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Evaluation of Traits Related to Water Deficit Stress in Winter Rapeseed Cultivars

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Abstract:

In order to evaluate traits related to water deficit stress in winter rapeseed cultivars and to determine the tolerant and sensitive cultivars, an experiment was carried out in factorial based on randomized complete block design with 3 replications in the greenhouse of Agricultural Faculty of Tabriz-Iran University. First factor including 12 winter rapeseed cultivars, named: Zarfam, Okapi, Modena, Dexter, Olera, Licord, Arc-4, Elite, Opera, SLM046, Fornax, Orient; and the second factor include different levels of water stress that were: severe stress (50% FC), mild stress (75% FC) and well watered (100% FC) conditions. Water deficit stress was imposed from stem elongation to physiological maturity. Moreover, gypsum blocks were used to control the soil moist. The results indicated that there is a significant difference between cultivars and stress related to studied traits. Also, cultivars * stress interaction of proline content and seed yield was significant. The mean comparison of cultivars showed that SLM046 and Orient cultivars have the highest value, while Fornax and Olera cultivars have the lowest value. According to drought tolerance, MP, GMP and TOL indices were the most favorable indices. Also SLM046 and Orient are the most tolerant cultivars under severe stress and mild stress conditions respectively, while Fornax is the most sensitive cultivar in both conditions. The canonical correlation analysis under three environmental conditions showed significant correlation between canonical variables of physiological traits and yield related traits. The regression analysis in different stress levels demonstrated that the silique per plant and seed per silique has important role in increasing seed yield and these verities can help to choose cultivars. The cultivars grouping by cluster analysis showed that in middle stress levels SLM046 and Orient has been placed in same group and have higher value than overall mean. Moreover, Fornax and Olera cultivars hold lower value and are placed in another group. Other cultivars are settled in between.

Keywords: Canonical correlation, Cluster analysis, Drought tolerance index, Rapeseed, Water deficit stress, Regression analysis.

1.0 Introduction:

Rapeseed is the most important plant oil source and the second plant oil in the world after soybean (FAO, 2007). New varieties naturally contain %40- %45 oil which is used as raw materials to produce industrial and hydraulic oil, cleanser, soap and biodegradable plastics (Friedt, 2007). After extracting the oil, the remained, which contains % 38-% 44 high-quality proteins, is used for animal nutrition (Walker and Booth, 2001). Drought and its stress is one of the commonest environmental stresses which limit farm products in around %25 of world's land (Mendham and Salisbury, 1995). Get access to water is one of the main limitations in the yield and quality of most species and it may erupt during the whole growth stage or in critical conditions (Parry et al, 2005). Plants apply a range of particular responses in order to minimize the effects of water shortage or to increase water absorbing rate (Morison et al, 2008). The effect of water stress is a function of genotype, stress degree, weather condition, growth and developing stage of rapeseed (Robertson and Holland, 2004). Water stress in particular stages of rapeseed phenology affects seed qualitative properties such as oil and protein's percentage and the amount of glucosinolate (Strocher et al, 1995).

Liang et al (1992) by evaluating the morphological and physiological responses to water stress showed that *Brassica Juncea* is more adaptable to water stress than *B.napus*. The results of Kumar and Singh experiments (1998) indicate that in oily species of *Brassica* the cell turgid is maintained up o 2.4 Mega Pascal leaf water potential by the genotypes with high osmotic adjustment but with low osmotic adjustment, the fall rate in pressure potential was fast accordingly. Also Valeric et al (2002) remarked that when the separately planted rapeseed leaves were positioned in under high osmotic laboratory, huge amount of proline flocked in leaves. Zulini et al (2002) found a significant correlation between Fv/Fm and leaf water potential in stressed plants so when leaf water potential decreases to less than 0.9 Mega Pascal, decrease in Fv/Fm can be observed.

Numerous experiments suggest that the rapeseed yield is influenced by high number of pods per plant or per area unit (Rao and Mendham, 1991). Jensen et al (1996) reported that the eruption of water stress in vegetative growth and flowering stages didn't have significant effect on each rapeseed weight. However, during water shortage in seed filling stage their weight reduce. It has shown that supplemental irrigation of rapeseed increases the number of pods and seeds per pod by extending flowering stage; and it's because of having many leaves in this stage (Kimber and McGregor, 1995).

2.0 Materials and Methods:

The experiment was conducted under greenhouse conditions in Agricultural Faculty of Tabriz-Iran University, in 2007-2008. Temperature in during the day was 23˚c-25˚c and during the night was 15˚c-17˚c with 14 hours lightening. Also the relative moist was %50-%60.

