Indian Res. J. Genet. & Biotech. 8(2) : 112-119 (2016)

Effects of Alien Cytoplasms on Yield and Quality Traits of Bread Wheat

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(Received : March, 2016 : Revised : April, 2016; Accepted : May, 2016)

Abstract

This study was conducted to investigate the effects of alien cytoplasms on grain yield and specific quality traits; test weight, thousand-kernel weight, protein percentage, protein quality, and grain hardness of bread wheat (*Triticum aestivum* L.). Genetic material consisted of F_3 populations from crosses between three bread wheat cultivars (Gerek-79, Bezostaja-1, and Dagdas-94) widely grown in Central Anatolia and five alloplasmic lines of Selkirk. The experimental plots were grown in Cumra and Konya locations in Turkey using a factorial complete randomized block design with four replications. Nuclear gene and location effects dominated the traits but significant cytoplasmic effects were also observed. Cytoplasmic effects varied depending on nucleus x cytoplasm interactions. The effect of a given cytoplasm also varied depending on growing conditions. While some cytoplasms showed good potential for improving specific traits (e.g., *Aegilops ventricosa* and *Ae. juvenalis* for grain yield, *Ae. juvenalis* for softer grains, *Ae. uniaristata* and *Ae. ventricosa* for harder grains, *Ae. variabilis* and *Ae. uniaristata* for high test weight, and *Ae. juvenalis* for high thousand kernel weight, TKW), cytoplasmic effects on protein percentage and protein quality were either neutral or negative. Significant cytoplasm x nucleus interactions suggests that suitable combinations could be identified to increase grain yield and quality in wheat

Keywords: Wheat, cytoplasm, grain yield, grain quality

Introduction

Genetic effects on various traits can be expressed as nuclear effects, cytoplasmic effects, and nucleus x cytoplasm interactions (Palilova & Silikova, 1986; Milanko, 1988; Ekiz et al.,1998; Liu et al., 2002; Zhan et al., 2004). Although most studies on the inheritance of some plant traits in different species indicated the predominating significance of nuclear genes, cytoplasmic factors and cytoplasmic x nuclear interactions were also found to be significant in some studies (Jan, 1992; Berbec, 1994; Ekiz & Konzak, 1994; Yadav, 1994; Wu et al., 1998; Liu et al., 2002; Gehlhar et al., 2005).

The relationship between cytoplasmic and nuclear genes is not well understood at the molecular level. The genetic analysis of cytoplasmic effects is complicated and current molecular techniques have severe limitations in characterizing of the complex relationship between cytoplasmic and nuclear genes (Tsunewaki, 1988; Jan, 1992; Gehlhar et al., 2005). Most information about cytoplasmic genetic variability has been drawn from classical experiments by comparing alloplasmic lines to euplasmic lines (Panayotov et al.,1982; Tsunewaki, 1988; Ekiz and Konzak, 1998; Wu et al., 1998; Gehlhar et al., 2005; Soltani et al. 2016).

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Published by Indian Society of Genetics, Biotechnology Research and Development,
5, E Biotech Bhawan, Nikhil Estate, Mugalia Road, Shastripuram, Sikandra, Agra 282007
Online management by www.isgbrd.co.in

Different studies demonstrated that cytoplasmic effects were of significant importance in the expression of some plant characteristics in wheat. Aegilops squarrosa and Ae. variabilis cytoplasm increased the rust sensitivity of the bread wheat Chinese Spring while all plants with Ae. mutica cytoplasm were resistant (Dhitaphichit et al., 1989). According to Panayotov et al., (1982), cytoplasms belonging to eight Aegilops and three Triticum species showed significant differences in the expression of protein percentage and milling and baking characteristics. Ae. squarrosa cytoplasm increased the protein percentage and brown rust resistance of a wheat variety from Kenya (Zhang et al., 1985) and Ae. ovata cytoplasm increased the cold tolerance of Yellow Fertile and Haruhikari wheat vareties (Kinoshita, 1988).

