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Drought Stress Tolerance Evaluation of Spring Rapeseed Cultivars in Winter Planting

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Abstract- To assess the drought tolerance of spring rapeseed (*Brassica napus* L.) cultivars in winter planting, a two year field experiment was conducted in Karaj, Iran during 2006-2008 growing seasons. The experiments was laid out in a four-replicated-randomized complete block, split plot design with two irrigation levels (I: I_1= irrigation on the basis of 80 ml evaporation from the class A pan (normal irrigation) and I_2: interruption of irrigation from the flowering stage (water stress) as the main plot and cultivar including C_1: RGS 003, C_2: Amica, C_3: Sarigol, C_4: Option 500, C_5: Hyola 401, C_6: Hyola 42, C_7: Hyola 60, C_8: Hyola 420, C_9: Hyola 330, C_{10}: Hyola 308, C_{11}: Kimberly, C_{12}: RGS 006, C_{13}: 19-H, C_{14}: Syn-3, C_{15}: PR-401/16, C_{16}: PP-401/15E, C_{17}: PP 308/8, C_{18}: PP 308/3, C_{19}: ORS 3150-3006, C_{20}: ORS 3150-3008, C_{21}: RG 4403, C_{22}: RG 405/03, C_{23}: RGAS 0324 and C_{24}: RG 405/02 as subplot. The results of combined analysis of two years revealed that under normal irrigation condition ORS 3150-3008 cultivar by average of 2285 kg ha^{-1} and RG 4403 cultivar by average of 809 kg ha^{-1} produced the highest seed yield and seed oil yield, respectively. Under water stress condition, RG 405/03 produced the highest seed yield and seed oil yield by average of 1544 and 588.2 kg ha^{-1}, respectively.

Key words: *Rape seed; Brassica napus L.; Spring cultivars; Drought stress; Winter planting.*

1. Introduction

Low water availability is the main environmental factor limiting plant growth and yield worldwide, and global changes will likely make water scarcity an even greater limitation to plant productivity across an increasing amount of land [1, 2]. Drought stress reduces the capacity of plants to take up water from the soil [3]. Even temporary drought can cause substantial losses in crop yield [4]. The effect of drought stress is a function of genotype, intensity and duration of stress, weather conditions, growth and developmental stages [5]. The occurrence time is more important than the water stress intensity [6]. Severe stress decreases the duration of reproductive growth [7] and stress during flowering or ripening stages results in large yield losses [8]. Water stress occurring at any time during reproductive growth can result a drastic change in seed yield. Water deficit is one of the most important factors threatening the expansion of area under rapeseed cultivation and its yield. Since there is no logical way to increase precipitation in drought periods so using the most appropriate agricultural practices and also cultivars which are more tolerant than the others to dryness are the best solutions to modify the undesirable drought stress effects [9]. This study aimed to evaluate the drought tolerance of spring rapeseed cultivars in winter planting and choose the cultivars with high degrees of tolerance which are appropriate for cultivation in a cold temperate and semi arid region.

I. Materials and methods

The experiments were conducted at experimental farm in Karaj (50°75′E, 35°9′N; 1313 m a.s.l), Iran on a randomized complete block design arranged in split plot form with four replications during the 2006-2007 and 2007-2008 crop years. Karaj is a cold temperate and semi arid region. Treatments were included two agents: Irrigation in two levels including I_1: irrigation on the basis of 80 ml evaporation from the class A pan (normal irrigation) and I_2: interruption of irrigation from the flowering stage (water stress) as the main plots and cultivar including C_1: RGS 003, C_2: Amica, C_3: Sarigol, C_4: Option 500, C_5: Hyola 401, C_6: Hyola 42, C_7: Hyola 60, C_8: Hyola 420, C_9: Hyola 330, C_{10}: Hyola 308, C_{11}: Kimberly, C_{12}: RGS 006, C_{13}: 19-H, C_{14}: Syn-3, C_{15}: PR-401/16, C_{16}: PP-401/15E, C_{17}: PP 308/8, C_{18}: PP 308/3, C_{19}: ORS 3150-3006, C_{20}: ORS 3150-3008, C_{21}: RG 4403, C_{22}: RG 405/03, C_{23}: RGAS 0324 and C_{24}: RG 405/02 as the subplots. Each experimental plot consisted of 4 rows, 4 m long with 30 cm spaced between rows and 4 cm distance between plants on the rows. According to soil analysis, N, P and K fertilizer rates recommended. P and K fertilizer applied pre-plant and N fertilizer applied in three stages: one-third pre plant, one-third in stemming stage and one-third in flowering stage.

