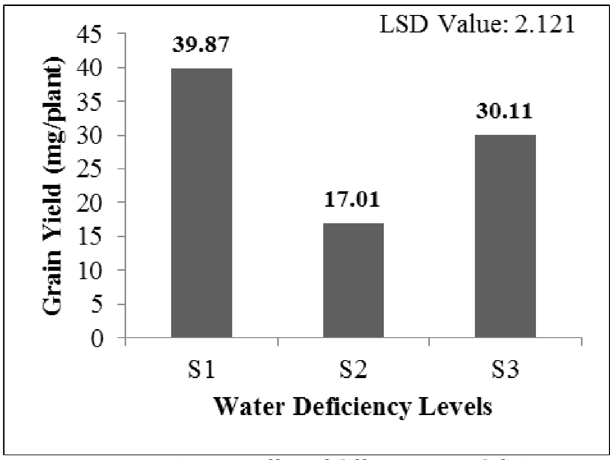


**Figure 2: Effect of different water deficiency levels on grain yield.**

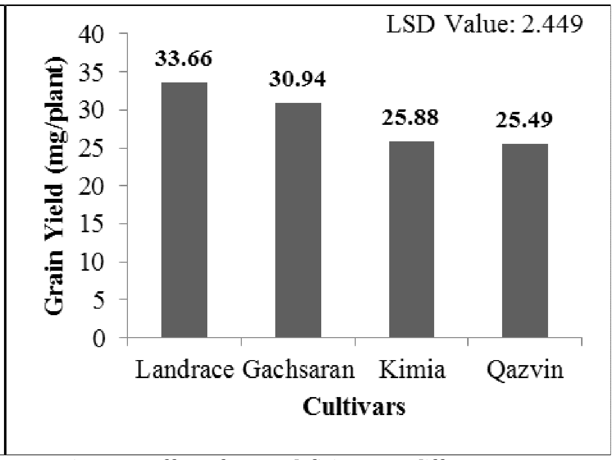


**Figure 3: Effect of water deficiency on different Cultivars grain yield**

*($S_1$: Control, $S_2$ and $S_3$: water deficiency during vegetative and reproductive growth stage)*

**Table 2: Analysis of variance for grain yield, RWC, stomatal resistance and chlorophyll fluorescence**

| SOV | Mean Square | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Grain Yield | RWC | | Stomatal Resistance | | Proline | | Fv/Fm | |
| | | V | R | V | R | V | R | V | R |
| **Drought Stress** | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| **Cultivar** | ** | n.s | ** | ** | ** | ** | ** | n.s | n.s |
| **Stress × Cultivar** | * | n.s | n.s | ** | ** | n.s | ** | n.s | n.s |
| **Error** | 24.84 | 144.6 | 76.89 | 156.7 | 206.1 | 0.085 | 0.082 | 0.002 | 0.004 |
| **%CV** | 17.20 | 16.99 | 14.45 | 13.93 | 13.94 | 17.54 | 13.39 | 6.88 | 12.08 |

*V: Vegetative R: Reproductive * Significant at 5% level, ** Significant at 1% level, n.s no significant difference*

WD*cultivar interaction had significant effect on grain yield (p<0.05) (Table 2). In control condition, Gachsaran cultivar had the highest grain yield (45.11 mg/plant). In two levels of WD, Landrace cultivar had the highest grain yield with the least grain yield reduction down to control situation. These result showed that with respect to grain yield production in control treatment and two levels of WD, Landrace cultivar is more resistant cultivar to WD occurrence at vegetative growth stage and reproductive stage than the other evaluated cultivars (Table 3). Reference [16] – [1] reached same results on lentil and mungbean, respectively.

**Table 3. Mean comparisons of grain yield and grain yield reduction of different lentil cultivars in two water deficiency treatments at vegetative and reproductive stages down to control**.

| Cultivar | Control ($S_1$) (mg/plant) | $S_2$ (mg/plant) | Decrease down to $S_1$ (%) | $S_3$ (mg/plant) | Decrease down to $S_1$ (%) |
|---|---|---|---|---|---|
| **Landrace** | 40.80 | 24.08 | 40.98 | 36.08 | 11.56 |
| **Gachsaran** | 45.11 | 17.39 | 61.44 | 30.31 | 32.80 |
| **Kimia** | 36.33 | 13.58 | 62.62 | 27.72 | 23.69 |
| **Qazvin** | 37.21 | 12.92 | 62.27 | 26.32 | 29.26 |

*($S_1$: Control, $S_2$ and $S_3$: Water deficiency during vegetative and reproductive growth stage)*
*(LSD Value: 4.242)*

**Relative Water Content:** RWC affected by drought stress in both vegetative and reproductive growth stages ($p < 0.01$) as well as cultivar had significant effect just on reproductive growth stage while interaction between stress and cultivar had no significant effect on RWC (Table 2).