Probably, it is too difficult to find a cytoplasm which confers positive effects on all agronomic and quality traits. While some traits are improved, others may be affected negatively. For example Zhan et al., (2004) reported that A. kotschyi cytoplasm, in field experiments, was disadvantageous to agronomic traits, while advantageous to quality traits. Plant height, yield, 1000 kernel weight and grain weight/ear were affected negatively while positive effects dominated on grain protein content and wet gluten content. Zhang et al., (2003) pointed out that the release rate of phytosiderophores from roots of common wheat could be considerably influenced by alien cytoplasms. Some alien cytoplasms exerted positive effects, some ones did negative effects, and the other ones had no significant effects. Some alien cytoplasms, such as Chinese Spring host with Ae. speltoides tauschi and Ae. cylindrica cytoplasms showed promising potential in improving the rate of phytosiderophore release in common wheat.

In other studies more clear information has been extracted to understand the potential of the use of cytoplasmic genetic variation and cytoplasm x nuclear interactions. A study in wheat by Murai (1997) demonstrated that A. crassa cytoplasm expressed no seriously deleterious effects of on grain quality and, in spite of reduced grain fertility, showed an average 14% increase for grain weight per plant over the mid-parental value of the parents with wheat cytoplasm. Wu et al., (1998) conducted a comparative study of several homonuclear-heterocytoplasmic lines and homocytoplasmic-heteronuclear lines involving different cytoplasm donors and around 60 Triticum aestivum genotypes as nucleus donors and showed that some alloplasmic types were able to produce useful genetic effects on grain yield, grain quality, tolerance to salt and resistance to diseases. Among the species studied, the cytoplasms of A. crassa, A. squarrosa and A. ventricosa contributed the best effects and specific combinations of nuclear and cytoplasmic genes conferred specific characteristics. In particular, the nucleocytoplasmic hybrid with A. crassa cytoplasm proved the best in production, demonstration and regional tests and was consequently pre-approved for large-scale cultivation. Similarly, in another study (Liu et al., 2002), Aegilops crassa cytoplasm depicted consistent beneficial effects in common wheats. The agronomic performance of alloplasmic lines was superior to that of euplasmic controls in general and the useful genetic attributes for high yield, good quality and salt tolerance were identified although nucleus x cytoplasmic interactions were significant.

The effect of the nuclear-encoded species cytoplasm specific (scs) genes is not to restore male fertility in hybrid combinations, but rather to re-establish the compatible interaction between the nucleus and the alien cytoplasm. The scs locus operated a critical function in the evolution of grass species. Its genomic location is refined by deploying RH and sequencing of contrasting bulks (Bassi et al., 2016).

In a recent study the role of nuclear-cytoplasmic interactions were dissected in wheat (Triticum aestivum) alloplasmic lines carrying the cytoplasm of Aegilops mutica by using comparative quantitative trait locus (QTL) and epigenome analysis (Soltani et al., 2016). The cytoplasmic genomes can modify the magnitude of QTL controlling certain physiological traits such as dry matter weight. Novel nuclear-cytoplasmic interactions can potentially trigger an epigenetic modification cascade in nuclear genes which eventually change the genetic network controlling physiological traits (Soltani et al., 2016).

Genetic variation for yield and quality traits at cytoplasmic level could contribute to the development of new wheat cultivars. However, the results so far have not enough clear confirmation for the benefit of using different cytoplasms. Therefore, the objective of present study was to investigate the effects of foreign cytoplasms on grain yield and quality traits of bread wheat.

Materials and Methods

The effect of foreign cytoplasms on grain yield, thousand-kernel weight (TKW), test weight, protein percentage, protein quality and grain hardness was examined using three winter bread wheat (Triticum aestivum L.) cultivars widely grown in Central Anatolia (Gerek-79, Bezostaja-1, and Dagdas-94) and five alloplasmic lines of Selkirk with Ae. juvenalis, Ae. cylindrica, Ae. variabilis, Ae. uniaristata and Ae ventricosa cytoplasms.

F1 hybrid seed from crosses made in 1993 was planted in hill plots during 1994-1995 crop year to obtain F2 seed. In order to produce sufficient F3 seed for the establishment of replicated F3 yield trials, F2's were planted in large plots (4 m x 4 rows) during 1995-1996 crop year.

