ISSN 1517-6398/ *e*-ISSN 1983-4063 - *www.agro.ufg.br/pat* - Pesq. Agropec. Trop., Goiânia, v. 39, n. 3, p. 243-250, jul./set. 2009

RESPONSE OF SIX OILSEED RAPE GENOTYPES TO WATER STRESS AND HYDROGEL APPLICATION[1]

H. R. Tohidi-Moghadam[2], A. H. Shirani-Rad[3], G. Nour-Mohammadi[2],
D. Habibi[4], S. A. M. Modarres-Sanavy[5], M. Mashhadi-Akbar-Boojar[6], A. Dolatabadian[5]

RESUMO

RESPOSTA DE SEIS GENÓTIPOS DE CANOLA
A ESTRESSE HÍDRICO E APLICAÇÃO DE HIDROGEL

Os hidrogéis condicionadores podem melhorar o estabelecimento e crescimento de plântulas, pelo aumento da capacidade de retenção de água dos solos e regulagem do suprimento de água disponível para as plantas, especialmente em ambientes áridos. Este estudo foi desenvolvido para avaliar o papel de polímero superabsorvente, em genótipos de canola (*Brassica napus* L.), sob estresse hídrico, avaliando-se alguns caracteres agronômicos (biomassa total, produção de grãos, componentes da produção e índice de colheita) e fisiológicos (conteúdo de clorofila). O experimento foi conduzido na estação experimental do Instituto para Melhoramento de Sementes e Plantas, em 2007-2008, em Karaj, Irã (35°59´N, 50°75´E, 151 m de altitude), em desenho blocos ao acaso e arranjo fatorial de parcelas divididas, com três repetições. A irrigação teve dois níveis (irrigação após evaporação de 80% de tanque classe A, como testemunha, e estresse hídrico, da floração à maturidade fisiológica) e aplicação de superabsorvente, em dois níveis (ausência de superabsorvente, como testemunha, e aplicação, na concentração de 7%). Os genótipos Rgs003 (V_1), Sarigol (V_2), Option500 (V_3), Hyola 401 (V_4), Hyola330 (V_5) e Hyola420 (V_6) foram alocados em subparcelas. Os resultados mostraram diferença significativa entre os tratamentos de irrigação, superabsorvente e genótipos, nos caracteres agronômicos e fisiológicos. A deficiência de água reduziu a biomassa total, os componentes da produção de grãos, o índice de colheita e o conteúdo de clorofila. Por outro lado, sob condições de campo, o uso de superabsorvente, a 7%, aumentou o desempenho dos caracteres agronômicos e fisiológicos. Os resultados de campo mostraram que a deficiência de água e a ausência de superabsorvente levaram a um decréscimo em todos os parâmetros agronômicos. Estes resultados podem ser creditados à redução da fotossíntese e do conteúdo de clorofila. Neste estudo, o superabsorvente foi capaz de reduzir o efeito destruidor da deficiência de água, pela absorção e preservação da água, o que redundou em melhoria, em diversos caracteres agronômicos. Observando-se o aumento da produção e de seus componentes e da redução da demanda de água, conclui-se que o material é tecnicamente aceitável.

PALAVRAS-CHAVE: *Brassica napus*; hidrogel; estresse hídrico; caracteres agronômicos; conteúdo de clorofila.

ABSTRACT

The hydrogel amendments may improve seedling growth and establishment by increasing water retention capacity of soils and regulation of plants available water supplies, especially under arid environments. This study was conducted to evaluate the role of super absorbent polymer use in oilseed rape (*Brassica napus* L.) genotypes, under drought stress, evaluating some agronomic (total biomass, seed yield, yield components and harvest index) and physiological characters (chlorophyll content). The experiment was carried out in the research farm of the Seed and Plant Improvement Institute, in 2007-2008, in Karaj, Iran (35°59´N, 50°75E, 151 m altitude), as a randomized complete block design, with factorial split-plot arrangement, with three replications. The irrigation strategy had two levels (irrigation after 80% of water evaporation, from class A Pan as control, and drought stress, starting from the flowering stage to physiological maturity) and the application of super absorbent also occurred at two levels (absence of super absorbent as control, and application of super absorbent at 7% concentration), as main plots. Genotypes Rgs003 (V_1), Sarigol (V_2), Option500 (V_3), Hyola401 (V_4), Hyola330 (V_5), and Hyola420 (V_6) were allotted to subplots. Results showed a significant difference between irrigation treatments, presence of super absorbent, and genotypes on agronomic and physiological characters. Water stress decreased total biomass, seed yield components, harvest index, and chlorophyll content. On the other hand, under field conditions, the use of 7% of super absorbent increased agronomic and physiological characters performance. Field results showed that drought stress and absence of super absorbent lead to a decrease in all agronomic parameters. These results may be due to the reduction of photosynthesis and chlorophyll content. In our study, the super absorbent was able to reduce the destructive effect of water deficiency, by absorbing and preserving water and improving several agronomic characters. Observing the increased yield and its components and decreasing plant water requirement, it seems that this material is technically acceptable.

