

The Effects of Water Deficit During Growth Stages of Canola (*Brassica napus* L.)

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Abstract: This study was carried out in farm of the department of agronomy Islamic Azad University science and research branch, in 2004-5 and 2005-6 to determine the effect of different forms of irrigation on the canola (*Brassica napus* L.) Yield and yield components, seed oil and protein content. Ebonit, Elite and SLM046 Cultivars were planted pot experiments under eight treatments including short and long periods of water stress during different growth stages. The greatest seed yield reduction was observed when water stress occurred at flowering (30.3%) and then at silique development (20.7%). Seed yield reduction by short-term water stresses during stem elongation, flowering and silique development were mostly associated with the reduction of silique number per plant but by short-term water stress during seed development was due to the reduction of seed weight. A little compensation was observed by seed weight when water stress occurred before flowering. The number of siliques per plant was the most sensitive yield components under long-term water stress. Seed oil content was decreased by water stress but protein content increased.

Key words: Water deficit % *Brassica napus* L % growth stages % yield and yield components % physiological traits

INTRODUCTION

The world is facing serious shortages of fresh water and growing competition for clear water makes less water available for agriculture. The great challenge for the coming decades will be the task of increasing food production with less water, particularly in countries with limited water and land resources. While on a global scale water resources are still ample, serious water shortages are developing in the arid and semi arid regions, as existing water resources are fully exploited. The situation is exacerbated by the declining quality of water and soil resources. Dependency on water for future development has become a critical constraint for development, which threatens to slow down development, endanger food supplies and aggravate rural poverty. Sustainable food production will depend on the judicious use of water resources to meet future

food demands and to address the growing competition for clean water. Water productivity in terms of output per unit of food per m³ of water used needs to be increased in both irrigated and rain fed agriculture substantially: in short: more crop per drop [1]. Drought, salinity, heat and freezing are environmental conditions that cause adverse effects on the growth of plants. Water deficit more than other stresses limits the growth and the productivity of crops [2]. It is known that one of essential nutrients in human consumption oil or fat is applied from the plant and animal source. Oil seed crops are grown throughout of Iran for use as oils [3]. The increasing area of oil seed crop production is an indication of the success of plant breeders and agronomists in developing suitable cultivars and production methods in semi arid region [4]. The lack of oil in Iran has been met by imports that have entailed considerable costs to make up for the lack of oil in Iran,

oil seed production can be increased by growing oil crops in dry land farming or area with water deficit. According to annual precipitation many regions in Iran suffer from water deficit. Canola is one of the best crops for rotation with wheat. High temperature during maturation and ripening is a major source of stress in karaj environments [5]. Without sufficient water to maintain transpiration, leaf temperature can rise above their optimum for metabolism [6]. Seed yield of *Brassica napus*, *B. juncea* and *B. was* increased due to drought stress [7-11]. The effect of drought stress is a function of genotype, intensity and duration of stress, weather, conditions, growth and developmental stages of rape seed [12]. The occurrence time is more important than the water stress intensity [13]. It is known that the most sensitive growth stage to drought stress is seed filling in bean (*phaseolus vulgaris* L.) [14], heading and flowering in wheat (*Triticum aestivum* L.) [15], seed filling in soybean (*Glycine max* L.) [16], flowering and seed filling in pea (*Cicer arietinum* L.) [17], 2-3 weeks after silking in maize (*zea mays* L.) [18], flowering and anthesis in rice (*Oryza sativa* L.) [19]. Other researchers like Angadi *et al.* [20], Mailer and Cornish [21] and Walton and Bowden [22] also reported that during their experiments the post anthesis duration was significantly correlated with the post anthesis rainfall and was negatively correlated with the main daily temperature during seed development.

Rahnema *et al.* [5] reported that the highest rate of yield reduction was occurred by spring irrigation cut off and one spring irrigation treatments in PF which was the late maturity variety. Also the lowest rate of yield reduction was obtained in spring irrigation cut off and one spring irrigation treatments in H308 hybrid respectively. Gunasekera *et al.* [23] reported that rainfall and thus soil moisture are the most important factors affecting crop production in the typical Mediterranean environment. Seed yield is primarily limited by the relatively short duration of soil moisture during the latter phases of reproductive development. Genotypes having great tolerance to water stress, in addition to earliness, generally would have positive effect on improving adaptability and seed yield in such environments. Nielsen [24] reported that water stress during the grain-filling stage resulted in a more rapid loss of leaf area than during other growth stages. Lower yield resulted from fewer branches per plant, pods per branch and smaller seed. Smis *et al.* [25] observed that canola yield in Montana increased with higher availability of water, but had a lower mean oil content. Miller and Cornish [4] determines that oil content fell from 36.9 to