Drought stress on vegetative growth stage caused %41.77 decrease in RWC while it was %85 in control. Drought stress brought same results in reproductive growth stage (Fig. 4) Landrace Cultivar had maximum RWC between others (Fig. 5).

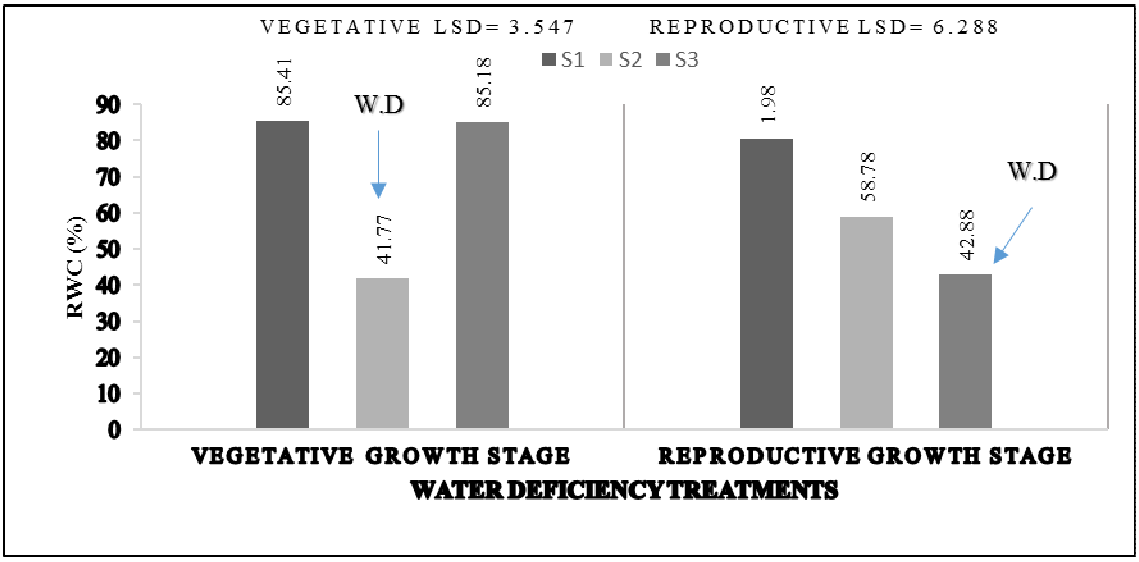


**Figure 4: RWC in different drought treatments and growth stages**

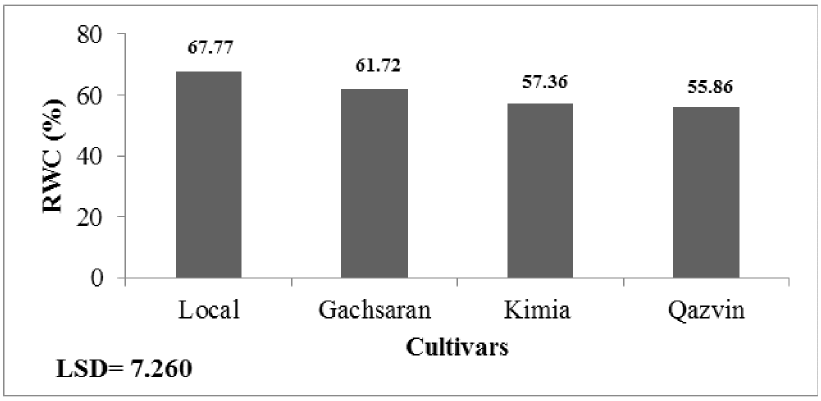


**Figure 5: RWC in different cultivars**

**Stomatal Resistance:** Effect of drought stress, cultivar and interaction between stress and cultivar was significant ($p < 0.01$) on stomatal resistance in both vegetative and reproductive growth stages (Table 2).