KEY-WORDS: *Brassica napus*; hydrogel; water stress; agronomic character; chlorophyll content.

1. Article submitted on May/2009 and accepted for publishing on July/2009 (n°: PAT 6312).
2. Islamic Azad University, Science and Research Branch, Tehran, Iran.
E-mails: hamid_tohidi2008@yahoo.com, noormohamadi@yahoo.com.
3. Seed and Plant Improvement Institute, Karaj, Iran. E-mail: shirani.rad@gmail.com.
4. Islamic Azad University, Karaj Branch, Karaj, Iran. E-mail: dhabibi@kiau.ac.ir.
5. Tarbiat Modares University, Tehran, Iran. E-mails: modaresa@modares.ac.ir, dolatabadian@yahoo.com.
6. Tehran University, Terbiat Moalem, Tehran, Iran. E-mail: aboojar@yahoo.com.

INTRODUCTION

Drought stress significantly limits plant growth and crop productivity. However, in certain tolerant-adaptable crop plants, such as rape seed, morphological and metabolic changes occur in response to drought, which contribute towards adaptation to such unavoidable environmental constraints (Sinha et al. 1982, Blum 1996).

The fact that water stress effects on growth and yield are genotype-dependent is well known (Bannayan et al. 2008). In Iran, water is a scarce resource, due to the high variability of rainfall. The effects of water stress depend on timing, duration, and magnitude of water deficiency (Pandey et al. 2001). Identification of the critical irrigation timing and scheduling of irrigation, based on a timely and accurate basis to the crop, is the key for conserving water and improving irrigation performance and sustainability of irrigated agriculture (Igbadun et al. 2006, Ngouajio et al. 2007). In arid and semi-arid environments, both efficient use of available water and a higher yield and quality of safflower are in demand (Lovelli et al. 2007, Dordas & Sioulas 2008, Koutroubas et al. 2008).

Efficient management of soil moisture is important for agricultural production in the light of scarce water resources. Soil conditioners, both natural and synthetic, contribute significantly to provide a reservoir of soil water to plants on demand in the upper layers of the soil, where the root systems normally develops. These polymeric organic materials and hydrogels, apart from improving the soil physical properties, also serve as buffers against temporary drought stress and reduce the risk of plant failure, during establishment (De Boodt 1990, Johnson & leah 1990). This is achieved by means of reduction of evaporation through restricted movement of water from the sub-surface to the surface layer (Ouchi et al. 1990). Brassica oilseed species now hold the third position among the oilseed crops and are an important source of vegetable oil (Ashraf & McNeilly 2004).

The reaction of plants to water stress differ significantly, at various organizational levels, depending upon intensity and duration of stress, as well as plant species and its stage of development (Chaves et al. 2003). Environmental stresses, including drought and temperature, affect nearly every aspect of the physiology and biochemistry of plants and significantly diminish yield (Munns 2002, Pitman & Lauchli 2002). Therefore, the primary objective of the present investigation was to examine the effect of water stress on the agronomic characters and physiological exchanges in leaves of rape seed. The work was also aimed at verifying whether a super absorbent polymer supply to plant might be a strategy for increasing the drought tolerance.

MATERIAL AND METHODS

The experiment was carried out at the Seed and Plant Improvement Institute (35°59´N, 50°75´E, and altitude of 151 m above the sea level), in Karaj, Iran, in 2007-2008. This region has a semi-arid climate (354 mm annual rainfall). The soil of the experimental site is a clay loam, with montmorillionite clay mineral, low in nitrogen (0.06-0.07%), low in organic matter (0.56-0.60%), and alkaline in reaction, with a pH of 7.9 and Ec = 0.66 dS m^{-1}. The soil texture is sandy loam, with 10% of neutralizing substances. The experiment was organized in a randomized complete block design, with factorial split plot arrangement, with three replications.

Irrigation strategy and super absorbent application were allotted to main plots. Irrigation strategy had two levels: 80% of evaporation as control (I_1), and water deficit stress, starting from flowering stage (I_2). Super absorbent application was performed at two levels: absence of super absorbent as control (S_1), and application of super absorbent with 7% concentration. Genotypes Rgs003 (V_1), Sarigol (V_2), Option500 (V_3), Hyola401(V_4), Hyola330 (V_5), and Hyola420 (V_6) were allotted to subplots. The 7% concentration of super absorbent, for each plot, was applied. After calculation, super absorbents were poured in adequate amount, on each pail, separately, and sufficient water was added. Thirty minutes were allowed for complete water absorption. Then, it was spread on the whole plot, monotonously and accurately. After settling, each plot was covered with soil. Irrigation of control group was done with seven days apart. Irrigation was carried out by flooding between plant rows. The measured parameters were total biomass, seed yield, yield components, harvest index, and chlorophyll content.