31.4% when high temperature occurred during the post anthesis seed development in canola. Final seed number and seed yield reduction was approved by high temperature effect during reproductive and ripening growth stages. Under dry land conditions, Henry and Macdonald [26] reported that severe drought decreased oil and increased protein content of rape seed. Jensen *et al.* [7] found that under low evaporative demands (2-4 mm day⁻¹) oil and seed yield were not influenced by soil drying. Under high evaporative demands (4-5 mm day⁻¹) oil and seed yields were significantly decreased, but protein content was not. Thompson [27] observed little effect of water stress on seed protein content in soybean. Whereas Hobbs and Muendle [28] reported that drought stress increased protein content. The occurrence time and intensity of drought differ annually in field. Thus, its very important to determine critical stages of oil seed rape crops against drought stress. The growth especially reproductive growth of rape seed is exposed to drought stress in many areas of Iran. For the Iran with high temperature and the shortage of water during stem elongation, flowering and ripening stages still we need to introduce new varieties to farmers which could more adapted to this environment and also to identify the best optimum irrigation level for this region.

MATERIALS AND METHODS

This study was carried out at the experimental farm of the department of agronomy and crop breeding faculty of agriculture and natural resources, science and research branch, Islamic Azad University Karaj Iran 2004-5 and 2005-6. The climatic data of the region are representing in (Table1). The soil has clay loam texture (the values of texture components is missing in the Table 2) and low organic matter (Table2).

The study was established using a split-plot laid out in a RCB Design with four replication. Three water treatments: water stress free (i.e. normal irrigation treatment as control), moderate and high water stress during reproductive growth (from flowering to seed ripening) were as main-plot and Ebonit, Elite and SLM046 cultivars were as sub-plot. Watering of the control, moderate and high water stress treatments occurred when 25, 50 and 75% of AW were depleted, respectively. The amount of water applied was calculated to restore the water to FC, 25 and 50% depletion of AW for control, moderate and high stress treatments, respectively. FC and PWP were measured by pressure plate.

Table 1: Climatic data of experimental farm of I.A.Univ in 2004-5 and 2005-6 (in growth period) *,**

Year and month	Rainfall (mm)	Min temp (°c)	Average temp (°c)	Max temp (°c)	Evapotranspiration (%)
2004-5					
September	3.0	19.8	28.65	37.5	111.7
October	3.5	17.1	25.65	34.2	91.2
November	19.7	14.3	20.40	26.5	80.0
December	95.3	9.0	13.35	17.7	67.1
January	115.6	5.1	9.60	14.1	56.8
February	29.1	5.0	9.75	14.5	61.3
March	13.3	10.1	18.40	26.7	107.1
April	9.4	15.7	22.00	28.3	139.2
May	0.0	26.7	32.75	38.8	361.4
2005-6					
September	11.0	17.1	26.35	35.6	119.2
October	18.9	19.6	27.30	35.0	85.5
November	25.6	12.2	20.60	29.0	75.2
December	91.4	8.1	13.10	18.1	60.2
January	136.1	6.0	9.00	12.0	55.2
February	45.1	4.8	10.40	16.0	59.0
March	10.2	14.4	20.90	27.4	111.0
April	7.2	15.0	22.00	29.0	140.2
May	0.0	30.4	35.10	39.8	389.0

* Taken from the recording of irrigation department in agricultural & natural resource faculty of I.A.Univ., ** (Data recording): meteorological data were collected 300m from the experiment site. Maximum and minimum temperature, rainfall and class A pan evaporation data for the experimental period

Table 2: Result of some chemical and physical analysis of experimental soil*

Depth (cm)	Potassium (ppm)	Phosphor (ppm)	Nitrogen (%)	Organic matter (%)	EC (mmhos /cm)	PH	FC	PWP
0-30	171	3.8	0.05	0.49	1.2	7.86	18.75	6.33
30-60	179	2.8	0.04	0.29	2.19	7.67	17.91	6.36

*Soil analysis was done at the laboratories of soil science department in I.A. Univ.