During the 1996-1997 crop season, replicated F3 yield trials were established in which 15 populations (3 x 5) were planted in two different locations (Konya-Center and Cumra) in plots containing 6 rows, each 8 m long, with 18 cm row spacing (total plot area = 6 rows x 8.0 m x 0.18 m = 11.2 m2) and four replications in a factorial complete randomized block design. Fertilizer was applied at a rate of 90 kg P2O5 and 80 kg N/ha. Precipitation during the 1996-97 was 357 mm in Konya-Center and 336 mm in Cumra. Precipitation during autumn and winter was adequate but in spring it occurred mostly in May and June, with an erratic distribution.

Test weight and TKW were determined according to Uluöz (1965). Milling was done according to Atlı (1985). Protein percentage and grain hardness (PSI: particle size index) were analyzed by NIR (near-infrared spectroscopy) and SDS-sedimentation was used to determine flour protein quality (Williams et al., 1986).

In addition to conducting general statistical analyses, we analyzed crosses between specific varieties and different alloplasmic lines to determine the importance of cytoplasmic effects, including nuclear x cytoplasmic interactions.

Results

Yield results - Results of a combined analysis of 15 genotypes and two environments revealed highly significant differences in the effects of genotype, location and location x genotype interactions on grain yield. Although higher grain yield was obtained in Cumra (4750 and 3780 kg/ha), genotypic differences were highly significant in both test locations (Table 1).

In terms of cytoplasmic effects, when cross groups with the same nucleus and five different cytoplasms were examined, cytoplasm, location, and location x cytoplasm effects in each group were significant, as were cytoplasm x nucleus interactions. Aegilops juvenalis cytoplasm with Gerek-79 nucleus produced the highest yield (5500 kg/ha) in Cumra, but had the lowest yield in Konya (2690 kg/ha). In Cumra, Ae. variabilis (2880 kg/ha) and Ae. uniaristata (409 kg/ha) cytoplasms resulted in the lowest yields among the Gerek-79 alloplasmic lines. When location means were examined, Ae. ventricosa had the highest yield (4340 kg/ha), and Ae. variabilis had the lowest (3060 kg/ha). In Bezostaja-1, the lowest yields were produced by Ae. uniaristata (3650 kg/ha) in Cumra and Ae. variabilis (3590 kg/ha) in Konya. The highest average yields were produced by Ae. juvenalis (4910 kg/ha) and Ae. ventricosa (5050 kg/ha), and the lowest by Ae. uniaristata (3750 kg/ha). In Dagdas-94 lines, Ae. cylindrica had the lowest yield in both Cumra and Konya (4450 and 3010 kg/ha, respectively), while Ae. juvenalis had relatively lower yield in Konya. The most successful cytoplasms in this group were Ae. variabilis and Ae. ventricosa (Table 1). Aegilops ventricosa increased yield in the three groups. Depending on nuclear types and location, Ae. juvenalis showed positive and negative effects. Aegilops variabilis showed negative effects in general and expressed positive effects only in Dagdas-94. These results suggested the importance of cytoplasm x nucleus and cytoplasm x location effects.

Grain hardness - Results for grain hardness showed significant effects only of nuclear genotypes, while location and location x genotype interaction effects were found to be non-significant (Table 1). When the cross groups were evaluated within themselves, location effect was significant for the Gerek-79 lines only. In both the Gerek-79 and Bezostaja-1 groups, genotypic differences were not significant but they were significant in the Dagdas-94 group. In this group, the lowest grain hardness values recorded were for Ae. ventricosa in Cumra (58%) and Konya (60%), and Ae. cylindrica (60%) and Ae. uniaristata (60.5%) in Konya. The highest average grain hardness was obtained with Ae. juvenalis (70.8%) cytoplasm, and the lowest values were obtained with Ae. uniaristata (62.3%) and Ae. ventricosa (59%). While no significant effects were observed with Ae. variabilis, other cytoplasms expressed significant effects that could change depending on location. Again significant cytoplasm x nucleus and cytoplasm x location effects were observed.