Agronomic characters and sampling

Ten plants per plot were selected at random, at the maturity stage, and the average was determined for two parameters: number of grains per pod and number of pods per plant. Then, thousand grain weight was calculated. For determination of total biomass and seed yield, the samples consisted of 3 m along the center row of each plot, discarding two rows on the border. The remaining plants were cut at ground level, the samples dried and total biomass calculated. Seed yield was determined with the experimental combine harvester machine. Harvest index was computed as the ratio of grain yield to total above ground biomass.

Chlorophyll assay

Chlorophyll was extracted in 80% acetone from leaf samples, according to the method of Arnon (1949). Extracts were filtrated and the content of total Chl, Chl a and Chl b were determined by spectrophotometer, at 645 nm and 663 nm. The content of Chl was expressed as mg g $^{-1}$ FW.

Statistical analysis

All data were analyzed using the SAS software (SAS Institute Inc. 1997). Each treatment was analyzed in three replications. When ANOVA showed significant treatment effects, Duncan's multiple range test was applied to compare the means at $p < 0.05$ (Steel & Torrie 1980).

RESULTS AND DISCUSSION

Natural rainfall varied between the 2007 and 2008 seasons. Total rainfall, during the growing season, was 149.1 mm, in 2007, and 186.6 mm, in 2008. As shown in Table 1, the main effects of all experimental factors were significant for all agronomic traits, in both years, except for concentration of super absorbent on thousand grain weight. Three-way interactions among them were significant for all agronomic traits and chlorophyll content, in both years, except for number of grains per pod.

As main effects of all experimental factors, shown in Tables 2, 3, and 4, water deficit stress decreases all agronomic traits, as well as chlorophyll content, in both years; application of super absorbent increases all agronomic traits and chlorophyll content, in both years, except for thousand grain weight; genotypes show that the highest number of grains per pod and thousand grain weight belong to Hyola401, Hyola330, and Hyola420, and that the highest number of pods per plant belongs to Sarigol genotype. The highest obtained yield was 2.528 kg ha^{-1}, in 2007, and 3.663 kg ha^{-1}, in 2008, and the highest harvest index and chlorophyll content obtained were for the Hyola330 genotype. The number of grains per pod, number of pods per plant, thousand grain weight, seed yield, total biomass, and chlorophyll content responses at maturity were different for each season and were generally higher in 2008 than in 2007. The more

Table 1. Variance analysis for experimental traits.

Treatment	d.f.	Mean Square: Number of grains per pod	Number of pods per plant	Thousand grain weight	Yield	Total biomass	Harvest index	Total chl
Year	1	441.175**	11123.218^{ns}	19.936**	26117465.78**	261651922.5**	142.291**	0.91043^{ns}
Error	4	1.960	3636.595	0.004	530869.03	8198058.0	0.0001	0.55745
Irrigation	1	488.962**	50108.822**	68.918**	63670159.41**	653337030.2**	146.872**	43.879**
Super absorbent	1	244.270**	45035.914**	0.807^{ns}	62248812.54**	642732777.2**	137.250**	13.340**
Irrigation* super absorbent	1	25.967^{ns}	2707.468**	0.005^{ns}	12858260.46	5565234.9**	1223.373**	0.13020**
Year* irrigation	1	1.925^{ns}	478.880^{ns}	0.859*	2102910.85**	14492043.5**	0.187**	0.00036^{ns}
Year* super absorbent	1	1.572^{ns}	427.800^{ns}	0.009^{ns}	2069593.94**	14257609.6**	0.175**	0.00003^{ns}
Year* super absorbent * irrigation	1	0.082^{ns}	19.654^{ns}	0.0001^{ns}	419979.60**	123523.0^{ns}	1.559**	0.00180^{ns}
Error	12	7.686	112.740	0.158	28979.07	301246.9	0.0001	0.00109
Genotype	5	95.242**	11724.021**	**4.045**	6499892.94**	182125267.7**	2850.73231**	2.058**
Irrigation* genotype	5	62.125**	1857.074**	**2.655**	1388768.81**	10643842.3**	77.72876**	0.00655**
Super absorbent* genotype	5	2.710^{ns}	1797.048**	**0.324**	1381621.11**	10638978.2**	73.26103**	0.01440**
Year* genotype	5	0.446^{ns}	114.578**	0.049^{ns}	225859.71**	4039780.9**	3.63713**	0.00079^{ns}
Irrigation* super absorbent* genotype	5	5.119^{ns}	1810.589**	**0.526**	4582683.29**	36379390.6**	135.09023**	0.00999**
Year* genotype* irrigation	5	0.428^{ns}	18.650^{ns}	0.034^{ns}	48946.61**	236112.2**	0.09898**	0.00102^{ns}
Year* genotype* super absorbent	5	0.035^{ns}	18.077^{ns}	0.004^{ns}	50239.94**	235981.0**	0.09347**	0.00041^{ns}
Year* genotype* super absorbent* irrigation	5	0.043^{ns}	18.138^{ns}	0.006^{ns}	159016.29**	806871.3**	0.17236**	0.00047^{ns}
Error	80	9.455	14.162	0.056	3188.8	41434	0.0001	0.00057
Total	143							
C.V.		13.18	4.28	7.1	2.42	2.250	0.038	1.032

