RESEARCH ARTICLE **Open Access)**

Effect of Partial Root Drying (PRD) and Potassium Fertilizer on Water Use Efficiency and Agronomical Characteristics of Canola (*Brassica Napus* L.)

MOHAMMAD MEHDI RAHIMI[1]

[1]Department of Agriculture, Yasooj Branch, Islamic Azad University, Yasooj, Iran

Abstract

In order to evaluate the interaction of the Partial root-zone drying (PRD) and potassium fertilizer on the water consumption efficiency and agronomical characteristics of canola, an experiment was conducted during 2012-13 in Semirom, Isfahan province, Iran. Factorial testing was carried out in split plot, randomized complete design (RCD) in four replications. The irrigation had the main plot with three factors, control (irrigation), intermittent irrigation Partial root-zone drying (PRD), constant irrigation Partial root-zone drying (PRD) at one side of the roots, and potassium fertilizer in subplots in three levels: 0, 50, 100 kg/ha. The study specifications include: number of pods per plant, number of seeds in pod, weight of thousand grains, biological yield, yield, harvest index, and water consumption efficiency after data analysis, the results of the experiment showed that the irrigation effect on all specifications was significant at 1% probability. Finding showed The highest yield was observed at 79/3 %, which was equal to 47,330 kg/ha with consumption of water 53% in interaction of intermittent Partial Root Drying (PRD) and 100 kg/ha potassium fertilizer treatment. Based on the results, in order to Efficiency in irrigation using of intermittent Partial Root Drying (PRD) and 100 kg/ha potassium fertilizer treatment is recommended for cultivation in areas that climatic conditions similar to Semirom.

Keywords: canola (*Brassica napus* L); partial root-zone drying (PRD); potassium fertilizer; water consumption efficiency.

1. Introduction

Canola has an important role in provision of foodstuff's oil in the world. According to the data in 2010 it has the third position among other plant oils for its special features. On the basis of data which is obtained, the global production of Canola in 1979-81 was 11.3 million ton, which this amount was raised about 34.7 million ton in 1995. That is indicates 300% percent growth in production and now this rate do not observable in any other product [11]. Low-irrigated or irrigated is away for optimum use of water; therefore they can adapt productions with arid situations and performance diminution [8]. In fact low-irrigated is not an emergency method in arid situations, but it is a kind of efficient management in utilization [18]. It is less than two decades that a new method offers for irrigated a part of root by the name of partial irrigated [2].

Partial root-zone drying (PRD) is a modified form of deficit irrigation (DI) [5]. In partial irrigated approach, instead of usual and steady irrigated approach in all over parts of roots, provision of water is performed periodically and only in one side of root. Also this action in next irrigated is reversed [10]. Potassium fertilizer plays an important role in some plants that have environmental tensions. Potassium fertilizer is useful for some physiological process including photosynthesis, transferring the produced material of photosynthesis to the resourced organs, preservation of Torsuesance, enzymes activities, decreasing of Potassium ion ' s additions in salty tension. Potassium fertilizer is the first action that becomes filled in the plant in aridity situations [1, 15]. show that with implementation of partial irrigated technique PRD, the efficiency of water usage is doubled, whereas the amount of water is reduced by half, the bean's performance is decreased just 9/56% percent. The studies of Saeedi et al in treatment irrigated approach PRD on potato indicate that water consumption is reduced to 29% and its efficiency is raised to 19%. They indicated the implementation of

*Corresponding author: Mohammad Mehdi Rahimi; E-mail: rahimi.agronomy@Gmail.com
(Accepted for publication September 20, 2015)
***ISSN**: 2218-2020, © Agricultural University of Tirana*