The crop was kept free from weeds by applying 2.5 L ha^{-1} Terfelan pre-plant. Cabbage aphid also controlled during the growing seasons using Metasistox at a rate of 1.5 L ha^{-1}.
Seed yield, oil percent and seed oil yield were determined for each cultivar under both normal irrigation and water stress.
Simple analysis of variance (ANOVA) was performed for assessed traits at the end of each year. Combined analysis of variance was performed for assessed traits after 2 years of experiment. Also Duncan's Multiple Range Test (DMRT) (P = 0.05) was used to conduct means comparison.

II. Results and discussion

III.I. First year of the experiment
Seed yield
The simple effects of irrigation and cultivar and their interaction on seed yield were significant at P = 0.01 (Table 1). Normal irrigation by average of 1736.8 kg ha^{-1} showed a significant preference in comparison to interruption of irrigation from the flowering stage by average of 1005.5 kg ha^{-1}. Also assessed cultivars from the seed yield point of view placed in different statistical groups as ORS 3150-3008 by average of 1798 kg ha^{-1} and Hyola 401 by average of 970.31 kg ha^{-1} produced the highest and lowest seed yield, respectively (Table 2). Study of the interaction effect of irrigation and cultivar on this trait revealed that assessed cultivars from the seed yield point of view, in different levels of irrigation placed in different statistical groups as ORS 3150-3008 by average of 2241 kg ha^{-1} under normal irrigation condition and Hyola 401 by average of 487.5 kg ha^{-1} under water stress condition produced the highest and lowest seed yield, respectively. Generally ORS 3150-3008 under normal irrigation condition and RG 405/03 under water stress condition produced the highest seed yield (Fig. 1).
Seed oil percent
The simple effect of irrigation on seed oil percent was significant at P = 0.05 and the simple effect of cultivar and interaction effect of irrigation and cultivar on seed oil percent were significant at P = 0.01 (Table 1). Interruption of irrigation from the flowering stage by average of 38.57% showed a significant preference in comparison to normal irrigation by average of 36.44%. Also assessed cultivars from the seed oil percent point of view placed in different statistical groups as Hyola 330 by average of 39.42% and RG 405/02 by average of 35.96% produced the highest and lowest seed oil percent, respectively (Table 2). Study of the interaction effect of irrigation and cultivar on this trait revealed that the assessed cultivars from the seed oil percent point of view, in different levels of irrigation placed in different statistical groups as Hyola 330 by average of 40.47% in water stress condition and RGS 003 by average of 34.16% in normal irrigation condition produced the highest and lowest seed oil percent, respectively. Generally Hyola 330 under both irrigation regimes produced the highest seed oil percent (Fig. 2).
Seed oil yield
The simple effects of treatments and the interaction effect of them on seed oil yield were significant at P = 0.01 (Table 1). Normal irrigation by average of 632.7 kg ha^{-1} showed a significant preference in comparison to interruption of irrigation from the flowering stage by average of 386.9 kg ha^{-1}. Also assessed cultivars from the seed oil yield point of view placed in different statistical groups as RG 4403 by average of 650.5 kg ha^{-1} and Hyola 401 by average of 366.9 kg ha^{-1} produced the highest and lowest seed oil yield, respectively (Table 2). Study of the interaction effect of irrigation and cultivar on this trait revealed that assessed cultivars from the seed oil yield point of view, in different levels of irrigation placed in different statistical groups as RG 4403 by average of 785.1 kg ha^{-1} under normal irrigation condition and Hyola 401 by average of 192.5 kg ha^{-1} under water stress condition produced the highest and lowest seed oil yield, respectively. Generally RG 4403 under normal irrigation condition and RG 405/03 under water stress condition produced the highest seed oil yield (Fig. 3).