ns, *, and **: non-significant and significant, at the 5% and 1% levels of probability, respectively.

Table 2. Effects of irrigation regimes (IR), super absorbent concentration (SU), and genotype (VA) on yield components and seed yield of canola, in 2007 and 2008.

			Number of pods per plant		Thousand grain weight		Seed yield	
IR	SU	VA	2007	2008	2007	2008	2007	2008
					g		kg/ha	
I1			95.867 a	117.092 a	3.587a	4.486a	2443.90a	3537.35a
I2			62.206 b	76.136 b	2.358b	2.948b	1355.70b	1965.76b
	S1		63.075 b	77.206 b	2.906a	3.634a	1362.20b	1974.19b
	S2		94.997 a	116.022 a	3.040a	3.800a	2437.40a	3528.92a
		RGS003	93.083 b	113.833 b	2.740b	3.426b	1570.89e	2277.78e
		Sarigol	103.083 a	126.008 a	2.538c	3.175c	1330.19f	1912.84f
		Option500	93.242 b	113.708 b	2.665c	3.334bc	2158.15b	3129.33b
		Hyola401	60.108 d	73.483 d	3.330a	4.164a	1878.68d	2724.10d
		Hyol330	55.600 e	68.017 e	3.207a	4.007a	2528.78a	3663.73a
		Hyola420	69.100 c	84.633 c	3.356a	4.196a	1932.12c	2801.56c
I1	S1	RGS003	97.533 a	119.333 a	2.966b	3.710b	1419.83d	2058.73d
		Sarigol	91.767 a	112.267 a	2.513c	3.143c	1312.13e	1902.60e
		Option500	94.267 a	115.333 a	2.763bc	3.456bc	2467.50a	3577.90a
		Hyola401	48.500 c	59.433 c	4.340a	5.426a	1341.47e	1945.13e
		Hyol330	49.167 c	60.333 c	4.250a	5.313a	1889.70b	2728.07b
		Hyola420	74.400 b	91.167 b	4.263a	5.330a	1538.30c	2230.50c
	S2	RGS003	107.200 c	131.067 c	3.366cd	4.206cd	2320.60d	3364.87d
		Sarigol	164.233 a	200.600 a	2.940d	3.676d	2065.93e	2931.87e
		Option500	117.700 b	142.433 b	3.536bc	4.423bc	2878.67c	4174.07c
		Hyola401	123.200 b	150.300 b	4.150a	5.186a	3632.70b	5267.43b
		Hyol330	103.033 c	125.600 c	3.993ab	5.000a	4817.40a	6985.23a
		Hyola420	79.400 d	97.233 d	3.970ab	4.963ab	3642.60b	5281.77b
I2	S1	RGS003	71.567 a	87.467 a	2.176a	2.723a	1126.07c	1632.77c
		Sarigol	66.333 a	81.067 a	2.393a	2.993a	644.37f	934.33f
		Option500	68.667 a	84.033 a	2.170a	2.713a	832.20e	1206.70e
		Hyola401	22.567 c	27.633 c	2.300a	2.876a	1219.10b	1767.70b
		Hyol330	22.667 c	27.833 c	2.156a	2.696a	1527.60a	2215.00a
		Hyola420	49.467 b	60.567 b	2.583a	3.230a	1028.17d	1490.83d
	S2	RGS003	96.033 a	117.467 a	2.453ab	3.066ab	1417.07d	2054.77d
		Sarigol	90.000 b	110.100 b	2.306bc	2.886bc	1298.33e	1882.57e
		Option500	92.333 ab	113.033 ab	2.193c	2.743c	2454.23a	3558.63a
		Hyola401	46.167 d	56.567 d	2.530ab	3.166ab	1321.47e	1916.13e
		Hyol330	47.533 d	58.300 d	2.430abc	3.020abc	1880.40b	2726.60b
		Hyola420	73.133 c	89.567 c	2.610a	3.263a	1519.40c	2203.13c

Means, within each column of each section, followed by the same letter, are not significantly different ($p < 0.05$).

favorable weather conditions, in 2008, resulted in a better performance of the above mentioned traits. Also, results of the three-way interaction among irrigation × super absorbent × genotype show that, under water deficit stress and absence of super absorbent, the highest number of pods per plant and thousand grain weight belong to RGS003, Sarigol, and Option500 genotypes, in both years. The same way, the highest seed yield, harvest index, and total chlorophyll content belong to Hyola330, and the highest total biomass belongs to RGS003.