Individual plots consisted of 8 rows, 4m long and spaced 30cm apart. Seeds were planted 1 to 1.5cm deep at a rate of 100 seeds m⁻² on 25 September. For all treatments, N:P:K fertilizers applied at a rates of 150:60:50 kg ha⁻¹, respectively. P, K and one-third of N were applied per plant and incorporated. Other two-third of N was split equally at the beginning of the stem elongation and the flowering. All rainfall were excluded by mobile shelter during reproductive growth grass

weeds were controlled by application of gallant-super (Haloxypop r-methyl ester) at 0.6L ha⁻¹ broad-leaf weeds were also hand weeded during the season. Final harvests were carried out at the 30 may. Data collected included acheine yield (obtained by combining the six center rows at each experimental unit), dry matter was determined after drying at 70°C for at least 48 h in an air oven [29, 30]. The following measurements were carried out: biological (above-ground), straw and seed yields, harvest of siliques per plant (with at least on seed), the number index (seed yield divided by biological yield), the number of seed per silique and 1000-seed weight. seed oil and protein content were determined by the Nuclear Magnetic Resonance (NMR) and the Kjeldahl (Protein = 6.25*N) methods, respectively. The experimental data were statistically analyzed for variance using the SAS system [31]. When analysis of variance showed significant treatments effects, Duncan Multiple Range Test was applied to compare the means at P<0.05.

RESULTS

Biological yield decreased 20.7 and 31.2% under moderate and high water stresses compared to the control, respectively. Straw dry matter production also reduced by 21.2 and 30.6%, respectively (Table 3). SLM046 was the most sensitive cultivar to water stress in terms of biological straw and seed yields. Ebonit produced the most seed yield, however seed yield decreased by 19.4 and 32.8% at the moderate high stresses compared to the control, respectively. The number of siliques per plant was the most sensitive yield components to drought stress during reproductive growth. The silique number per plant and seed weight significantly decreased when water stress intensified (Table 3). A little compensation was observed at the moderate water stress by seeds per silique, but there was not under high stress. The number of siliques per plant in SLM 046 was more at the control, but fewer at the moderate and high stresses compared to other cultivars. The number of seeds per silique and 1000-seed weight in Ebonit were significantly higher than other cultivars. The effect of water stress intensity was significant (p = 0.01) on the seed oil and protein contents (Table 3). The effect of water stress was more important on the oil and protein yield than there concentrations. For example, the oil concentration decreased only by 0.39 and 2.16% in the moderate and high water stresses compared to the

Table 3: Bennial mean comparison of biological(BY)straw(StY)and seed(SY)yields, harvest index(HI),the number of siliques per plant(Si/Pl),the number of seeds per silique (S/Si),seed weight (SW),oil content(OC),protein content(PC) and oil yield (OY)in different water stress intensities, cultivars and their interaction (for the field experiment)

Treatment	BY(g mG ²)	StY(g mG ²)	SY(g mG ²)	HI(%)	Si/Pl	S/Si	SW(mg)	OC(%)	PC(%)	OY(g mG ²)
Control(w1)	1125a	807a	318a	28.1a	103a	20.7a	3.37a	48.4a	20.3b	154.0a
Mod. stress(w2)	894b	638b	258b	28.8a	78b	20.9a	3.17b	48.0a	20.7b	124.0b
High stress(w3)	775c	561c	214c	27.6b	63c	19.8a	3.16b	46.3b	22.9a	99.1c
LSD 5%	77	45	19	1.46	6	1.59	0.15	0.71	1.28	6.53
Ebonit	935a	614b	321a	34.3a	77b	23.2a	3.73a	48.3a	19.6b	155.6a
Elite	932a	694a	238b	25.5b	84a	18.9b	2.99b	46.3a	22.2a	110.2b
SLM046	929b	699a	230b	24.7b	84a	19.3b	2.98b	48.2a	22.2a	110.9b
LSD 5%	70	41	14	1.14	6	1.17	0.17	0.55	0.7	5.32
V1*w1	1106a	731b	375a	33.9a	92c	23.5a	3.88a	48.0a	19.1c	180.0a
V1*w2	905b	589de	316b	34.9a	77de	23.2a	3.59b	48.7a	18.8c	153.9b
V1*w3	794cd	520e	274d	34.5a	61fg	22.8a	3.71ab	47.5b	21.0b	130.1c
V2*w1	1117a	831a	286cd	25.6b	104b	19.5bc	3.08cd	47.2b	20.9b	135.0c
V2*w2	912b	677bc	235e	25.7b	81d	19.3bc	2.99cd	46.7b	21.9b	110.2d
V2*w3	789cd	593de	196f	24.8b	69ef	17.9c	2.91cd	44.8c	23.6a	88.0e
V3*w1	1181a	883a	298c	25.2b	114a	19.0bc	3.14c	49.3a	21.0b	146.9b
V3*w2	867bc	646cd	221e	25.5b	78d	20.2b	2.93cd	48.7a	21.4b	108.0d
V3*w3	741d	569de	172g	23.2c	60g	18.7bc	2.85cd	46.5b	24.2a	80.0e
LSD 5%	86	73	18	1.36	8	1.44	0.21	0.95	1.21	9.21