2.1 Plant Materials:

Plants including the 12 winter rapeseed cultivars named Zarfam, Okapi, Modena, Licord, Olera, Dexter, Arc-4, Elite, Opera, SLM046, Fornax, and Orient were provided from Agricultural and Natural Resources Research Center of East Azerbaijan province-Iran. Cultivation was done in 8-kilogram flowerpots with 5 seeds planted in each. Then thinning was done in dileaf stage and one plant was kept in each flowerpot. Considering that cultivars were winter type, vernalization was done on cultivars. Water deficit stress was imposed from stem elongation to physiological maturity. Gypsum blocks were used in order to control soil moist. The factorial experiment was done with two factors irrigation at 3 levels: well watered stress (100% FC), mild stress (75% FC), severe stress (50% FC) and 12 winter rapeseed cultivars in randomized complete block design with 3 replications.

2.2 Abbreviation:

LWP: Leaf Water Potential, RWC: Relative Water Content, OP: Osmotic Potential, PC: Proline Content, CF: Chlorophyll Fluorescence, CI: Chlorophyll Index, SC: Stomata Conductance, PH: Plant Height, PDW: Plant Dry Weight, RV: Root Volume, RDW: Root Dry Weight, SL: Silique Length, SPP: Silique Per Plant, SPS: Seed Per Silique, 1000-GW: 1000-Grain Weight, Y: Yield

2.3 Measured Traits:

1. Leaf water potential measured by Pressure Chamber; model: Soil Moisture Equipment Crop, Sanata Barbara, CA.
2. **Relative water content**: The method of Morant-manceau et al (2004) was used. First the Fresh Weight (FW) of samples was measured. Then we put the samples in distilled water and after 24 hours the Turgid Wight (TW) was measured and after putting samples in 75˚c Aven the Dry Weight (DW) was measured. Finally the leaf relative water content measured percent by this theorem:
RWC= FW-DW/TW-DW*100
3. Osmotic potential measured by Osmometer; mode: Osmomat 010, Genotel.
4. Stomata conductance measured by Porometer; model: AP4- Porometer (Delta-T Devices) Cambridge, UK.
5. For chlorophyll fluorescence we used florometer; model: Opti Science, OS-30, USA.
6. Chlorophyll index is determined by Chlorophyll meter; model: SPAD-502, Minolta, Japan.
7. Proline contents were measured by Acid Hydrin method. The plant height, plant dry weight, volume of root, root dry weight, length of silique, silique per plant, seed per silique and 1000-grain weight were measured at the end of growth stage.

2.4 Statistical Analysis:

2.4.1 Cluster Analysis:

It was used to classify genotypes in middle stress level, by Ward method according to characteristics analysis.

2.4.2 Regression Analysis:

It was used to determine the best regression equation and also to determine the most influential variants on dependant variant (seed yield), with Stepwise regression analysis method in various stress level.

2.4.3 Canonical Correlation Analysis:
It was applied in two groups of variants which include physiologic traits (V) such as leaf water potential, leaf relative water content, leaf osmotic potential, proline contents, chlorophyll fluorescence, chlorophyll index and stomata conductance and the other which include seed yield traits (W) such as silique per plant, seed per silique, 1000-grain weight and seed yield.

2.4.4 Drought Tolerance Index:
In order to evaluate and recognize the most tolerant and sensitive cultivar, Stress Tolerance Indices (STI), Geometric Mean Productivity (GMP) of Fernandez (1992), Tolerance indices (TOL) and Mean Productivity (MP) of Rosielle and Hamblin (1989) and water Stress Sensitivity Indices (SSI) of Fischer and Maurer (1978) were used.

3.0 Results and Discussion:
Variance analysis showed there is significant difference in cultivars which suggests the significant genetic diversity (tables 1A, 1B, 2A and 2B). A significant difference in stress levels can be observed as well (tables 1A, 1B, 3A and 3B). Cultivars * stress interaction was significant only in proline content and seed yield (tables 4 and 5); it means cultivars show different reactions in different stress levels. So it should choose separately the cultivars that have high yield in each stress level. Jongdee *et al* (2002) report genetic diversity in protection of leaf water potential and osmotic adjustment in rice under water shortage condition. Nasri *et al* (2008) announce that the number of pods per plant is reduced by the severe increase of water stress. Mostajeran and Rahimi (2009) showed that the proline content in fresh and old rice leaves increased under the effect of water stress.