The stress treatments decreased the number of days required for canola plants to reach 50% flowering or maturity, by an average of 4-7 days, if compared with the unstressed control. Similar findings have been reported for faba bean (*Vicia faba* L.), by Mwanamwenge et al. (1999). Acceleration of flowering and/or maturity probably contributed to reduce the impact of drought stress in canola genotypes. The decrease in yield and yield components, in different safflower genotypes, due to water deficiency, has

Table 3. Effects of irrigation regimes (IR), super absorbent concentration (SU), and genotype (VA) on harvest index total biomass and total chlorophyll of canola, in 2007 and 2008.

			Harvest index		Total biomass		Total chl	
IR	SU	VA	2007	2008	2007	2008	2007	2008
			%		kg/ha		mg g^{-1} FW	
I1			27.810 a	29.870 a	9515.4 a	12845.8 a	2.791 a	2.947 a
I2			25.862 b	27.778 b	5889.8 b	7951.3 b	1.684 b	1.846 b
	S1		25.895 b	27.813 b	5904.6 b	7971.2 b	1.933 b	2.091 b
	S2		27.777 a	29.835 a	9500.6 a	12825.9 a	2.541 a	2.701 a
		RGS003	15.579 e	16.733 e	10841.14 a	14635.55 a	1.990 e	2.145 e
		Sarigol	13.581 f	14.588 f	9931.19 b	13407.12 b	1.956 f	2.115 f
		Option500	25.913 d	27.832 d	8269.65 c	11164.03 c	2.093 d	2.245 d
		Hyola401	34.756 b	37.331 b	5118.65 f	6910.18 f	2.475 b	2.625 b
		Hyol330	39.646 a	42.583 a	6194.12 d	8362.17 d	2.698 a	2.855 a
		Hyola420	31.542 c	33.878 c	5860.99 e	7912.37 e	2.211 c	2.393 c
I1	S1	RGS003	11.328 f	12.167 f	12533.5 a	16920.2 a	2.276 e	2.433 e
		Sarigol	12.885 e	13.839 e	10183.3 b	13747.5 b	2.206 f	2.383 e
		Option500	26.250 d	28.195 d	9399.9 c	12689.9 c	2.390 d	2.503 d
		Hyola401	29.025 c	31.175 c	4621.7 e	6239.3 e	2.773 b	2.890 b
		Hyol330	35.739 a	38.386 a	5287.5 d	7138.1 d	2.956 a	3.093 a
		Hyola420	29.123 b	31.279 b	5282.3 d	7131.3 d	2.523 c	2.710 c
	S2	RGS003	17.56 e	18.86 e	13218.8 b	17845.4 b	2.820 e	2.953 e
		Sarigol	13.70 f	14.72 f	15079.1 a	20356.8 a	2.740 f	2.903 f
		Option500	26.25 d	28.19 d	10966.7 c	14805.0 c	2.930 d	3.070 d
		Hyola401	47.56 a	51.09 a	7637.4 f	10310.5 f	3.280 b	3.463 b
		Hyol330	45.55 b	48.93 b	10575.0 d	14276.3 d	3.563 a	3.736 a
		Hyola420	38.75 c	41.62 c	9399.9 e	12689.9 e	3.036 c	3.226 c
I2	S1	RGS003	22.116 e	23.754 e	5091.50 a	6873.53 a	1.123 e	1.293 e
		Sarigol	14.956 f	16.063 f	4308.40 b	5816.33 b	1.033 f	1.190 f
		Option500	24.996 d	26.848 d	3329.30 f	4494.57 f	1.183 d	1.370 d
		Hyola401	33.686 b	36.182 b	3618.90 d	4885.53 d	1.626 b	1.786 b
		Hyol330	41.140 a	44.188 a	3713.10 c	5012.67 c	1.780 a	1.940 a
		Hyola420	29.496 c	31.680 c	3485.80 e	4705.80 e	1.333 c	1.510 c
	S2	RGS003	11.32 f	12.16 f	12520.8 a	16903.1 a	1.743 e	1.900 f
		Sarigol	12.79 e	13.73 e	10154.0 b	13707.8 b	1.846 d	1.986 e
		Option500	26.16 d	28.09 d	9382.7 c	12666.6 c	1.870 d	2.040 d
		Hyola401	28.75 c	30.88 c	4596.6 e	6205.4 e	2.223 b	2.363 b
		Hyol330	36.15 a	38.83 a	5200.9 d	7021.6 d	2.493 a	2.650 a
		Hyola420	28.80 b	30.93 b	5275.9 d	7122.5 d	1.953 c	2.126 c