Mean followed by the same letter(s) in each column (between to horizontal lines)are not significantly different (Duncan 5%)

control, but the oil yield decreased by 20and 35.6% respectively the protein yield also decreased despite increased protein concentration.

DISCUSSION

First, flowering, silique development were the critical stages of Canola to water stress. The seed yield reduction due to water stress during flowering (S2) was associated with the reduction of the silique number per plant (26.5%) and the seed number per silique (9.9%). The seed yield reduction at S1 and S3 treatments were also associated mostly with the reduction of the silique per plant. Water stress during seed development (S4) reduced seed yield via reduction of seed weight. Since, water stress during seed development did not affect on the sink size (seeds per plant), decreased source capacity led to reduction of seed weight. Richard and Thurling [32] observed that some cultivars were more sensitive at flowering and others were at silique development. Mingeau [33] demonstrated a critical period from anthesis to anthesis +2 weeks, that seed yield was reduced by (20%) due to water stress during this period. Champolivier and Merrien [34] reported that the most sensitive period of *B.napus* to water stress was between flowering and silique development. Water stress during vegetative or early

reproductive stages of soybean usually reduces yield by reduction of seed number per unit area [13], 1 while stress during seed filling reduces seed size [16, 35, 36]. In a field experiment on *B.napus* and *B.juncea* in west Australia, Gunasekara *at al.* [23] observed that the mean biological yield was decreased by 17.9 and 32.1% and the mean seed yield was decreased by 18.5 and 38.7% by moderate and high water stresses during reproductive growth compared to the control, respectively The number of silique per plant was the most sensitive yield components to water stress during reproductive growth in both pot and field experiments. In Canola, Mendham *et al.* [37] have argued that Canola breeders should be aiming to produce plants with fewer pods but with a higher potential number of seeds per pod as this maximizes seed survival and hence increases seed number per unit area. A similar ideotype has been suggested for both Canola and mustard [38, 39]. There was not the compensation effect between yield components under long-term water stress in the pot and the field experiments. Clarke and Simpson [40] did not observe any compensation between the number of siliques and seeds per silique, too. Kumar *et al.* [41] demonstrated increased 1000-seed weight (a compensation effect) following water stress and reduced the seeds per plant. Straw and seed yields were similarly influenced at S2, S3 and S4 treatments,

consequently harvest indices did not differ compared to the control, harvest index was higher at S1 treatment, because water stress during stem elongation was more affected straw dry matter production than seed yield. The reduction of vegetative dry matter is due to reduction of leaf area and photosynthesis rate [11]. Long-term water stress during reproductive growth decreased harvest index in the pot experiment, but did not affect in the field experiment. Ali *et al.* [42] observed an increase in harvest index following drought stress, but Wright *et al.* [39] obtained reduction of harvest index..

CONCLUSIONS

The objective of this study was to test the hypothesis that although annual precipitation in Iran has variation in period, time and content but to decrease the oil seed import to Iran is this possible that use the new region with water deficit. Also could be produced oil seed by canola in this area. In addition what is the effect of water deficit in different stages of vegetative and reproductive on yield components, seed yield, seed oil and protein contents. It is concluded from the present study that water stress during reproductive growth of canola mainly decreased seed yield by reduction of the silique number per plant. The number of seeds per silique less change than the silique per plant. Therefore, selection or breeding of genotypes with high seeds per silique seems better under water deficit conditions. This characteristic leads to higher seed yield with higher seed yield stability under drought stress. Even though seed weight is usually depend on genotype, heavier individual seed weight is also a good characteristic.