this treatment does not reduce the performance of nodes after passing 6 weeks of growing plant. Mohammad Nejad et al showed in their studies on wheat arrived at this conclusion that PRD irrigated has a significant effect on the number of bean's features in Virgo, the number of spike in Virgo, the length and height of Virgo, the height of bush, biological performance, the weight of Virgo, bean performance, bean diametric, the length of bean and the efficiency of water consumption. In one research that is done in Turkey on a partial irrigated system cleared that, this approach cause to economize amount of water consumption considerably, which is used for irrigated cotton. Also the products become ready for harvest some weeks earlier than harvesting products in traditional method [12]. Davies et al., (2003) indicated keeping dry a part of root (PRD) can limit the growth of fruit, and this condition shows the role of root's signals and their free transferring from aerial organs to fruit [4]. Zegbe et al (2004) indicated the effect of partial irrigated system on tomato with using two ways, include irrigated in drops and furrow irrigated [23]. [23]. The results show that the efficiency rate of water consumption in PRD treatment is increased in comparison with other treatments. Partial irrigated raised efficiency of water consumption to 70% percent [23]. Rabiee and TosiKahol (2009) reported that the amount of potassium fertilizer have a significant effect on bean performance , the number of cluster in bush, the height of bush, the length of cluster and the number of sub branches in Canola [16]. Zaman khan et al (2004) in their experiments on Canola showed various levels of potassium fertilizer have a significant effect on bean performance features, the weight of thousands bean, the number of bean in cluster and the number of branches; therefore increasing the use of potassium fertilizer improved the performance of these features [22]. Sing et al (2005) had studied the role of potassium fertilizer on adjustment of water tension in different level of growth on pea's performance and quality; so they concluded that the space of water tension can lead to considerable decrease in the number of shell and bean in each bush [19]. This research is performed for reviewing the effect of PRD partial irrigated approach on Canola's performance , its components ' performance and determination of the best method of PRD and the level of potassium fertilizer for Canola. This research is done in Samirom an area in Esfahan.

2. Material and Methods

2.1. Location of project

This experiment was conducted in crop year 2013 in the Semirom city. Geographical coordinates of the project place was 51 degrees and 34 minutes of eastern longitude and 31 degrees and 24 minutes of northern latitude. Elevation from sea level was 2400 meters and average rainfall in the last ten years was 410mm.

2.2.Climate characteristics of the test area

Meteorological characteristics of test location are presented according to the Semirom's weather station in Table (1).

Table 1: Monthly weather data according to the Semirom's weather station Pedological Studies In agricultural season

Month	Temperature C°	Relative humidity %	Rate of Rainfall mm	Days of Glacial
October	17.6	28.2	15.5	-
November	12.5	32.3	25.2	-
December	4.23	36.9	98.65	19
January	- 5.5	41.65	130.5	20
February	- 8.5	43.28	74.32	17
March	-4.28	42.4	69.89	12
April	12.1	38.3	41.2	5
May	15.9	39.3	23	-
June	23.6	23.5	-	-
July	27.5	21.6	-	-
August	22.41	20.5	-	-

Table 2: Pedological studies of soil

Soil Texture	Saturation %	Electrical conductivity	Soil saturation reaction	Organic carbon	Azote %	Phosphor PPm	Potassium fertlizer ppm	Clay %	Silt	Sand
Clay - Loamy	42.5	0.33	8	0.975	0.116	11.5	266	34	30	36

Based on climatic classification, Semirom area have cool and cold climate and summer is warm and dry. In this area usually daily temperature average from 20 ° C in February decreased to 12 ° C in September and then increased to 28 ° C in August.

In pedological studies, as well as determination of soil appearance condition and stone or grains presence in the soil, profiles were dug in the plant habitat and samples of the soil were collected and transported to the laboratory in order to measure the experimental of soil texture and other factors In accordance table 2.

2.3.Treatments and experimental design

This study was conducted in a split plot in a randomized complete block design. In this experiment, Irrigation were conducted in four replications as the main plot with three factors, control (full irrigation), intermittent irrigation (PRD), and irrigation (PRD), on one side of the root fixed And potassium fertilizer as sub-plots at three levels of control (0, 50 and 100 kg/ha).