Means, within each column of each section, followed by the same letter, are not significantly different ($p < 0.05$).

also been reported by other researchers (Zaman & Das 1991, Kar et al. 2007, Lovelli et al. 2007). Anyia & Herzog (2004) indicated that water deficit caused between 11% and more than 40% reduction of biomass, across the genotypes of cowpea (*Vigna unguiculata* L.), due to the decline in leaf gas exchange and leaf area.

Canola yield is, to a very large degree, a result of the interaction between nitrogen and carbon acquisition, throughout the life cycle, and a partitioning of these resources to seed production. Thus, effects of irrigation regimes and reservoir of soil water and micronutrients to plants, on successful acquisition of these resources, in different genotypes, may be useful as tools for improved yield and water use efficiency. Results also show that number of grains per pod and thousand grain weight may be important factors in yield increment. Lovelli et al. (2007) reported that water stress greatly reduced the number of capitula per plant of safflower, while other production components were not influenced. In the present study, the number of pods per plant was significantly correlated with seed yield ($r = 0.46$, $p < 0.05$). Although the highest seed yield belongs to the Hyola330 genotype, in both

Table 4. Effects of irrigation regimes (IR), super absorbent concentration (SU), and genotype (VA) on number of grains per pod in canola, in 2007 and 2008.

			Number of grains per pod	
IR	SU	VA	2007	2008
I1			23.747 a	27.788 a
I2			20.019 b	23.425 b
	S1		20.694 b	24.216 b
	S2		23.072 a	26.997 a
		RGS003	21.242 ab	24.858 ab
		Sarigol	19.850 b	23.233 b
		Option500	19.825 b	23.200 b
		Hyola401	23.667 a	27.683 a
		Hyol330	22.467 ab	26.292 ab
		Hyola420	24.250 a	28.375 a
I1		RGS003	24.000 ab	28.083 ab
		Sarigol	19.700 b	23.050 b
		Option500	19.517 b	22.850 b
		Hyola401	26.800 a	31.350 a
		Hyol330	25.533 a	29.883 a
		Hyola420	26.933 a	31.517 a
I2		RGS003	18.483 a	21.633 a
		Sarigol	20.000 a	23.417 a
		Option500	20.133 a	23.550 a
		Hyola401	20.533 a	24.017 a
		Hyol330	19.400 a	22.700 a
		Hyola420	21.567 a	25.233 a

Means, within each column of each section, followed by the same letter, are not significantly different ($p < 0.05$).

years, the highest total biomass belongs to the RGS003 genotype. That can be explained by the fact that the highest harvest index belongs to Hyola330 and, in this condition, translocation and remobilization of photosynthetic sources increased yield seed in the Hyola330 genotype.

Water deficit stress caused significant declines in chlorophyll content in canola. Dramatic decline in canola under water deficit stress was closely related to a decrease in Relative Water Content, during the initial periods of stress, but not chlorophyll content. Dry and hot environments induce abnormal transpiration water loss, which has a cooling effect, but also can cause rapid cell desiccation (Turner et al. 1966, Nobel 1988a, 1988b). Prolonged periods of water deficit caused loss of chlorophyll and lipid peroxidation, which could lead to further quality decline. Chlorophyll content in live plants is an important factor for determining photosynthetic capacity. Decreased or unchanged chlorophyll level, during drought stress, has been observed in other species, depending on drought duration and severity (Rensburg & Kruger 1994, Kyparissis et al. 1995, Zhang & Kirkham 1996, Jagtap et al. 1998). Changes in leaf chlorophyll content, with drought and heat injury, may involve a severe chlorophyll photooxidation, mediated by oxy-radicals (Wise & Naylor 1987). Also, results for three-way interaction among irrigation × super absorbent × genotype show that, in water deficit stress and application of super absorbent, the highest number of pods belongs to the RGS003 and Option500 genotypes, in both years, and the lowest thousand grain weight belongs to Sarigol and Option500. The highest yield belongs to Option500, the highest total biomass belongs to RGS003, and the highest harvest index and total chlorophyll content belong to the Hyola330 genotype.