S.O.V.	DF	SY	SOC	SOY
Replication	3			
Irrigation	1	**	*	**
Error	3			
Cultivar	23	**	**	**
Irrigation× Cultivar	23	**	**	**
Error	138			
Total	191	-	-	-
CV (%)	-	9.68	2.57	9.97

*, ** significant at 5 and 1% respectively, ns: not significant
Table1. Analysis of variance for assessed traits (2006-2007)

Treatment	Mean SY (Kg ha^{-1})	SOC (%)	SOY (Kg ha^{-1})
Irrigation			
Normal	1736.8 a	36.44 b	632.7 a

irrigation			
Water stress	1005.5 b	38.57 a	386.9 b
Cultivar			
RGS 003	1502 c-g	36 j	537 b-f
Amica	1277 hij	37.5 d-g	476.8 g-j
Sarigol	1336 hi	37.69 c-g	500.1 e-i
Option 500	1245 ijk	39.21 ab	485.9 f-j
Hyola 401	970.3 l	38.32 b-e	366.9 l
Hyola 42	1240 ijk	36.94 g-j	456.2 ijk
Hyola 60	1167 jk	38.73 abc	450.2 ijk
Hyola 420	1369 f-i	38.45 a-d	521.3 c-h
Hyola 330	1345 hi	39.42 a	526 c-h
Hyola 308	1165 jk	37.99 c-g	440.3 jk
Kimberly	1383 e-i	38.55 a-d	530.1 c-g
RGS 006	1362 ghi	38.56 a-d	520.2 c-h
19-H	1127 k	37.26 e-h	412.5 kl
SYN-3	1313 hij	37.58 d-g	490 f-j
PR-401/16	1298 hij	36.92 g-j	475.5 g-j
PP-401/15E	1371 f-i	36.96 g-j	504.1 d-i
PP-308/8	1282 hij	37.1 f-i	467.8 h-k
PP-308/3	1516 c-f	37.14 f-i	560.4 bcd
ORS 3150-3006	1538 cd	36.1 ij	549.5 b-e
ORS 3150-3008	1798 a	36.2 hij	643.1 a
RG 4403	1716 ab	38.08 c-f	650.5 a
RG 405/03	1641 bc	36.21 hij	592 b
RGAS 0324	1528 cd	37.3 efg	571.1 bc
RG 405/02	1419 d-h	35.96 j	507 d-i

Any two means sharing a common letter not differ significantly from each other at 5% probability

Table2. Effects and mean comparisons (simple effect) of irrigation and cultivar for assessed traits (2006-2007)

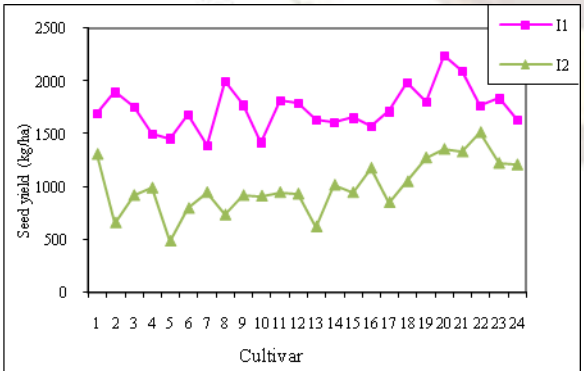

Fig.1. Interaction effect of irrigation and cultivar on seed yield (kg ha^{-1}) (2006-2007)