Table 1A: Variance analysis in rapeseed traits under water deficit stress

Source of variation	Degree of freedom	Mean of Squares							
		LWP	RWC	OP	PC	CF	CI	SC	PH
Block	2	.02^{ns}	317.15**	.01^{ns}	23.93**	.001^{ns}	2.72^{ns}	.001^{ns}	57.61**
Cultivar	11	.7**	138.64**	.34**	16.56**	.01^{ns}	219.82**	.23**	1296.12**
Stress	2	2.43**	238.18**	2.47**	99.61**	.06**	560.8**	2.56**	18511.42**
Cultivar * Stress	22	.02^{ns}	2.32^{ns}	.05^{ns}	2.77**	.001^{ns}	3.92^{ns}	.003^{ns}	44.67^{ns}
Error	70	.03	2.99	.06	.36	.01	10.13	.01	58.69
Coefficient of variations %		14.73	2.12	21.75	25.41	12.5	9.5	16.19	6.91

Table 1B

Source of variation	Degree of freedom	Mean of Squares							
		PDW	RV	RDW	SL	SPP	SPS	1000-GW	Y
Block	2	195.93**	1.04^{ns}	2.78**	.02^{ns}	3596.51^{ns}	16.21^{ns}	1.79**	66.94**
Cultivar	11	299.57**	5.91**	1.95**	3.05**	46453.17**	53.54**	1.74**	196.01**
Stress	2	844.44**	50.61**	12.46**	21.31**	81341.78**	696.74**	.93*	979.74**
Cultivar * Stress	22	14.43^{ns}	1.13^{ns}	.21^{ns}	.21^{ns}	1259.72^{ns}	4.61^{ns}	.19^{ns}	22.91**
Error	70	15.86	1.22	.37	.26	1329.57	5.42	.26	7.99
Coefficient of variations %		18.85	17.75	27.69	12.17	22.5	18.83	11.69	29.86

ns, *, **, sequentially non significant and significant in 5% and 1%

Table 2A: Mean of rapeseed cultivar of studied traits in middle of water deficit stress level

Cultivar	LWP	RWC	OP	CF	CI	SC	PH
Zarfam	-1.22b	84.26b	-1.27cd	.8cde	34.04bc	.53bcd	112.27bcd
Okapi	-.89a	84.9b	-.94ab	.82cd	39.92a	.46ab	119.48ab
Modena	-1.73f	82.29cd	-1.3cd	.78e	31.35cd	.5abc	107.06d
Dexter	-1.29bc	83.21bcd	-1.24cd	.82bc	29.62de	.94g	108.4d
Olera	-1.44cd	79e	-1.22cd	.81cd	31.77cd	.46ab	111.67bcd
Licord	-1.14b	83. 88 bc	-1.18bcd	.85ab	33.91bc	.58cd	117.88abc
Arc – 4	-1.48de	81.56d	-1.25cd	.8cde	31.81cd	.7ef	121.58a
Elite	-1.29bc	82.42cd	-1.44d	.73f	27.8ef	.85g	111.3cd
Opera	-1.29bc	81.44d	-1.27cd	.8cde	36.86b	.62def	109.31d
SLM0 46	-.91a	87.46a	-1.09bc	.86a	36.17b	.71f	124.09a
Fomax	-1.65ef	73.03f	-1.42d	.71g	25.25f	.61de	77.03e
Orient	-.91a	87.95a	-.75a	.85ab	42.58a	.4a	109.98cd

Non similar letter in each column, significant difference between rapeseed cultivar in 5%.

Table 2B

Cultivar	PDW	RV	RDW	SL	SPP	SPS	1000-gw
Zarfam	18.01cd	6.14b	1.73de	4.05cd	143.67e	12.77bcd	4.25cd
Okapi	19.48cd	6.64ab	2.4bc	4.28bc	183.56cd	13.72bc	4d
Modena	19.11cd	6.03b	2.42bc	4.06cd	156.44de	11.35cde	4.75 bc
Dexter	21.25c	6.1b	2.06bcd	3.66d	177.56cde	10.25e	4.83b
Olera	37.4a	6.69ab	2.13bcd	2.96e	24.44f	13.66bc	5.4a
Licord	20.48c	7.48a	2.58ab	4.64ab	196.11c	13.67bc	4d
Arc – 4	20.9c	6.16b	2.24bcd	4.08cd	161.89cde	10.87de	4.77bc
Elite	15.25d	6.01b	2.63ab	4.11cd	160.56cde	12.26bcde	4.08d
Opera	19.94cd	5.91b	1.84cde	4.09cd	197.56c	12.43bcde	4.15d
SLM0 46	17.34cd	5.92b	2.21bcd	4.91a	234.89b	16.71a	3.97d
Fornax	20.38c	4.43c	1.32e	3.06e	33.66f	6.82f	4.4bcd
Orient	26.12b	7.56a	3.11a	4.58abc	274.11a	14.01b	4.48bcd

Non similar letter in each column, significant difference between rapeseed cultivar in 5%.