The application of super absorbent polymer could reserve different amounts of water for itself and so increase the soil water storage and preservation, and, at last, under water deficiency, result in plant water need, improving its growth. Thus, in drought stress, application of super absorbent affected yield and harvest index. Results are in accordance with Padman's studies (1994), based on increasing the seed yield in improved treatment with this substance. To induce high yield, adequate water is necessary. Then, these substances result in better and more effective use of water and nutrition, increasing available water for plants and resulting in increased yield. In notification to this harvest index, that is actually the proportion of seed yield to biologic yield, with better access of plant to moisture and nutrition by super absorbent, rate of both qualities increases and, at last, the harvest index rate increases. The result of harvest index decrease during stress is compatible with Turk et al. (1980) results. They concluded that, due to stress and water deficiency, certainly the transmission of photosynthetic substances to shoot organs decrease and, in the end, yield components are reduced. Indeed, with the reduction of these components, the harvest rate index decreases. Also, results for two-way interaction between irrigation × genotypes (Table 4) showed that, in irrigation conditions, the lowest number of grains per pod belongs to the Sarigol and Option500 genotypes, in both years, as well, in water deficit stress conditions, there were no significant differences between genotypes.

CONCLUSIONS

Results demonstrate that all tested oilseed rape genotypes responded positively to treatments, in both years. The flowering stage was the most sensitive to water deficit. Drought stress, during this period, caused a reduction in the number of grains per plant and in time to maturity. Consequently, reduced sink capacity and shorter growing period lead to lower seed yield. Water deficit stress, during vegetative growth and seed filling stages, resulted in similar seed yield. This suggested that it is possible to obtain high seed yield with less applied water, when the irrigation halt happens at a tolerant phenological stage. Averaged over both years of the experiment, seed yield was highest with application of super absorbent, due to a better ability to recover from stress, at the flowering and seed filling stages. In this condition, total chlorophyll, total biomass and yield components increased. In conclusion, this study has shown that application of super absorbent polymer can increase the survival capacity of canola plants, under conditions of water deficit stress. The increase in resistance to water deficit stress is associated with the antioxidant activity. According to these results, it may be suggested that the use of super absorbent polymer can reduce the harmful effects of reactive oxygen species and improve plant drought resistance.

REFERENCES

ANYIA, A. O.; HERZOG, H. Water-use efficiency, leaf area and leaf gas exchange of cowpeas under mid-season drought. *European Journal of Agronomy*, Amsterdam, v. 20, n. 4, p. 327-339, 2004.

ARNON, D. I. Copper enzymes in isolated chloroplasts: polyphenoloxidase in *Beta vulgaris*. *Plant Physiology*, Rockville, v. 24, n. 1, p. 1-15, 1949.

ASHRAF, M.; McNEILLY, T. Salinity tolerance in some *Brassica* oilseed. *Critical Reviews in Plant Sciences*, London, v. 23, n. 2, p. 157-174, 2004.

BANNAYAN, M. et al. Yield and seed quality of *Plantago ovata* and *Nigella sativa* under different irrigation treatments. *Industrial Crops and Products*, Amsterdam, v. 27, n. 1, p. 11-16, 2008.

BLUM, A. Crop responses to drought and the interpretation of adaptation. *Plant Growth Regulation*, New York, v. 20, n. 2, p. 135-148, 1996.

CHAVES, M. M.; MAROCO, J. P.; PEREIRA, J. S. Understanding plant responses to drought: from genes to the whole plant. *Functional Plant Biology*, Collingwood, v. 30, n. 3, p. 239-264, 2003.

DE BOOT, M. Application of polymeric substances as physical soil conditioners. In: DE BOOT, M. et al. (Eds.). *Soil colloids and their association in soil aggregates.* London: Planum Publishing Corporation, 1990. p. 580-592.

DORDAS, C. A.; SIOULAS, C. Safflower yield, chlorophyll content, photosynthesis, and water use efficiency response to nitrogen fertilization under rainfed conditions. *Industrial Crops and Products*, Amsterdam, v. 27, n. 1, p. 75-85, 2008.

IGBADUN, H. E. et al. Crop water productivity of an irrigated maize crop in Mkoji sub-catchment of the Great Ruaha River Basin, Tanzania. *Agricultural Water Management*, Amsterdam, v. 85, n. 1/2, p. 141-150, 2006.

JAGTAP, V. et al. Comparative effect of water, heat and light stresses on photosynthetic reactions in *Sorghum bicolor* (L.). Moench. *Journal of Experimental Botany*, Lancaster, v. 49, n. 327, p. 1715-1721, 1998.

JOHNSON, M. S.; LEAH, R. T. Effect of superabsorbent polyacrylamide on efficacy of water use by crop seedlings. *Journal of the Science of Food and Agriculture*, London, v. 52, n. 3, p. 431-434, 1990.

KAR, G.; KUMAR, A.; MARTHA, M. Water use efficiency and crop coefficients of dry season oilseed crops. *Agricultural Water Management*, Amsterdam, v. 87, n. 1, p. 73-82, 2007.