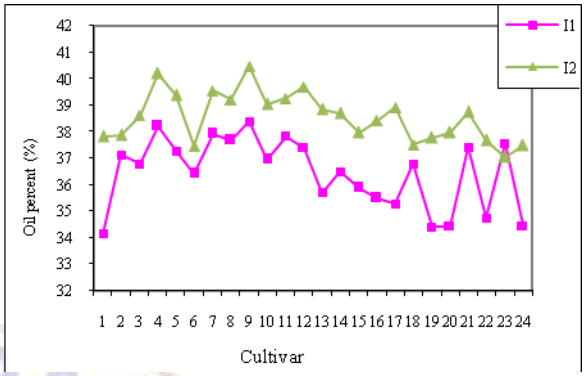

Fig.2. Interaction effect of irrigation and cultivar on seed oil percent (%) (2006-2007)

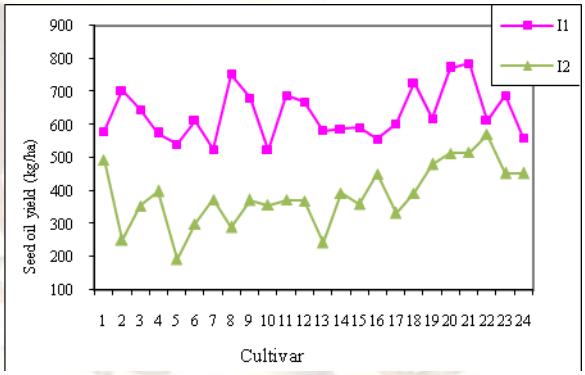

Fig.3. Interaction effect of irrigation and cultivar on seed oil yield (kg ha^{-1}) (2006-2007)

III.II. Second year of the experiment

Seed yield

The simple effects of treatments and the interaction effect of them on seed yield were significant at $P = 0.01$ (Table 3). Normal irrigation by average of 1806.3 kg ha^{-1} showed a significant preference in comparison to interruption of irrigation from the flowering stage by average of 1045.7 kg ha^{-1}. Also assessed cultivars from the seed yield point of view placed in different statistical groups as ORS 3150-3008 by average of 1870 kg ha^{-1} and Hyola 401 by average of 1009 kg ha^{-1} produced the highest and lowest seed yield, respectively (Table 4). Study of the interaction effects of irrigation and cultivar on this trait revealed that assessed cultivars from the seed yield point of view, in different levels of irrigation placed in different statistical groups as ORS 3150-3008 by average of 2330 kg ha^{-1} under normal irrigation condition and Hyola 401 by average of 507 kg ha^{-1} under water stress condition produced the highest and lowest seed yield, respectively. Generally ORS 3150-3008 under normal irrigation condition and RG 405/03 under water stress condition produced the highest seed yield (Fig. 4).

Seed oil percent

The simple effect of irrigation on seed oil percent was significant at $P = 0.05$ and the simple effect of cultivar and interaction effect of irrigation and cultivar on seed oil percent were significant at $P = 0.01$ (Table 3). Interruption of irrigation from the flowering stage by average of 39.34% showed a significant preference in comparison to normal irrigation by average of 37.17%. Also assessed cultivars from the seed oil percent point of view placed in different statistical groups as Hyola 330 by average of 40.21% and RG 405/02 by average of 36.68% produced the highest and lowest seed oil percent, respectively (Table 4). Study of the interaction effect of irrigation and cultivar on this trait revealed that the assessed cultivars from the seed oil percent point of view, in different levels of irrigation placed in different statistical groups as Hyola 330 by average of 41.27% in water stress condition and RGS 003 by average of 34.85% in normal irrigation condition produced the highest and lowest seed oil percent, respectively. Generally Hyola 330 under both irrigation regimes produced the highest seed oil percent (Fig. 5).