Table 3A: Mean of different level of water deficit stress in rapeseed traits

Soil moisture level	LWP	RWC	OP	CF	CI	SC	PH
100% FC	-1.02a	85.16a	-1.48c	.84a	37.81a	.9c	134.38a
75%FC	-1.24b	82.67b	-1.16b	.8b	32.31b	.57b	108.99b
50%FC	-1.54c	80.02c	-.96a	.76c	30.15c	.37a	89.14c

Table 3B:

Soil moisture level	PDW	RV	RDW	SL	SPP	SPS	1000-GW
100%FC	26.46a	5.29c	1.8b	4.82a	208.75a	17.09a	4.26b
75% FC	19.98b	5.88b	1.98b	4.01b	163.64b	11.66b	4.42ab
50% FC	16.98c	7.57a	2.98a	3.29c	113.72c	8.38c	4.59a

Table 4: Mean of yield per plant in rapeseed cultivar under water deficit stress

Cultivar	50%FC	75% FC	100% FC
Zarfam	2.57e	8.45c	13.95 c
Okapi	6.49b	6.33d	18.46 b
Modena	2.11e	8.7c	18.46b
Dexter	5.1c	7.48c	17b
Olera	.41f	1.74e	4.5e
Licord	7.89b	10.27b	14.36c
Arc – 4	3.99d	6.95d	16.16b
Elite	3.49d	8.64c	12.74d
Opera	4.7c	12.51b	12.74d
SLM0 46	11.37a	11.64b	24.57a
Fornax	.31f	.98e	1.99e
Orient	9.58a	18.28a	25.53a

Table 5: Mean of proline content in rapeseed cultivar under water deficit stress

Cultivar	50%FC	75% FC	100% FC
Zarfam	4.67c	2.01c	1.02b
Okapi	10.17a	5.42a	1.02b
Modena	4.03c	1.54d	.87c
Dexter	4.17c	2.44c	.88c
Olera	3.73d	2.14c	1.06b
Licord	2.52e	1.25d	.51d
Arc – 4	2.36e	1.11d	.52d
Elite	2.07e	.86e	.27e
Opera	3.57d	1.71d	.27e
SLM0 46	3.88d	2.72c	.82c
Fornax	1.88f	.82e	.54d
Orient	6.74b	3.77b	1.32a

Table 6: Mean of drought tolerance indices in different genotype based on grain yield under severe water deficit stress

Index / Genotype	TOL	MP	GMP	SSI	STI
Zarfam	5.21	8.26	5.92	1.55	.15
Okapi	5.43	12.45	10.87	1.18	.54
Modena	7.62	10.28	6.11	1.61	.17
Dexter	11.68	11.06	8.39	1.11	.4
Olera	9.18	2.46	1.36	1.69	.008
Licord	5.41	11.12	10.36	.62	.47
Arc – 4	12.52	10.07	7.58	1.46	.23
Elite	10.27	8.11	6.56	1.27	.18
Opera	9.38	9.23	8.02	1.21	.29
SLM046	3.58	17.97	17.7	1.06	1.32
Fomax	15.32	1.94	.77	1.59	.002
Orient	4.05	77.53	15.53	1.15	1.05

3.1 Drought Tolerance Index:

Among drought tolerance indices, MP, GMP and TOL, were known as the most suitable and the best indices. Because these indices always choose genotypes that have high yield mean in different environments. In this study, according to MP, GMP and TOL indices, SLM046 and Orient were the most tolerant cultivars under severe as well as mild stress conditions, while Fornax was the most sensitive cultivar under both conditions (tables 6 and 7). Sundari at al (2005) introduced MP and GMP indices as the best indices to tolerate stress. Similar results in evaluating wheat genotypes to water stress were reported by Sio-se Mardeh et al (2006). Richard (1996) believes that choosing genotypes in both non-stress and stressed conditions cause the aggregation of favorite alleles and high-yield genotypes will be chosen.