Test weight - Location and genotypic effects on test weight were highly significant. Although there were some significant differences among genotypes in Cumra, differences were not significant in Konya (Table 1). As for cross groups, only for Dagdas-94 were significant cytoplasmic differences recorded. Aegilops juvenalis in both Cumra (75 kg) and Konya (75 kg), as well as Ae. cylindrica in Cumra (73.6 kg), produced the lowest values, whereas Ae. variabilis (76.8 kg) and Ae. uniaristata (77.1 kg) produced the highest. Location and nucleus x cytoplasm interactions were also significant.

Thousand-kernel weight - Based on overall data analysis, location and genotype effects on TKW were highly significant. The highest values were recorded for Dagdas-94, and the lowest for Gerek-79 (Table 2). In the Bezostaja-1 group, no significant effects were observed, except for location. Among Gerek-79 lines (except Ae. juvenalis), cytoplasms expressed significant negative effects in one or two locations. Aegilops juvenalis had the highest mean TKW (35.5 g), whereas Ae. variabilis (29.5 g), Ae. uniaristata (32.4 g), and Ae. ventricosa (31.6 g) had the lower means. Among Dagdas-94 lines, Ae. juvenalis (38.1 g) also had the highest value, while the lowest values were recorded for Ae. cylindrica (35.0 g) and Ae. ventricosa (34.5 g). Aegilops juvenalis was the most successful cytoplasm, for it had significant positive effects in two cross groups. Interactions between location and nucleus and the different cytoplasms were significant.

Protein percentage -Only genotypic effects on protein percentage were highly significant. When the cross groups were examined, only Dagdas-94 lines showed significant differences in Cumra. In this location, Ae. juvenalis (13%) and Ae. uniaristata (13%) had the lowest values (Table 2). Interactions between nucleus and location and the different cytoplasms were also significant.

SDS-sedimentation - General statistical analysis of results showed that location and genotypic effects on SDS-sedimentation were highly significant (Table 2). When the groups were evaluated within themselves, among the Gerek-79 alloplasmic lines Ae. ventricosa (33.5 ml) in Cumra, and Ae. variabilis (43 ml) and Ae. uniaristata (45 ml) in Konya had the lowest values. Aegilops uniaristata (46.5 ml) and Ae. ventricosa (45.0 ml) in Konya gave the lowest values in Bezostaja-1. Aegilops cylindrica (28.5 ml) in Cumra and Ae. uniaristata in Cumra (25 ml) and Konya (33 ml) gave the lowest values in Dagdas-94. Aegilops juvenalis was the only cytoplasm to show no negative effect on this trait. Nucleus effects and location x cytoplasm interactions were significant.

Discussion

Important cytoplasmic effects were found for all traits tested in this study. However, as found in some studies (Tsunewaki, 1988; Jan, 1992; Murai, 1997; Ekiz *et al.,* 1998; Wu et al., 1998; Zhan et al., 2004; Gehlhar et al., 2005) these effects were not positive in all traits in every to make cytoplasmic use more beneficial. For example, the fact that cytoplasmic effects on grain yield were both negative and positive, whereas cytoplasmic effects on protein quality were always negative is an important obstacle to employ alien cytoplasms for practical use.

Our results confirmed the results of the study by Ekiz *et al.,* (1998), who found that Triticum aestivum cytoplasms improved some quality traits such as TKW, protein percentage, grain hardness. Also it was clear that nuclear genetic effects were dominating provided that significant effects due to cytoplasm and cytoplasm x nucleus interactions to less extent were also exerted. Cultivar x cytoplasm interactions was also significant. For example, cytoplasmic effects in Dagdas-94 nucleus were most obvious than the others. On the other hand, genetic variation exerted by cytoplasmic sources were different. These results showed a consistency with the results by Silkova & Palilova (1986), who found that cytoplasms belonging to Aegilops and Agropyron species did not show much interaction with some varieties.

The fact that cytoplasms produce different results depending on location, nucleus type, and trait investigated, reduces the efficient use of cytoplasms. As an example, Ae. ventricosa showed a positive effect on grain yield in all three groups but had negative effects on grain hardness, TKW, and protein quality; its effect on the remaining traits was neutral. Other cytoplasms were found to have good potential for improving specific traits (e.g., Ae. ventricosa and Ae. juvenalis for grain yield, Ae. juvenalis for softer grain, Ae. uniaristata and Ae. ventricosa for harder grain, Ae. variabilis and Ae. uniaristata for high test weight, and Ae. juvenalis for high TKW). Cytoplasmic effects on protein percentage and protein quality were either neutral or negative.