Seed oil yield

The simple effects of treatments and the interaction effect of them on seed oil yield were significant at $P = 0.01$ (Table 3). Normal irrigation by average of 671.1 kg ha^{-1} showed a significant preference in comparison to interruption of irrigation from the flowering stage by average of 410.4 kg ha^{-1}. Also assessed cultivars from the seed oil yield point of view placed in different statistical groups as RG 4403 by average of 690.1 kg ha^{-1} and Hyola 401 by average of 389.2 kg ha^{-1} produced the highest and lowest seed oil yield, respectively (Table 4). Study of the interaction effects of irrigation and cultivar on this trait revealed that assessed cultivars from the seed oil yield point of view, in different levels of irrigation placed in different statistical groups as RG 4403 by average of 832.9 kg ha^{-1} under normal irrigation condition and Hyola 401 by average of 204.2 kg ha^{-1} under water stress condition produced the highest and lowest seed oil yield, respectively. Generally RG 4403 under normal irrigation condition and RG 405/03 under water stress condition produced the highest seed oil yield (Fig. 6).

S.O.V.	DF	SY	SOC	SOY
Replication	3			
Irrigation	1	**	*	**
Error	3			
Cultivar	23	**	**	**
Irrigation×	23	**	**	**
Cultivar				
Error	138			
Total	191	-	-	-
CV (%)	-	9.97	3.26	9.53

*, ** significant at 5 and 1% respectively, ns: not significant

Table3. Analysis of variance for assessed traits (2007-2008)

Treatment	Mean SY (Kg ha^{-1})	SOC (%)	SOY (Kg ha^{-1})
Irrigation			
Normal irrigation	1806.3 a	37.17 b	671.1 a
Water stress	1045.7 b	39.34 a	410.4 b
Cultivar			
RGS 003	15.62 c-g	36.72 j	569.7 b-f
Amica	1328 hij	38.25 d-g	505.8 g-j
Sarigol	1389 hi	38.45 c-g	530.5 e-i
Option 500	1294 ijk	39.99 ab	515.5 f-j
Hyola 401	1009 l	39.08 b-e	389.2 l
Hyola 42	1289 ijk	37.67 g-j	483.9 ijk
Hyola 60	1214 jk	39.51 abc	477.6 ijk
Hyola 420	1424 f-i	39.22 a-d	553 c-h
Hyola 330	1399 hi	40.21 a	558 c-h
Hyola 308	1211 jk	38.75 c-g	467.1 jk
Kimberly	1438 e-i	39.32 a-d	562.4 c-g
RGS 006	1416 ghi	39.33 a-d	551.8 c-h
19-H	1172 k	38.01 e-h	437.6 kl
SYN-3	1365 hij	38.33 d-g	519.8 f-j
PR-401/16	1350 hij	37.66 g-j	504.5 g-j
PP-401/15E	1426 f-i	37.7 g-j	534.8 d-i
PP-308/8	1333 hij	37.84 f-i	496.2 h-k
PP-308/3	1577 c-f	37.88 f-i	594.4 bcd
ORS 3150-3006	1599 cd	36.82 ij	582.9 b-e
ORS 3150-3008	1870 a	36.92 hij	682.2 a
RG 4403	1784 ab	38.84 c-f	690.1 a
RG 405/03	1706 bc	36.94 hij	628 b
RGAS 0324	1589 cde	38.05 efg	605.8 bc
RG 405/02	1476 d-h	36.68 j	537.8 d-i

Any two means sharing a common letter not differ significantly from each other at 5% probability

Table4. Effects and mean comparisons (simple effect) of irrigation and cultivar for assessed traits (2007-2008)