KOUTROUBAS, S. D.; PAPAKOSTA, D. K.; DOITSINIS, A. Nitrogen utilization efficiency of safflower hybrids and open-pollinated varieties under Mediterranean conditions. *Field Crops Research*, v. 107, n. 1, p. 56-61, 2008.

KYPARISSIS, A.; PETROPOULUN, Y.; MANETAS, Y. Summer survival of leaves in a soft-leaved shrub *(Phlomis fruticosa* L., Labiatae) under Mediterranean field conditions: avoidance of photoinhibitory damage through decreased chlorophyll contents. *Journal of Experimental Botany*, Lancaster, v. 46, n. 12, p. 1825-1831, 1995.

LOVELLI, S. et al. Yield response factor to water (Ky) and water use efficiency of *Carthamus tinctorius* L. and *Solanum melongena* L. *Agricultural Water Management*, Amsterdam, v. 92, n. 1/2, p. 73-80, 2007.

MUNNS, R. Comparative physiology of salt and water stress. *Plant, Cell and Environment*, Camberra, v. 25, n. 2, p. 239-250, 2002.

MWANAMWENGE, J. et al. Effect of water stress during floral initiation, flowering and podding on the growth and yield of faba bean (*Vicia faba* L.). *European Journal of Agronomy*, Amsterdam, v. 11, n. 1, p. 1-11, 1999.

NGOUAJIO, M.; WANG, G.; GOLDY, R. Withholding of drip irrigation between transplanting and flowering increases the yield of field-grown tomato under plastic mulch. *Agricultural Water Management*, Amsterdam, v. 87, n. 3, p. 285-291, 2007.

NOBEL, P. S. *Environmental biology of agaves and cacti*. New York: Cambridge University Press, 1988a.

NOBEL, P. S. Principles underlying the prediction of temperature in plants, with special reference to desert succulents. *Symposia of the Society for Experimental Biology*, London, v. 42, n. 1, p. 1-23, 1988b.

OUCHI, S.; NISHIKAWA, A.; KAMEDA, E. Soil-improving effect of a super-water-absorbent-polymer. II. Evaporation, leaching of salts and growth of vegetables. *Journal of the Science of Soil and Manure*, Tokyo, v. 61, n. 6, p. 606-613, 1990.

PADMAN, D. R.; PORWAL, B. L.; PTEL, J. C. Effect of levels of irrigation, nitrogen and jalashakti on growth and yield of Indian mustard. *Indian Journal of Agronomy*, New Delhi, v. 39, n. 4, p. 599-603, 1994.

PANDEY, R. K.; MARANVILLE, J. W.; ADMOU, A. Tropical wheat response to irrigation and nitrogen in a Sahelian environment. I. Grain yield, yield components and water use efficiency. *European Journal of Agronomy*, Amsterdam, v. 15, n. 2, p. 93-105, 2001.

PITMAN, M. G.; LAUCHLI, A. Global impact of salinity and agricultural ecosystems. In: LAUCHLI, A.; LUTTGE, K. V. (Eds.). *Salinity*: environment-plants molecules. Netherlands: Springer, 2002. p. 3-20.

RENSBURG, L. V.; KRUGER, G. H. J. Evaluation of components of oxidative stress metabolism for use selection of drought tolerant cultivars of *Nicotiana tabacum*. L. *Journal of Plant Physiology*, Jena, v. 143, n. 6, p. 730-737, 1994.

SINHA, S. K. et al. Effect of drought on shoot growth: significance of metabolism to growth and yield. In: ______. *Drought resistance in crops with emphasis on rice*. Manila: IRRI, 1982. p. 153-169.

STEEL, R. G.; TORRIE, J. H. *Principals and procedures of statistics*: a biometric approach. New York: McGraw-Hill, 1980.

TURK, K. J.; HALL, A. E.; ASBELL, G. W. Drought adaptation of cowpea. I. Influence of drought on seed yield. *Agronomy Journal*, Madison, v. 72, n. 3, p. 413-42, 1980.

TURNER, R. M. et al. The influence of shade, soil and water on saguaro seedlings establishment. *Botanical Gazette*, Chicago, v. 127, n. 2/3, p. 95-102, 1966.

WISE, R. R.; NAYLOR, W. A. Chilling-enhanced photo-oxidation: the peroxidative destruction of lipids during chilling injury to photosynthesis and ultra structure . *Plant Physiology*, Rockville, v. 83, n. 2, p. 278-282, 1987.

ZAMAN, A.; DAS, P. K. Effect of irrigation and nitrogen on yield and quality of safflower. *Indian Journal of Agronomy*, New Delhi, v. 36, n. 2, p. 177-179, 1991.

ZHANG, J.; KIRKHAM, M. B. Antioxidant response to drought in sunflower and sorghum seedlings. *New Phytologist*, v. 132, n. 3, p. 361-373, 1996.