2.4.Canola cultivation

In order to prepare the land for cultivation at first the land was plowed by the plow and then plan map was implemented in four replicates with the distance of one meter from each other. In total, 36 plots were created, so that at each repeat 9 plot with the size of 3×5cm and 50cm distance from each other was created. Finally, rows were created in each plot with the distance of 30cm and canola cultivation was carried out furrow irrigation in the second week of November 2002. The seeds were green after about 8 days. Irrigation pipes were created in the furrow to apply irrigation treatments. In the control treatment, irrigation always was done in two rows cultivate and PRD intermittent irrigation method, at each irrigation, were irrigated a side of the rows (right or left) and PRD irrigation fixed, always one side of rows was irrigated constantly, in this type of irrigation, water with pressure 2 atmosphere was entered to tubes and then were irrigated rows. In the later stages, irrigation was applied accordance with treatment intended in the experiment. Weeding was done in step 5 to 7, also nitrogen fertilizer used to the amount of 100 kg per hectare. During the perseveration stage some necessary actions is accomplished for taking care of the plant, like pest control and some diseases. Also the necessary parameters and indexes are noted until that treatments reach to the harvest stage. After that some features including the height of bush , the number of cluster in bush, the number of beans in cluster, the weight of thousands of beans, biological performance, bean performance, harvest index and the efficiency of water consumption are noted , and then evaluated carefully. For determining the harvest index, they measure the biological performance (Biomass) and the rate of bean's performance in a unit of scale, and then the harvest index of product that indicates the bean's performance (economic) to biological performance (biomass) is getting from this formula:

(Harvest index = economical and biological performance × 100).

The results of traits were analyzed using SAS statistical software. Data average was compared using Duncan's multiple range tests at the level of one to five percent. All diagrams relating to the tests drawn by Excel.

3. Results and Discussion

3.1.Number of pod per bush

According to analysis the variance of data (Table 3), irrigation had significant effect on number of pods per bush 1%, this result is conformed to finding of Soltani

et al on canola plant [20]. According to analysis the variance of data (Table 3), Potassium Fertilizer had significant effect on number of pods per bush at 1%, this result is conformed to findings of Rabei and Tosi on the canola plant and Mohamad Nezhad et al on the wheat plant and Sing et al on the Chickpea plant [14, 16, 19]. They were indicated potassium fertilizer had significant effect on number of pods per plant and by increasing potassium fertilizer number of pods per plant increased. According to analysis the variance of data, they indicated potassium fertilizer had significant effect on the number of pod per bush and by increasing potassium fertilizer number of pod in bush increased. According to the results of analysis and data variance, the interaction of irrigated and potassium fertilizer treatments had significant effect on the number of pod in bush at the level of 5% percent (Table 3).

Table3: The variance analysis of mean square of different levels of Irrigation and potassium fertilizer on Canola

Alteration sources	DF	Number of Pod per Bush	Number of seed in pod	Weight of thousand seeds (gr)	Biological Yield (kg)	Yield (kg)	Harvest Index (%)	Water consumption levels M3.ha^{-1}	Water use efficiency kg. m^2
Replication	3	294.35*	29.43**	0.32^{ns}	613559.22^{ns}	137156.3^{ns}	14.96^{ns}	11302500**	0.0007**
Irrigation	2	5158.99**	321.69**	4.25**	15145358.6**	10500171.78**	200.56**	64855833**	0.004**
Error of Main Factor	6	213.76	5.99	0.14	624715.24	242204.98	24.06	2919167	0.00022
potassium fertilizer	2	5237.19**	48.69**	1.70**	17015648.05**	2982480.21**	7.37^{ns}	18707500**	0.012**
Irrigation× potassium fertilizer	4	306.65*	2.02^{ns}	0.08^{ns}	1005862.36*	206970.84*	5.38^{ns}	377333.0**	0.0006**
Error	18	96.43	1.80	0.13	329209.15	58415.34	7.33	330278	0.0001
CV		4.45	4.68	8.94	4.58	5.5	7.75	2.54	6.59

*: Significant at %1 **: Significant at the 5% level. Ns: no significant

Table4: Means comparison of Canola affected by interaction of different irrigation and Potassium fertilizer