These results demonstrate that wild related Triticum species have a potential to be a useful reservoir of genetic diversity for solving problems in wheat improvement, including agronomic fitness and grain quality. However, lack of genetic recombination and hybrid sterility are important obstacles to the use of alien germplasms. Nuclear-cytoplasmic incompatibility is known to exist widely. However, as an easier way, the developed series of alloplasmic lines can be employed in breeding programs to obtain specific cytoplasm x nuclear combinations, or, as reported by some studies (Murai, 1997; Ekiz *et al.,* 1998; Liu *et al.,* 2002; Gehlhar *et al.,* 2005). Also, a two-gene system that restores fertility through cytoplasm specific gene and the vitality gene system can also be used as reported by Gehlhar *et al.,* (2005).

It is clear that the performance of a good variety could be improved through cytoplasmic alterations as indicated by our present study and others (Panayotov *et al.,* 1982; Wu *et al.,* 1998; Liu *et al.,* 2002; Gehlhar et al., 2005). Even though this will be a tedious and time needing task for breeders, as Panayotov *et al.,* (1982), Tsunewaki (1988), Ekiz *et al.,* (1998) and Wu et al., (1998) studied, more comparative studies of several homonuclear-heterocytoplasmic lines and homocytoplasmic-heteronuclear lines involving different cytoplasm donors and wheat genotypes as nucleus donors are important to obtain alloplasmic types to produce useful genetic effects on yield, grain quality, tolerance for biotic and abiotic stresses. The modified genetic networks can serve as new sources of variation to accelerate the evolutionary process and these variation can synthetically be produced by breeders in their programs to develop epigenomic-segregating lines (Soltani *et al.,* 2016).

It is promising that specific combinations of nuclear and cytoplasmic genes may confer improvements in specific characteristics and help to cope with some problems.

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Table 1.Results for grain yield, grain hardness, and test weight.

Population		Yield (kg/ha)			Hardness (%)			Test weight (kg)		
		Cumra	Konya	Mean	Cumra	Konya	Mean	Cumra	Konya	Mean
(Aegilops juvenalis)-Selkirk / Gerek-79		5500	2690	4100	79.0	67.5	73.3	74.5	77.3	75.9
(Ae. cylindrica)-Selkirk / Gerek-79		4570	3350	3960	75.0	67.5	71.3	73.2	77.1	75.1
(Ae. variabilis)-Selkirk / Gerek-79		2880	3250	3060	72.0	71.5	71.8	71.6	74.4	73.0
(Ae. uniaristata)-Selkirk / Gerek-79		4090	3520	3810	75.0	75.0	75.0	72.8	77.3	75.0
(Ae. ventricosa)-Selkirk / Gerek-79		4500	4170	4340	72.0	71.0	71.5	73.5	76.0	74.7
MEAN		**4310**	**3400**	**3850**	**74.6**	**70.5**	**72.6**	**73.1**	**76.4**	**74.7**
	LSD=	138**	115**	-	ns	ns	-	ns	ns	-
	LSD=	L*, 81; L x G**, 143		G**, 119	L*, 3.8		G, ns	L**, 0.9		G, ns
(Aegilops juvenalis)-Selkirk / Bezostaja-1		5180	4640	4910	63.5	71.5	67.5	76.4	75.7	76.1
(Ae. cylindrica)-Selkirk / Bezostaja-1		5070	4160	4610	66.0	68.0	67.0	74.1	76.6	75.4
(Ae. variabilis)-Selkirk / Bezostaja-1		5390	3590	4490	65.0	68.0	66.5	76.5	75.1	75.8
(Ae. uniaristata)-Selkirk / Bezostaja-1		3650	3860	3750	66.5	68.5	67.5	74.9	75.9	75.4
(Ae. ventricosa)-Selkirk / Bezostaja-1		5770	4330	5050	70.5	72.0	71.3	74.7	76.7	75.7
MEAN		**5010**	**4120**	**4560**	**66.3**	**69.6**	**68.0**	**75.3**	**76.0**	**75.7**
	LSD =	123**	103**	-	ns	ns	-	ns	ns	-
	LSD=	L**, 94		G**, 118	L, ns		G, ns	L*, 0.8		G, ns
(Aegilops juvenalis)-Selkirk / Dagdas-94		4780	3230	4010	69.0	72.5	70.8	75.0	75.0	75.0
(Ae. cylindrica)-Selkirk / Dagdas-94		4450	3010	3730	65.5	60.0	62.8	73.6	76.3	74.9
(Ae. variabilis)-Selkirk / Dagdas-94		5200	4240	4720	64.0	64.5	64.3	76.6	77.1	76.8
(Ae. uniaristata)-Selkirk / Dagdas-94		5580	4280	4930	64.0	60.5	62.3	78.0	76.2	77.1
(Ae. ventricosa)-Selkirk / Dagdas-94		4710	4320	4520	58.0	60.0	59.0	75.8	76.0	75.9
MEAN		**4940**	**3820**	**4380**	**64.1**	**63.5**	**63.8**	**75.8**	**76.1**	**75.9**
	LSD=	122**	101**	-	9.0*	11.3**	-	2.4*	1.6**	-
	LSD=	L**, 83		G**, 107	L, ns		G**, 8.4	ns		G*, 2.0
OVERALL MEAN		**475**	**378**	**426**	**68.3**	**67.9**	**68.1**	**74.7**	**76.2**	**75.4**
RANGE		288-577	269-464	306-505	58.0-79.0	60.0-75.0	59.0-75.0	71.6-78.0	74.4-77.3	73.0-77.1
LSD WITHIN LOCATION		141**	102**	-	13.4**	11.0**	-	3.6**	ns	-
GENERAL LSD		**L**, 89, L x G**, 121**		**G**, 113**	**L, ns**		**G**, 9.1**	**L**, 0.6**		**G**, 3.5**
COEFFICIENT OF VARIATION		14	13	**15**	7.2	6.1	**7.0**	2.09	2.3	**2.4**