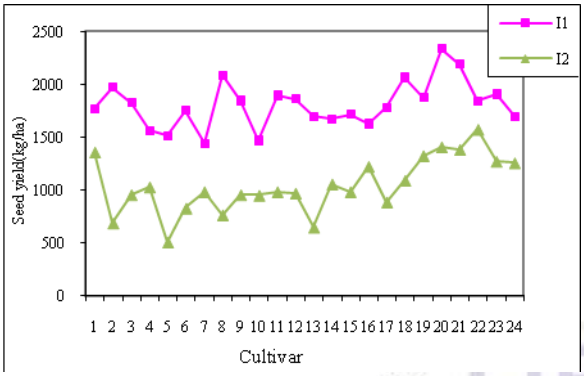

Fig.4. Interaction effect of irrigation and cultivar on seed yield (kg ha^{-1}) (2007-2008)

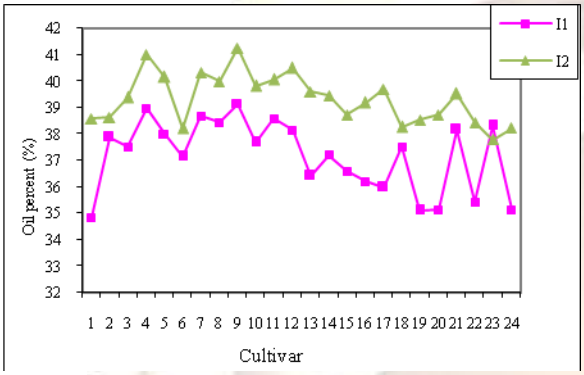

Fig.5. Interaction effect of irrigation and cultivar on seed oil percent (%) (2007-2008)

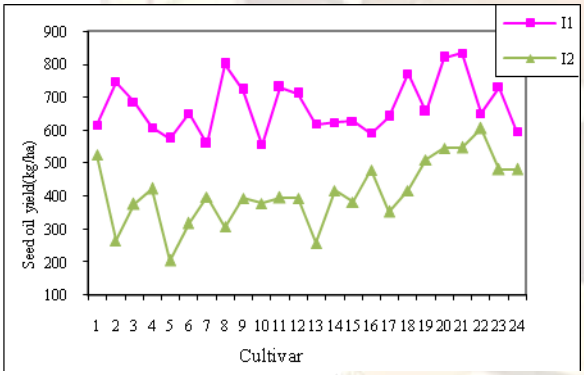

Fig.6. Interaction effect of irrigation and cultivar on seed oil yield (kg ha^{-1}) (2007-2008)

III.III. Both years of the experiment

Seed yield

The simple effects of treatments and the interaction effect of them on seed yield were significant at P = 0.01 (Table 5). Normal irrigation by average of 1771.6 kg ha^{-1} showed a significant preference in comparison to interruption of irrigation from the flowering stage by average of 1025.6 kg ha^{-1}. Also assessed cultivars from the seed yield point of view placed in different statistical groups as ORS 3150-3008 by average of 1834 kg ha^{-1} and Hyola 401 by average of 989.7 kg ha^{-1} produced the highest and lowest seed yield, respectively (Table 6). Study of the interaction effects of irrigation and cultivar on this trait revealed that assessed cultivars from the seed yield point of view, in different levels of irrigation placed in different statistical groups as ORS 3150-3008 by average of 2285 kg ha^{-1} under normal irrigation condition and Hyola 401 by average of 497.3 kg ha^{-1} under water stress condition produced the highest and lowest seed yield, respectively. Generally ORS 3150-3008 under normal irrigation condition and RG 405/03 under water stress condition produced the highest seed yield (Fig. 7). Plants respond to drought by closing their stomata, which reduces leaf transpiration and prevents the development of excessive water deficits in their tissues. The drawback of the stomatal closure for plants is that their carbon gain is lowered and their growth is impaired. Gammelvind et al. (1996) reported that water deficient in late vegetative and early reproductive growth stages reduces photosynthetic rate in leaves and yield [10].