Table 7: Mean of drought tolerance indices in different genotype based on grain yield under mild water deficit stress

Index / Genotype	TOL	MP	GMP	SSI	STI
Zarfarm	4.45	11.2	10.72	0.72	0.51
Okapi	7.29	12.37	10.7	1.23	0.53
Modena	6.01	13.49	12.43	1	0.69
Pexter	10.73	12.22	11.1	1.07	0.54
Olera	8.57	3.11	2.66	1.12	.03
Licord	5.03	12.31	12.08	.49	.57
Arc- 4	10.46	14.35	10.57	1.05	.53
Elite	9.82	10.69	10.46	.85	.47
Opera	7.12	13.13	13.1	.73	.78
SLM046	6.51	14.85	16.7	.91	1.21
Fornax	13.82	1.48	1.38	.94	.001
Orient	3.41	19.8	21.41	.52	2.06

3.2 Canonical Correlation Analysis:

3.2.1: Severe Water Stress

The first linear compound of physiological verities (Vi) and yield related traits (Wi) was obtained in this way.

V1= 0.20 X1+ 0.28 X2+ 0.19X3- 0.03X4 + 0.03X5+ 0.61X6+ 0.30X7
W1= 1.32Y1+ 1.01Y2- 0.18Y3- 1.23Y4

Structural correlation between physiological traits and their canonical variables under severe water stress has showed in tables 8 and 9. Among physiological traits, leaf water potential (0. 76), relative water content (0. 79), leaf osmotic potential (0. 67) and chlorophyll index (0. 86) had high and positive correlation with their canonical variables (V1). But proline content, chlorophyll fluorescence and stomata conductance had low correlation. Also, among yield related traits there was high and positive correlation between silique per plant (0. 81), seed per silique (0. 71) and grain yield per plant (0. 72) and their canonical variables (W1). However, 1000-grain weight had low and negative correlation of physiological traits with canonical variable of yield related traits under severe water stress showed among physiological traits leaf water potential, relative water content, leaf osmotic potential and chlorophyll index had high and positive correlation with canonical variables of yield related traits (W1). On the other hand, among yield related traits there was high and positive correlation between silique per plant, seed per silique and grain yield per plant and canonical variable of physiological traits(V1) (tables 10and 11).

As for above results, canonical variable of physiological traits (V1) were affected of yield related traits except 1000-grain weight and canonical variable of yield related traits (W1) were affected of physiological traits such as leaf water potential, relative water content, leaf osmotic potential and chlorophyll index. Thus, for selection high yield cultivars leaf water potential, relative water content, leaf osmotic potential and chlorophyll index can be an important scale. Pirdashti et al (2009) has observed significant and positive correlation between chlorophyll content, proline content and leaf relative water content with grain yield in rice cultivars under drought conditions.

Table 8: Structural correlation between physiological traits and their canonical variates under sever water deficit stress

Trait	V1	V2	V3	V4
LWP	.767	.098	-.19	.502
RWC	.798	-.318	-.158	.206
OP	.673	-.12	.094	.078
PC	.539	.591	-.255	.033
CF	.572	.247	.364	.336
CI	.868	.302	-.211	-.222
SC	-.173	-.258	.572	.142

Table 9: Structural correlation between grain yield traits and their canonical variates under severe water deficit stress

Trait	W1	W2	W3	W4
SPP	.817	-.192	.522	.146
SPS	.718	.464	-.088	.51
1000-GW	-.48	.563	.663	0.11
Y	.726	.09	.39	.558

Table 10: Correlation of physiological traits with canonical variable of grain yield under severe water deficit stress

Trait	W1	W2	W3	W4
LWP	.676	.06	-.06	.103
RWC	.703	-.161	-.05	-.005
OP	.594	-.061	.029	-.016
PC	.476	.3	-.08	.007
CF	.504	.125	.115	.069
CI	.466	.153	-.066	-.045
SC	-.153	-.13	.18	.029

Table 11: Correlation of grain yield traits with canonical variable of physiological traits under severe water deficit stress

Trait	V1	V2	V3	V4
SPP	.72	-.097	.164	.03
SPS	.633	.235	-.027	.106
1000-GW	-.423	.285	.209	.022
Y	.64	.045	.123	.115

3.2.2: Mild Water Stress:

The first linear compound of physiological traits (Vi) and yield related traits (Wi) was obtained in this way.