Landrace cultivar had fewest stomatal resistance in both vegetative and reproductive growth stage with 131.80 and 145.30 $s.m^{-1}$, respectively, in comparison with other cultivars while kimia and Qzvin cultivar with a significant difference had highest stomatal resistance (Table 4). Reference [3] reported same results.

**Proline:** water deficiency and cultivar had significant effect on proline concentration during vegetative growth stage, while interaction between water deficiency and cultivar just affected proline concentration during reproductive growth stage (Table 2). Proline accumulation in reproductive stage was more than vegetative stage. At reproductive stage, the amount of proline in treatments which affected by water deficiency during vegetative growth stage rose to 1.63 µmol/g fw (fig. 6).

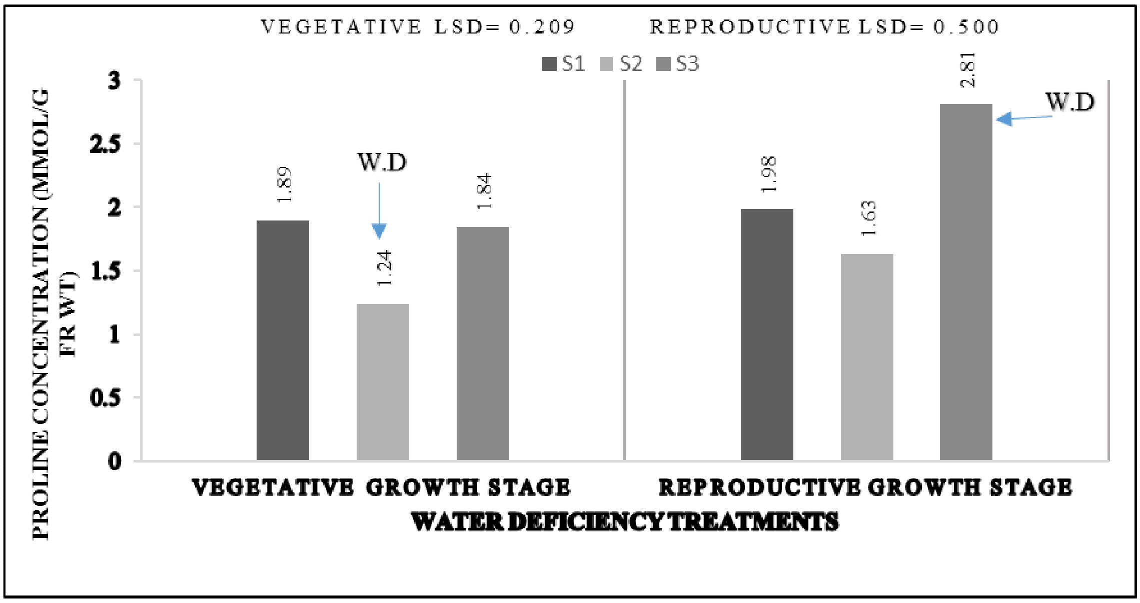


**Figure 6. Effect of water deficiency treatments at vegetative and reproductive growth stages on Proline concentration of Lentil cultivars. ($S_1$: Control, $S_2$ and $S_2$: Drought stress during and reproductive growth stage)**

Amount of proline increased during reproductive growth stage and it seems to have role in plant protection against water deficiency while in vegetative growth stage, the amount of proline decreased by affected of water deficiency. Gunes et al. [8] reported same results in their experiment on pea and said that proline acts as material for producing another substance to protect the plant against drought stress.

The Highest proline accumulation was related to Landrace cultivar with 4.23 µmol/g fw in water deficiency during reproductive growth stage and the least one belonged to kimia and Qazvin cultivars with 2.18 and 1.92 µmol/g fw, respectively (Table 4). According to Hamudi et al. [9] water deficiency caused increase of proline concentration in Cathayana leaves. Also Khan et al. [11] reported same results. Also same results about proline reported on Beet in affected by salinity stress [28].