Seed oil percent

The simple effect of irrigation on seed oil percent was significant at P = 0.05 and the simple effect of cultivar and interaction effect of irrigation and cultivar on seed oil percent were significant at P = 0.01 (Table 5). Interruption of irrigation from the flowering stage by average of 38.95% showed a significant preference in comparison to normal irrigation by average of 36.81%. Also assessed cultivars from the seed oil percent point of view placed in different statistical groups as Hyola 330 by average of 39.82% and RG 405/02 by average of 36.32% produced the highest and lowest seed oil percent, respectively (Table 6). Study of the interaction effect of irrigation and cultivar on this trait revealed that the assessed cultivars from the seed oil percent point of view, in different levels of irrigation placed in different statistical groups as Hyola 330 by average of 40.87% in water stress condition and RGS 003 by average of 34.5% in normal irrigation condition produced the highest and lowest seed oil percent, respectively. Generally Hyola 330 under both irrigation regimes produced the highest seed oil percent (Fig. 8).

Seed oil yield

The simple effects of treatments and the interaction effect of them on seed oil yield were significant at P = 0.01 (Table 5). Normal irrigation by average of 651.9 kg ha^{-1} showed a significant preference in comparison to interruption of irrigation from the

flowering stage by average of 398.6 kg ha^{-1}. Also assessed cultivars from the seed oil yield point of view placed in different statistical groups as RG 4403 by average of 670.3 kg ha^{-1} and Hyola 401 by average of 378 kg ha^{-1} produced the highest and lowest seed oil yield, respectively (Table 6). Study of the interaction effect of irrigation and cultivar on this trait revealed that the assessed cultivars from the seed oil yield point of view in different levels of irrigation placed in different statistical groups as RG 4403 by average of 809 kg ha^{-1} under normal irrigation condition and Hyola 401 by average of 198.4 kg ha^{-1} under water stress condition produced the highest and lowest seed oil yield, respectively. Generally RG 4403 under normal irrigation condition and RG 405/03 under water stress condition produced the highest seed oil yield (Fig. 9).

S.O.V.	DF	SY	SOC	SOY
Year	1	*	*	**
Error	6			
Irrigation	1	**	**	**
Year× Irrigation	1	ns	ns	ns
Error	6			
Cultivar	23	**	**	**
Year× Cultivar	23	ns	ns	ns
Irrigation× Cultivar	23	**	**	**
Year× Irrigation× Cultivar	23	ns	ns	ns
Error	276			
Total	383	-	-	-
CV (%)	-	9.67	2.52	9.95

*, ** significant at 5 and 1% respectively, ns: not significant

Table5. Combined analysis of variance for assessed traits (2006-2008)

Treatment	Mean SY (Kg ha^{-1})	SOC (%)	SOY (Kg ha^{-1})
Irrigation			
Normal irrigation	1771.6 a	36.81 b	651.9 a
Water stress	1025.6 b	38.95 a	398.6 b
Cultivar			
RGS 003	1532 cd	36.36 h	553.4 cde
Amica	1303 fg	37.88 efg	491.3 hij
Sarigol	1363 efg	38.07 d-g	515.3 e-h
Option 500	1269 gh	39.6 ab	500.7 ghi
Hyola 401	989.7 j	38.7 cd	378 l
Hyola 42	1265 gh	37.3 g	470 ij
Hyola 60	1191 hi	39.12 abc	463.9 ij
Hyola 420	1396 ef	38.83 c	537.2 d-g
Hyola 330	1372 efg	39.82 a	542 d-g
Hyola 308	1188 hi	38.37 c-f	453.7 jk
Kimberly	1410 ef	38.94 bc	546.3 def
RGS 006	1389 ef	38.94 bc	536 d-g
19-H	1150 i	37.64 fg	425 k
SYN-3	1339 efg	37.96 efg	504.9 f-i
PR-401/16	1324 fg	37.29 g	490 hij
PP-401/15E	1399 ef	37.33 g	519.4 e-h
PP-308/8	1308 fg	37.47 g	482 hij
PP-308/3	1547 c	37.51 g	577.4 bcd
ORS 3150-3006	1568 c	36.46 h	566.2 cd
ORS 3150-3008	1834 a	36.56 h	662.7 a
RG 4403	1750 ab	38.46 cde	670.3 a
RG 405/03	1673 b	36.57 h	610 b
RGAS 0324	1559 c	37.68 fg	588.4 bc
RG 405/02	1447 de	36.32 h	522.4 e-h