$V1= 1.08\ X1+ 0.16\ X2+ 0.29X3- 0.27X4 - 0.25X5+ 0.0006X6+ 0.01X7$

$W1=0.03Y1-0.19Y2- 0.72Y3+0.77Y4$

Structural correlation between physiological traits and their canonical variable under mild water stress has showed in tables 12 and 13. Leaf water potential (0. 93) and relative water content (0. 62) had high and positive correlation with their canonical variable (V1). Also, silique per plant (0. 78) and grain yield per plant (0. 71) had high and positive correlation with their canonical variable (W1). Atteya (2003) reported that seed yield at corn decreased by the increase of leaf water potential and amount of leaf relative water content under water stress. Correlation of physiological traits with canonical variable of yield related traits under mild water stress showed physiological traits such as leaf water potential and relative water content had high and positive correlation with canonical variable of yield related traits (W1).

On the other hand, among yield related traits threr was high and positive correlation between silique per plant and grain yield per plant and canonical variable of physiological traits(V1) (tables 14and 15). Under this condition, canonical variable of physiological traits (V1) were affected of yield related traits except seed per silique and 1000-grain weight and canonical variable of yield related traits (W1) were affected of physiological traits such as leaf water potential and relative water content.

Table 12: Structural correlation between physiological traits and their canonical variates under mild water deficit stress

Trait	V1	V2	V3	V4
LWP	.931	.145	-.134	-.068
RWC	.628	.356	-.204	-.071
OP	.245	.312	.748	.272
PC	.283	.323	.287	-.011
CF	.422	.844	-.159	.056
CI	.506	.545	.461	-.104
SC	.06	-.29	.028	-.69

Table 13: Structural correlation between grain yield traits and their canonical varites under mild water deficit stress

Trait	W1	W2	W3	W4
SPP	.782	.473	.338	-.221
SPS	.439	.428	-.57	.546
1000-GW	-.694	.491	.501	.157
Y	.717	.549	.309	.296

Table 14: Correlation of physiological traits with canonical variable of grain yield under mild water deficit stress

Trait	W1	W2	W3	W4
LWP	.697	.083	-.065	-.016
RWC	.47	.204	-.099	-.016
OP	.183	.179	.366	.064
PC	.212	.185	.14	-.028
CF	.316	.485	-.077	.013
CI	.379	.313	.225	-.24
SC	.045	-.167	.014	-.161

Table 15: Correlation of grain yield with canonical variable of physiological traits under mild water deficit stress

Trait	V1	V2	V3	V4
SPP	.585	.272	.165	-.052
SPS	.328	.246	-.278	.128
1000-GW	-.519	.282	.245	.037
Y	.537	.315	.151	.069

3.2.3: Well Watered Condition:

The first linear compound of physiological traits (Vi) and yield related traits (Wi) was obtained in this way.

V1=0.12 X1+ 0.34 X2+ 0.18X3+ 0.09X4 + 0.29X5+ 0.31X6+ 0.19X7
W1=1.11Y1+0.52Y2+ 0.18Y3-0.37Y4

Structural correlation between physiological traits and their canonical variable under well watered condition has showed in tables 16 and 17. Leaf water potential (0.78), relative water content (0.75), chlorophyll fluorescence (0.81) and chlorophyll index (0.81) had high and positive correlation with their canonical variable (V1). Other variables had low correlation.

Also, there was high and positive correlation between silique per plant (0.87), seed per silique (0.73), grain yield per plant (0.89) and their canonical variables (W1).but 1000-grain weight had low and negative correlation. Correlation of physiological traits with canonical variable of yield related traits under well watered showed leaf water potential, relative water content, chlorophyll fluorescence and chlorophyll index had high and positive correlation with canonical variable of yield related traits (W1). On the other hand, among yield related traits there was high and positive correlation between silique per plant, seed per silique, grain yield per plant and canonical variable of physiological traits (V1) (tables 18 and 19). In this condition, leaf water potential, relative water content, chlorophyll fluorescence and chlorophyll index can be used for selection of high yield, because canonical variable of yield related traits (W1) were affected of physiological traits such as leaf water potential, relative water content, chlorophyll fluorescence and chlorophyll index.