REFERENCES

1. FAO, 2000. Crops and Drops, Land and Water Development Division, FAO, Rome, Italy, pp: 24.
2. Yamaguchi-Shinozaki, K., M. Kasuga, Q. Liu, K. Nakashima, Y. Sakuma and Habe, 2002. Biological mechanisms of drought stress response. JIRCAS Working Report, pp: 1-8.
3. Nabipour, M.M. Meskarbashee and H. Yousefpour, 2007. The effect of water deficit on yield and yield component of safflower (*Carthamus tictorius* L.). Pak. J. Biol. Sci., 10: 421-426.
4. Miller, P., D. Baltensperger, G. Clayton, A. Johnson, G. Lafond, B. McConkey, B. Schatz and J. Starica, 2002. Pulse crop adaptation and impact across the northern Great Plains. Agron. J., 94: 261-272.
5. Rahnema and A.M. Bakhshande, 2006. Determination of optimum irrigation level and compatible canola varieties in the Mediterranean environment. Asian J. Plant Sci., 5: 543-546.
6. Mahan, J.R. and D.R. Upchurch, 1988. Maintenance of constant leaf temperature by plants. I. Hypothesis Limited homeothermy. Environ. Exp. Bot., 28: 351-357.
7. Jensen, C.R., V.O. Mogensen, J.K. fieldsen and J.H. Thage, 1996. Seed glucosinolate, oil and protein contents of field-grown rape (*Brassica napus* L.) affected by soil drying and evaporative demand. Field Crops Res., 47: 93-105.
8. Kumar, A. and D.P. Singh, 1998. Use of physiological indices as a screening technique for drought tolerance in oilseed *Brassica* species. Ann. Bot., 81: 413-420.
9. Sharma, D.K. and A. Kumar, 1989. Effect of irrigation on growth analysis, yield and use water in Indian mustard (*Brassica juncea* L.). Indian J. Agric. Sci., 59: 162-165.
10. Sharma, D.K., 1992. Physiological analysis of yield variations in mustard varieties under water stress and non water stress conditions. Ann. Agric. Res., 13: 174-176.
11. Wright, G.C., C.J. Smith and M.R. Woodroffe, 1988. The effect of irrigation and nitrogen fertilizer on rapeseed (*Brassica napus* L.) production in south-eastern Australia. Irrig. Sci., 9: 1-13.
12. Robertson, M.J. and J.F. Holland, 2004. Production risk of canola in the semi-arid subtropics of Australia. Aust. J. Agric. Res., 55: 525-538.
13. Korte, L.L., J.H. Williams, J.E. Specht and R.C. Sorenson, 1983. Irrigation of soybean genotypes during reproductive ontogeny: II. Yield component responses. Crop Sci., 23: 528-533.
14. Nielsen, D.C. and N.O. Nelson, 1998. Black bean sensitivity to water stress at various growth stages. Crop Sci., 38: 422-427.
15. Moustafa, M.A., L. Boersma and W.E. Kronstad, 1996. Response of four spring wheat cultivars to drought stress. Crop Sci., 36: 982-986.
16. Brevdan, R.E. and D.B. Egli, 2003. Short periods of water stress during seed filling, leaf senescence and yield of soybean. Crop Sci., 43: 2083-2088.
17. Singh, P., 1991. Influence of water deficits on phenology, growth and dry matter allocation in chickpea (*Cicer arietinum* L.). Field Crops Res., 28: 1-15.
18. Grant, R.F., B.S. Jackson, J.R. Kiniry and G.F. Arkin, 1989. Water deficit timing effects on yield components in maize. Agron. J., 81: 61-65.