Any two means sharing a common letter not differ significantly from each other at 5% probability

Table6. Effects and mean comparisons (simple effect) of irrigation and cultivar for assessed traits (2006-2008)

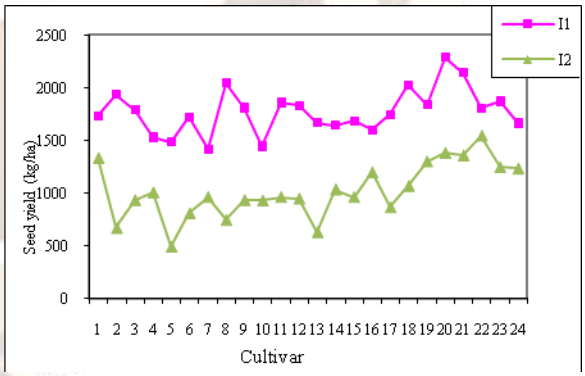

Fig.7. Interaction effect of irrigation and cultivar on seed yield (kg ha^{-1}) (2006-2008)

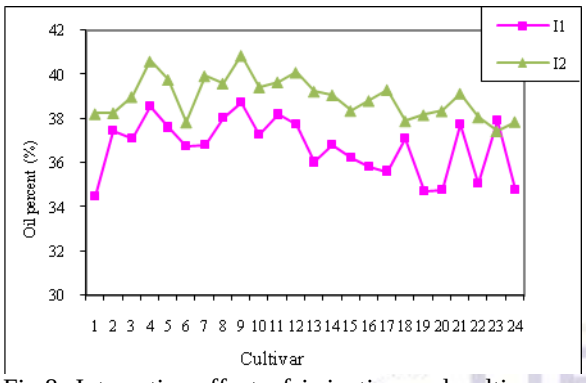

Fig.8. Interaction effect of irrigation and cultivar on seed oil percent (%) (2006-2008)

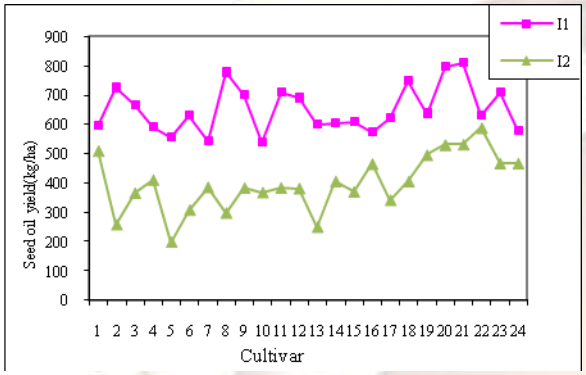

Fig.9. Interaction effect of irrigation and cultivar on seed oil yield (kg ha^{-1}) (2006-2008)

III. Conclusions

This study provides new information about the effect of drought stress from the flowering stage on yield, seed oil percent and seed oil yield of spring rapeseed cultivars in winter planting which helps us to choose the most appropriate and tolerant cultivar for cultivation in a region with cold temperate and semi arid region. Our results showed generally, under normal irrigation condition ORS 3150-3008 cultivar by average of 2285 kg ha^{-1} and RG 4403 cultivar by average of 809 kg ha^{-1} produced the highest seed yield and seed oil yield, respectively. Under water stress condition, RG 405/03 produced the highest seed yield and seed oil yield by average of 1544 and 588.2 kg ha^{-1}, respectively. Therefore ORS 3150-3008 recommended as the best cultivar if there is no water deficit in winter planting for a cold temperate region and RG 405/03 recommended as the best cultivar under late season drought condition in the same condition.

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