Irrigation	Potassium fertilizer	Number of pod per bush	Number of seed in pod	Weight of thousand seeds (gr)	Biological Yield (kg)	Yield (kg)	Harvest Index %	Water consumption levels (m^2. ha^{-1})	Water use efficiency (kg. m^3)
Control (Full Irrigation)	0	225.95^{bc}	33^{b}	4.25^{bc}	12879.36^{bc}	4890.65^{b}	38.09^{abc}	33500.00^{a}	0.15^{f}
	50	247.55^{a}	34.50^{ab}	5.03^{a}	13967.71^{a}	5528.44^{a}	39.61^{ab}	30750.00^{b}	0.18^{e}
	100	257.61^{a}	35.75^{a}	5.16^{a}	14541.16^{a}	5967.66^{a}	41.05^{a}	28825.00^{c}	0.21^{cd}
intermittent irrigation	0	192.55^{ef}	25.^{25de}	3.6^{cd}	10547.92^{e}	3466.15^{d}	33.02^{cd}	19525.00^{d}	0.18^{de}
	50	204.08^{de}	27.^{25cd}	3.96^{bcd}	11632.71^{d}	3702.86^{cd}	31.79^{d}	18375.00d^{e}	0.20^{c}
Partial root-zone drying	100	214.05^{ab}	29.50^{c}	4.39^{b}	13740.10^{ab}	4733.07^{b}	34.51^{bcd}	17800.00^{e}	0.27^{a}
constant irrigation	0	177.73	22.25^{f}	3.38^{d}	10415.85^{d}	3402.35^{d}	32.81^{cd}	18600.00d^{e}	0.18^{e}
	50	212.76^{cd}	23.^{5ef}	3.68^{cd}	12127.19^{cd}	3782.21^{cd}	31.46^{d}	17925.00^{e}	0.21^{bc}
Partial root-zone drying	100	222.76^{c}	27.25^{cd}	3.92^{bcd}	12697.22^{c}	4037.30^{c}	31.80^{d}	17575.00^{e}	0.23^{b}

Means scores of each column with at least one shared letter, are not significantly different

The comparison of data mean by Duncan's method in graph 2 indicates that all of treatments do not place in one statistics group and they clearly differ with each other. The maximum number of pod in bush (257.61 ha) observed in treatment interaction of usual irrigated and 1000kg potassium fertilizer and the minimum number of pod (177.73 ha) observed in treatment interaction of constant irrigated interaction (PRD) and 0 kilogram potassium fertilizer (Table 4).

According to the findings treatments of interaction irrigated with different level of potassium fertilizer is classified in one statistics group with treatment interaction of variable irrigated (PRD) and 1000 kilogram potassium fertilizer in each hectare but it had significant difference with other treatments and did not classified in one group.

3.2.Number of seed in pod

According to analysis the variance of data, irrigation had significant effect on number of seed in pod at ($P\leq0.01$) (Table 3), this result is conformed to finding of mohamadnejad et al on wheat plant [14].

According to the obtained results of the ANOVA, Potassium Fertilizer had significant effect on Number of seed in pod at ($P\leq0.01$) (Table 3); this result is conformed to findings of zaman khan et al on the canola plant and Mohamadnejad et al on the wheat plant and Sing et al on the Chickpea plant [19, 22].

According to the results of analysis and data variance (Table 3), the interaction of irrigated and potassium fertilizer treatments had not significant effect on the number of seed in pod. The maximum number of seed in pod (35.75) observed in treatment interaction of usual irrigated and 100kg/ha potassium fertilizer and the minimum number of pod (22.25) observed in treatment interaction of constant irrigated interaction (PRD) and 0 kilogram potassium fertilizer (Table 4).

3.3.Weight of thousand seeds

According to analysis the variance of data (Table 3), irrigation had significant effect on Weight of thousand seeds at ($P\leq0.01$), this result is conformed to finding of mohamadnejad et al on wheat plant [14].

According to the obtained results of the ANOVA, Potassium Fertilizer had significant effect on Weight of thousand seeds at ($P\leq0.01$) (Table 3); this result is conformed to findings of zaman khan et al on the canola plant and Mohamadnejad et al on the wheat plant and Sing et al on the Chickpea plant [14, 19, 22].