Table 16: Structural correlation between physiological traits and their canonical varieties under well watered

Trait	V1	V2	V3	V4
LWP	.781	.1	-.359	-.257
RWC	.758	.029	-.293	.218
OP	.526	-.327	.326	-.326
PC	.446	.593	.257	-.257
CF	.818	-.215	.239	-.239
CI	.816	.464	.001	-.134
SC	.045	-.512	-.041	.762

Table 17: Structural correlation between grain yield traits and their canonical varieties under well watered

Trait	W1	W2	W3	W4
LWP	.623	.053	-.17	-.082
RWC	.606	.015	-.138	.069
OP	.42	-.173	.026	-.104
PC	. 356	.314	.215	-.082
CF	.653	-.114	-.16	-.075
CI	.651	.246	.0006	-.043
SC	.036	-.271	-.019	.243

Table 18: Correlation of physiological traits with canonical variable of grain yield under well watered

Trait	W1	W2	W3	W4
SPP	.876	.003	-.277	.393
SPS	.736	.135	.201	-.63
1000-GW	-.153	.293	.942	-.046
Y	0.896	.345	-.089	.266

Table 19: Correlation of grain yield traits with canonical variable of physiological traits under well watered

Trait	V1	V2	V3	V4
SPP	.699	.002	-.131	.125
SPS	.588	.072	.095	-.201
1000-GW	-.122	.155	.445	-.015
Y	.714	.183	-.042	-.085

3.3 Regression Analysis:

3.3.1: Severe Water Stress:

Results from regression analysis in severe water stress (50% FC) showed that the silique per plant, seed per silique, chlorophyll index and stomatal conductivity cumulatively could explain more than %98 of the variation for grain yield per plant. The silique per plant and seed per silique being 0.77 and 0.64 respectively had the most direct influence on seed yield. The indirect effect of silique per plant by seeds per silique was 0.39, whereas indirect effect of seeds per silique by silique per plant was0.47 (table20). Yucel et al (2006) in a research on pea by path analysis showed the number and length of pod had direct positive effect on seed yield.

Table 20: Regression analysis of grain yield with other traits under severe water deficit stress

Trait	Direct effect	Indirect effect via				Correlation of x with y
		1	2	3	4	
SPP	.77	-	.39	-.25	.003	.91
SPS	.64	.47	-	-.31	.03	.83
CI	-.43	.46	.46	-	.08	.58
SC	-.15	-.02	-.14	.24	-	-.07

3.3.2: Mild Water Stress:

In mild stress condition (75% FC), silique per plant, seed per silique, chlorophyll index, 1000-grain weight and plant height explained more than %96 of the variation for grain yield per plant. The silique per plant and seed per silique being 0.68 and 0.61 respectively had the most direct influence on seed yield, but their indirect effects were low (table21). Ahmadzadeh et al (2008) in path analysis for safflower genotypes reported that the 1000-grain weight and hectolit weight had direct and positive effect on seed yield and said that choosing according to these characteristics will be effective in improving seed yield.

Table 21: Regression analysis of grain yield with other traits under mild water deficit stress

Trait	Direct effect	Indirect effect via					Correlation of x with y
		1	2	3	4	5	
SPP	.68	-	.31	-.07	-.01	-.05	.86
SPS	.61	.35	-	-.08	-.008	-.07	.81
CI	-.13	.37	.36	-	-.03	-.06	.52
1000-GW	.11	-.09	-.05	.04	-	.01	.02
PH	-.12	.31	.36	-.07	-.01	-	.48

3.3.3: Well Watered Condition:

In well watered condition (100% FC) silique per plant, seed per silique, 1000-grain weight, plant height and leaf water potential determined more than %94 of the variation in grain yield per plant. The silique per plant (0.83) and seed per silique (0.51) has the most direct effect on seed yield but the indirect effect was low (table22).

Table 22: Regression analysis of grain yield with other traits under well watered

Trait	Direct effect	Indirect effect via					Correlation of x with y
		1	2	3	4	5	
SPP	.83	-	.11	-.05	-.12	.09	.86
SPS	.51	.19	-	-.09	-.11	.06	.56
1000-GW	.32	-.14	-.14	-	.01	-.07	-.03
PH	-.25	.39	.23	-.01	-	.08	.44
LWP	.16	.46	.18	-.15	-.13	-	.52

As for above results, it can be said that the silique per plant and seed per silique has important role in increasing seed yield and these verities can help us in choosing cultivars. Because this traits had superior direct effect on grain yield. On the other hand, silique per plant and seed per silique had high correlation with grain yield.