19. Lilley, J.M. and S. Fukai, 1994. Effect of timing and severity of water deficit on four rice cultivars. III. Phenological development, crop growth and grain yield. *Field Crop Res.*, 37: 225-234.
20. Angadi, S.V., H.W. Cutforth, B.G. McConkey and Y. Gan, 2003. Yield adjustment by canola growth at different plant populations under semiarid conditions. *Crop Sci.*, 43: 1358-1366.
21. Mailer, R.J. and P.S. Cornish, 1987. Effects of water stress on glicosinolate and oil contents in the rape (*Brassica napus* L.) and turnip rape (*B. rapa* L.). *Aust. J. Exp. Agric.*, 27: 707-711.
22. Walton, G., P. Si and B. Boden, 1997. Environmental impact on canola yield and oil. www.Canola-ra/canola/ca7.htm.
23. Gunasekara, C.P., L.D. Martin, R.J. French, K.H.M. Siddique and G.H. Walton, 2003. Effects of water stress on water relations and yield of Indian mustard (*Brassica juncea* L.) and canola (*B. napus* L.). Proceedings of the 11 th Australian Agronomy Conference, Geelong, Australia.
24. Nielsen, D.C., 1997. Water use and yield of canola under dry land conditions in the central great planins. *Agriculture*, 10: 307-313.
25. Smis, J.R., D.J. Solum, D.M. Wichman, G.D. Kushnk and L.E. Welty *et al.*, 1993. Canola variety yield trials. *Montana Agro. Res.*, 10: 15-20.
26. Henry, J.L. and K.B. MacDonald, 1978. The effects of soil and fertilizer nitrogen and moisture stress on yield, oil and protein concentration of rape. *Can. J. Soil Sci.*, 58: 303-310.
27. Thompson, J.A., 1978. Effect of irrigation interval and plant population on growth, yield and water use of soybean in semi-arid environment. *Aust. J. Exp. Agric. Husb.*, 18: 276-281.
28. Hobbs, E.H. and H.H. Muendel, 1983. Water requirements of irrigation soybeans in southern Alberta. *Can. J. Plant Sci.*, 63: 855-860.
29. Schuurman, J.J. and M.A.J. Goedewaagen, 1971. *Methods for Examination of Root Systems and Roots*. 2nd Ed., Wageningen: Pudoc.
30. Veli, S., Y. Kirtok, S. Duzenli, S. Tukul and M. Klinec, 1994. Evaluation of salinity stress on germination characteristics and seedling growth of 3 bread wheat (*T. aestivum* L.). *Tarla Bitkileri Kong Agronomy Bildirileri, Bornova-Izmir. Cilt.*, 1: 57-61.
31. SAS Institute Inc., 1997. *SAS/STAT Users Guide*, version 6, 4th Ed., SAS Institute., Cary, NC, USA.
32. Richards, R.A. and N. Thurling, 1978. Variation between and within species of rape seed (*Brassica campestris* and *B. napus*) in response to drought stress. II. Growth and development under natural drought stress. *Aust. J. Agric. Res.*, 29: 479-490.
33. Mingeau, M., 1974. Comportement du colza de printemps a la secheresse. *Inf. Tech. CETIOM*, 36: 1-11.
34. Champolivier, L. and A. Merrien, 1996. Effects of water stress applied at different growth stages to *Brassica napus* L. var. *oliefera* on yield, yield components and seed quality. *Europ. J. Agron.*, 5: 153-160.
35. Meckel, L., D.B. Egli, R.E. Phillips, D. Radoliffe and J.E. Leggett, 1984. Effect of moisture stress on seed growth soybean. *Agron. J.*, 76: 647-650.
36. De-Souza, P.I., D.B. Egli and W.P. Bruening, 1997. Water stress during seed filling and leaf senescence in soybean. *Agron. J.*, 89: 807-812.
37. Mendham, N.J., J. Russel and G.C. Buzza, 1984. The contribution of seed survival to yield in new Australian cultivars of oil seed rape (*Brassica napus* L.). *J. Agric. Sci. Camb.*, 103: 303-316.
38. Bhargava, S.C. and D.P.S. Tomar, 1990. Physiological contribution for increased yields in rapeseed mustard. In: *proceedings of the International congress of plant physiology*. 15-20 feb. 1987, New Delhi, pp: 354-360.
39. Wright, P.R., J.M. Morgan, R.S. Jossop and A. Cass, 1995. Comparative adaptation of canola (*Brassica napus* L.) and Indian mustard (*B. juncea* L.) to soil water deficit. *Field Crops Res.*, 42: 1-13.
40. Clarke, J. and G.M. Simpson, 1978. Influence of irrigation and seeding rates on yield and yield components of *Brassica napus* cv. Tower. *Can. J. Plant Sci.*, 58: 731-737.
41. Kumar, A., Elston and P. Singh, 1994. Leaf area growth to two *Brassica* species in response to water stress. *Field Crops Res.*, 8: 594-602.
42. Ali, M.A., I. Ohlsson and H. svensk, 1988. Drought stress response in rapeseed (*Brassica Juncea* L. and *B. napus* L.). growth, yield and yield components. *Agric. Hortic. Genet.*, 46: 16-48.