According to the obtained results of the ANOVA, the interaction of irrigated and potassium fertilizer treatments had not significant effect on Weight of thousand seeds (Table 3). The maximum number of seed in pod (5.16 gr) observed in treatment interaction of usual irrigated and 100kg/ha potassium fertilizer and the minimum number of pod (3.38gr) observed in treatment interaction of constant irrigated interaction (PRD) and 0 kilogram potassium fertilizer (Table 4).

3.4.Biological Yield

According to analysis the variance of data (Table 3), irrigation had significant effect on biological yield at ($P\leq0.01$), this result is conformed to finding of mohamadnejad et al on wheat plant [14].

According to the obtained results of the ANOVA, Potassium Fertilizer had significant effect on biological yield at ($P\leq0.01$) (Table 3); this result is conformed to findings of zaman khan et al on the canola plant and Mohamadnejad et al on the wheat plant and Sing et al on the Chickpea plant [14, 19, 22].

According to the obtained results of the ANOVA, the interaction of irrigated and potassium fertilizer treatments had significant effect on biological yield at ($P\leq0.05$) (Table 3). The maximum number of biological yield (14541.16 gr) observed in treatment interaction of usual irrigated and 100kg/ha potassium fertilizer Whereas the minimum number of biological yield (10415.85gr) observed in treatment interaction of constant irrigated interaction (PRD) and 0 kilogram potassium fertilizer (Table 4).

3.5.Yield

According to analysis the variance of data (Table 3), irrigation had significant effect on yield at ($P\leq0.01$), this result is conformed to finding of Mohamadnejad et al on wheat plant, Mingo et al on Vitis vinifera and English and Raja [6, 14].

According to the obtained results of the ANOVA, Potassium Fertilizer had significant effect on yield at ($P\leq0.01$) (Table 3); this result is conformed to findings of [14, 16, 19]. According to the obtained results of the ANOVA, the interaction of irrigated and potassium fertilizer treatments had significant effect on yield at ($P\leq0.05$) (Table 3). The maximum number of biological yield (5967.66 gr) observed in treatment

interaction of usual irrigated and 100kg/ha potassium fertilizer whereas the minimum number of yield (3402.35gr) observed in treatment interaction of constant irrigated interaction (PRD) and 0 kilogram potassium fertilizer (Table 4). This result is conformed to finding of Mohamadnejad et al on wheat plant [14].

3.6.Harvest Index

According to analysis the variance of data (Table 3), irrigation had significant effect on Harvest Index at ($P \leq 0.01$), this result is conformed to finding of Soltani et al on Canola plant [20]. According to the obtained results of the ANOVA, Potassium Fertilizer had not significant effect on Harvest Index (Table 3).

According to the obtained results of the ANOVA, the interaction of irrigated and potassium fertilizer treatments had not significant effect on Harvest Index (Table 3). The maximum number of Harvest Index (41.05%) observed in treatment interaction of usual irrigated and 100kg/ha potassium fertilizer whereas the minimum number of yield (31.46%) observed in treatment interaction of constant irrigated interaction (PRD) and 50 kilogram potassium fertilizer (Table 4).

3.7.Water consumption levels

According to analysis the variance of data (Table 3), irrigation had significant effect on Water consumption levels at ($P \leq 0.01$) (Table 3), this result is conformed to finding of [3, 12].

According to the obtained results of the ANOVA, Potassium Fertilizer had significant effect on Water consumption levels at ($P \leq 0.01$) (Table 3).

According to the obtained results of the ANOVA, the interaction of irrigated and potassium fertilizer treatments had significant effect on Water consumption levels at ($P \leq 0.01$) (Table 3). The maximum number of Water consumption levels (33500 m3/ha) observed in treatment interaction of usual irrigated and 0kg/ha potassium fertilizer whereas the minimum number of Water consumption levels (17800 m3/ha) observed in treatment interaction of intermittent irrigated interaction (PRD) and 100 kilogram potassium fertilizer (Table 4).

3.8.Water use efficiency

According to analysis the variance of data (Table 3), Effect of irrigation on water use efficiency was significant at 1% level, These findings were consistent to results of Soltani et al on canola, Mohammadnejad et al on wheat, Mousavi et al on potato, Saeed et al on potatoes, karim et al on beans and Zegbe et al on tomato, expressed that irrigation had significant effect on the efficiency of irrigation water use and irrigation (PRD) cause to increase the efficiency of water use [14, 15, 20, 23].