3. 4 Cluster Analysis:

Figure 1 show the dendrogram of genotype cluster analysis based on evaluated traits under middle water stress. When the cutting of dendrogram was done in distance 7, the discernment function was significant in 5%. It means, the maximum difference was observed between groups of the first function. The cutting of dendrogram at this unit is led to form the five groups. Orient and Okapi were placed in the first group and had higher mean than overall mean with respect to all of the traits, except 1000-grain weight. In the second group SLM046 and Licord held higher mean values than overall mean regarding to all of the traits except proline content, plant dry weight and 1000-grain weight. Fornax in the third group and Olera in the fourth group had lower mean value for most of the traits. The remaining cultivars constituted the fifth cluster and characterized by higher mean values for stomatal conductance, plant height, number of siliques per plant and 1000-grain weight (table23).

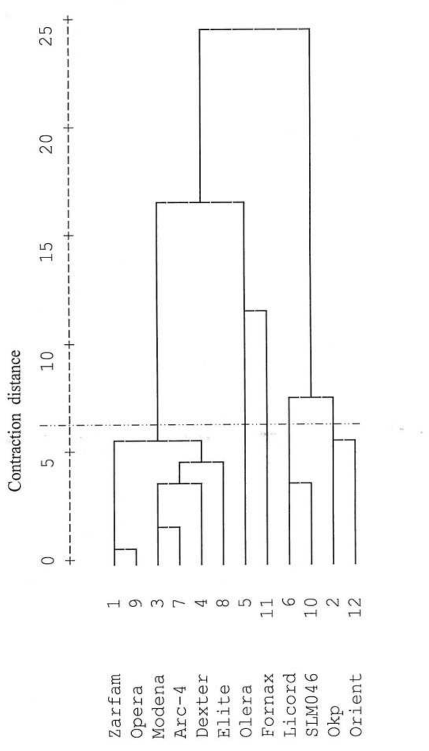

Figure 1: Dendrogram from cluster analysis for rapeseed cultivars under middl water stress by ward method

Table 23: Mean of groups from cluster analysis and percent of deviation from overall mean for rapeseed traits under mild water deficit

Group		LWP	RWC	OP	PC	CF	CI	SC	PH	PDW	RV	RDW	SL	SPP	SPS	1000-GW	Y
1	mean	-1.11	86.42	-.84	4.88	.83	41.25	.43	114.72	22.8	7.1	2.15	4.43	228.83	13.86	4.24	14.1
	Devation of mean %	-12.61	4.61	-30	105	3.75	23.42	-29.5	3.5	7.85	13.6	23.87	9.65	40.6	11.95	-4.07	48.73
2	mean	-1.02	85.67	-1.04	1.95	.85	35.04	.64	121.01	18.91	6.7	2.4	4.77	215.5	15.19	4.09	13.35
	Devation of mean %	-18.89	3.71	-13.33	-18	6.25	4.84	4.91	9.18	-10.54	7.2	8.1	18.06	33	22.7	-7.46	40.82
3	mean	-1.65	73.03	-1.32	.97	.71	28.72	.61	77.03	20.38	4.43	1.32	3.06	33.66	6.82	4.4	1.09
	Devation of mean %	29.92	-11.61	10	-59.24	-11.25	-14.06	0	-30.5	-3.6	-29.12	-40.54	-24.25	-79.18	-44.91	-.45	-88.51
4	mean	-1.44	79	-1.22	2.31	.81	31.7	.46	111.66	37.4	6.61	2.13	2.96	24.44	13.6	5.4	2.21
	Devation of mean %	13.38	-4.38	1.66	-2.94	1.25	-5.14	-24.6	.74	76.91	5.76	-4.05	-26.73	-85.53	9.85	22.17	-76.68
5	mean	-1.38	82.53	-1.29	1.94	.79	31.91	.69	111.65	18.74	6.06	2.15	4.01	166.27	11.66	4.47	9.25
	Devation of mean %	8.66	-.11	7.5	-18.48	-1.25	-4.51	13.11	.73	-11.35	-3.04	-3.15	-.74	2.61	-5.81	1.13	-2.42
Overall mean		-1.27	82.62	-1.2	2.38	.8	33.42	.61	110.83	21.14	6.25	2.22	4.04	162.03	12.38	4.42	9.48

4.0 Conclusion:

By considering obtained clusters under middle water stress, it can conclude that Orient and Okapi had the highest value for most of studied traits than overall mean and we can introduce them as the most tolerant drought genotypes. Also Fornax and Olera in most studied traits had lower value and couldn't adopt themselves to environmental conditions, so we can call them the sensitive drought genotypes. The other genotypes are in between. Therefore we can suggest cultivars of group 1 for direct cultivation or we can use these cultivars by mating with cultivars of group 3 and group 4 for genetic diversity.

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