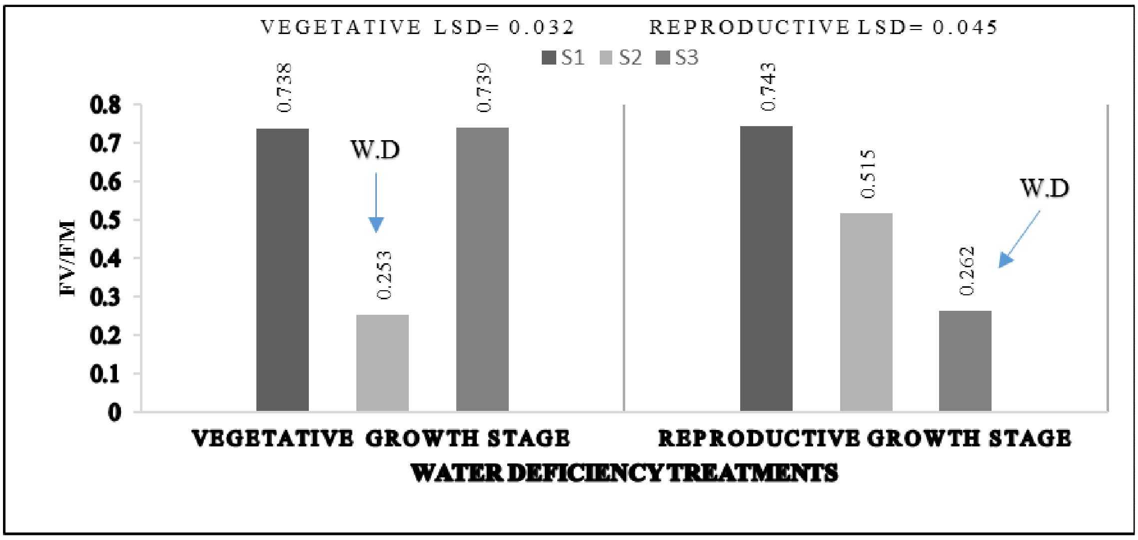


**Figure 7: Changes of quantum efficiency of photosystem II (Fv/Fm) in different drought treatments**

**Chlorophyll Fluorescence:** Fv/Fm just affected by drought stress in both vegetative and reproductive growth stages (Table 2). The maximum quantum efficiency of photosystem II decreased to 0.253 in drought stress during vegetative growth stage and fell to 0.263 in reproductive stage while it was 0.738 in control (Fig. 7). Fv/Fm showed an upward trend after removing stress in which treatments were under drought stress during vegetative growth stage and rose to 0.515 (Fig. 7). There is same results on cotton [15] and mungbean [1].

**Table 4: Mean comparison of grain yield, proline and stomatal resistance in three drought treatments**

| Drought Treatments | Cultivar | Grain Yield (mg.plant$^{-1}$) | Proline (mg.ml$^{-1}$) | Stomatal resistance (s.m$^{-1}$) | |
|---|---|---|---|---|---|
| | | | R | V | R |
| $S_1$ | Landrace | 40.80 | 2.51 | 54.94 | 65.31 |
| | Gachsaran | 45.11 | 2.46 | 50.69 | 59.79 |
| | Kimia | 36.33 | 1.46 | 65.45 | 75.42 |
| | Qazvin | 37.21 | 1.49 | 70.36 | 74.90 |
| $S_2$ | Landrace | 24.08 | 2.15 | 131.8 | 79.43 |
| | Gachsaran | 17.39 | 1.67 | 142.7 | 75.53 |
| | Kimia | 13.58 | 1.38 | 162.9 | 89.10 |
| | Qazvin | 12.92 | 1.34 | 159.5 | 85.64 |
| $S_3$ | Landrace | 36.08 | 4.23 | 53.70 | 245.3 |
| | Gachsaran | 30.31 | 2.92 | 50.74 | 156.3 |
| | Kimia | 27.72 | 2.18 | 65.39 | 165.8 |
| | Qazvin | 26.32 | 1.92 | 70.33 | 163.4 |
| LSD Value | | 4.242 | 0.101 | 5.066 | 5.819 |

*V: Vegetative growth stage R: Reproductive growth stage*
*$S_1$: Control, $S_2$: Drought stress during vegetative growth stage, $S_3$: Drought stress during reproductive stage*

## CONCLUSION

As for results, we conclude that Gachsaran has highest grain yield in normal condition while if there is any stress, Landrace cultivar shows a high tolerance in comparison with other cultivars and presents a high tolerance in face to water deficiency condition. There for if farmers use landrace cultivar in Mediterranean condition, they can expect a reasonable yield at the end of growth season.

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