According to analysis the variance of data (Table 3), effect of potassium fertilizer on water use efficiency was significant at 1% level. This finding is consistent with [14].

On the basis of variance data's analysis (Table 3), the mutual effect of irrigated and potassium fertilizer is noticeable on the efficiency of water consumption in level 1. The comparison of data mean according to Duncan's approach showed that the all of treatments do not classified in one statistical group and they are different with each other. The maximum efficiency of water consumption is related to the variable irrigated treatment with 100 kilogram potassium fertilizer in each hectare which is equal to 0.27 kilogram to a cubic meter, and its minimum amount of water consumption is related to the usual irrigated treatment with 0 kg potassium fertilizer in one hectare that is equal to 0.15 kg to a cubic meter. This finding is consistent to results of Mohammadnejad et al on wheat plant; they stated that the mutual effect of potassium fertilizer and irrigated has an important influence on the efficiency of water consumption, so with the use of irrigated PRD and potassium fertilizer the efficiency of water consumption is increased [14].

4.Conclusions

According to the performed experiments cleared that the maximum performance is obtained when the highest amount of irrigated is applied. Thus by doing PRD decreasing in performance have seen. This result is almost predictable. All of doing experiments indicate this topic. Also, English and Raja (1996) stated the benefit that is getting from decreasing of water consumption in dry areas is much more of disadvantages that are because of diminution of performance. This finding was been very important especially in Samirom area, that water is a restricted factor for farming. Experiment's findings indicate that PRD method reduced the performance by influencing on component performance, and these results were confirmed by [20].They stated that the performance in Canola is done by decreasing the number of pod. On the basis of the comparison that is completed between this two method (periodic and constant

implementation) cleared that the periodic implementation has a higher performance than constant implementation, so the studies of [7, 13, 21].confirmed this problem. They claim that transferring of chemical signals are effective in control of opening and closing the pores, the growth of leaf and fruit in the PRD irrigated method, and increasing performance causes to changing PRD conditions. The experiment's findings show that with increasing the amount of consumption fertilizer, the performance is increased, too. On the other side, potassium can decrease the tension influences.

This result is conformed to findings of [9]. As a whole, potassium can reform proportional content of water and potential water that is in leaves through adjustment of osmotic pressure; by this action it can prepare the necessary amount of salts for reforming the osmotic slope. Also it reduced photosynthesis action [9]. According to findings in this study, we have offer the variable irrigated treatments (PRD) and 1000 kilogram potassium fertilizer in each hectare for planting Canola in some areas like Semirom with similar climates.

5. Acknowledgments

Thanks from The Islamic Azad University for supporting projects. This research was supported by Islamic Azad University, Yasuj Branch, Yasuj, Iran

6. References

1. Alizadeh A, Majidi A, Nourmohamdi GH: **Effects of drought stress and soil nitrogen levels on nutrient uptake of maize.** *Res in Agri Sci* 2008, **4**: 124-129.
2. Asghari M, Alizadeh H, Liaghat A: **Evaluation of low-irrigation management**. Abstracts of articles in First International Conference about Water Crisis. Zabol University 2009, (In Persian).
3. Bota J, Medrano H, Cifre J, Flexas J, Escalona JM: **Physiological tools for irrigation scheduling in grapevine *(Vitis vinnifera L.)* Anopen gate to improve water- use efficiency?** *Agric. Ecosys. and Environ* 2005, **106**: 159-170.
4. Davies W J, Bacon M A, Thompson DS, Sobeigh W, Rodriguez LG: **Regulation of leaf and fruit growth in plants in drying soil: exploitation of the plant's chemical signalling system and hydraulic architecture to increase the efficiency of water use in agriculture.** *J. Exp. Bot* 2003, **51**: 1617–1626.
5. English MJ, Musick JT, Murty VVN. **Deficit irrigation. In: Management of farm irrigation systems (Hoffman, G.J., Howell, T.A., and Solomon, K.H., Editors).** ASAE Monograph no. 9. American Society of Agricultural Engineers publisher; 1990.
6. English M, Raja SN. **Perspectivees on deficit irrigation**. *Agricultural water management* 1996, **32**: 1-14.
7. Goving DJ, Davies WJ, Jones HG: **A positive root-sourced signal as indicator of soil drying in apple Malus domestica Borh.** *J. Exp. Bot* 1990, 41: 1535–1540.
8. Hasheminia, M. **Water management in agriculture**. First edition. Publications ferdowsi university of mashhad; 2005. (In persian).
9. Jensen CR, Tophoj H: **Potassium induced improvement of yield response in barley exposed to soil water stress**. **Irrigation Science** 1985, **6**: 117-129.
10. Jerie P, Zhang J, Kang S, Hu X: **The effects of partial rootzone drying on root, trunk sap flow and water balance in an irrigation pear *(pyrus communis)* Orchard.** *J. Hydrol* 2003, **280**: 192-206.
11. Jorgeh AR: **Determine the most appropriate planting date canola and the correlation study between yield and yield components.** Master Thesis Agriculture, Dezful Islamic Azad University. 2012: 158 pp. (In persian).
12. Kirda C, Topcu S, Kaman H, Cetin M, Topaloglu F, Derici R**: Prospects of Partial Root Drying Zone for increasing water use efficiency of major crops in the Medditerranean region**. The WUEMED Workshop. (Improving Water Use Effeciency in the Medditerranean Agriculture: what Limits the adoption of new technologies). Rome Italy. 29-30 September 2005.
13. Mingo MA, Anderson MM: **Fruit ripening in *Vitis vinifera* L. responses to seasonal water deficits.** *Am. J Enol. Vitic* 2003, **39**:313–320.
14. Mohammadnejad Z, Bohrani A, Ebrahimi CH: **Water use efficiency in the wheat (PRD).** MSc project. Ramhormoz Azad

University, page 98. Journal of Meteorology, Ministry of Roads and Urban Development Meteorology 1390-91. Tehran: Ministry of Urban Development, Office of Statistics and Information Technology 2012.

15. Mousavi sf, Soltani-Gerdefaramarzi S, Mostafazadeh-Fard B: Effects of partial rootzone drying on yield, yield components, and irrigation water use efficiency of canola. Pad. Water Environ 2010, 8: 157-163.
16. Rabiee M, Tosikahol P. **Effect of different amounts of potassium and nitrogen fertilizer on yield and yield components of canola after rice cultivation**. Elec J of Cr prod 2009: **50:** 151-158 pp
17. Saeed H, Grove IG, Kettlewell PS, Hall NW: **Potential of partial root zone drying as an alternative irrigation technique for potatoes *(Solanum tuberosum*)**. Ann Appl Biol 2008, **152**: 71–80.
18. Sepaskhah AR: Selection the irrigation method. Shiraz University Press 2002. 30pp. (In persian).
19. Sing G, Waraich EA, Ahmad A, Ashraf S, Ehsanullah MY: **Role of mineral nutrition in alleviation of drought stress in plants.** Australian Journal of Crop Sciences 2005, **6**:764-777.
20. Soltani SF, Mosavi B, Mostafazadeh M, Daneshvar A: **PRD effect on performance. Water use efficiency and nutrient concentrations in canola. Ninth Seminar on Irrigation and reduce evaporation**, Kerman 2008. (In persian).
21. Stoll M, Loveys B, Dry P: **Hormonal changes induced by partial rootzone drying of irrigated grapevine.** J. Exp. Bot 2000, **51**:1627–1634.
22. Zaman Khan H, Asghar Malik M, Farrukh Saleem M, Aziz I: **Effect of different potassium fertilization levels on growth, seed yield and oil contents of canola *(Brassica napus L.)***. *J. Agric. Biol* 2004, **6**: 557-559.
23. Zegbe jA, Clothier BE, Behboudian MH: **Partial root zone drying is a feasible option for irrigation processing tomatoes.** *Agric Wat Manag* 2004, **68**: 195-206.