*, **: Significant at p=0.05 and 0.01 level, respectively; ns: non-significant L : Location G: Genotype

Table 2. Results for thousand-kernel weight, protein percentage, and SDS-sedimentation.

Population	Thousand-kernel weight (g)			Protein percentage			SDS-sedimentation (ml)		
	Cumra	Konya	Mean	Cumra	Konya	Mean	Cumra	Konya	Mean
(Aegilops juvenalis) Selkirk / Gerek-79	37.4	33.6	35.5	12.5	12.6	12.6	35.5	50.5	43.0
(Ae. cylindrica) Selkirk / Gerek-79	32.8	33.4	33.1	12.5	12.8	12.6	39.0	51.0	45.0
(Ae. variabilis) Selkirk / Gerek-79	29.8	29.2	29.5	13.0	12.8	12.9	38.0	43.0	40.5
(Ae. uniaristata) Selkirk / Gerek-79	33.7	31.1	32.4	12.6	12.4	12.5	36.0	45.0	40.5
(Ae. ventricosa) Selkirk / Gerek-79	33.0	30.2	31.6	12.5	12.4	12.5	33.5	52.5	43.0
MEAN	**33.3**	**31.5**	**32.4**	**12.6**	**12.6**	**12.6**	**36.4**	**48.4**	**42.4**
LSD=	2.6**	2.7**	-	ns	ns	-	4.6*	7.4*	-
LSD=	L**, 1.1		G, 2.7**	L, ns		G, ns	L**, 3.1		G, ns
(Aegilops juvenalis) Selkirk / Bezostaja-1	37.2	35.9	36.5	13.4	13.7	13.5	37.5	57.0	47.3
(Ae. cylindrica) Selkirk / Bezostaja-1	37.7	33.7	35.7	12.9	13.5	13.2	40.5	54.5	47.5
(Ae. variabilis) Selkirk / Bezostaja-1	36.0	32.5	34.3	13.6	14.0	13.8	40.5	50.5	45.5
(Ae. uniaristata) Selkirk / Bezostaja-1	37.0	33.6	35.3	13.7	13.7	13.7	40.0	46.5	43.3
(Ae. ventricosa) Selkirk / Bezostaja-1	38.6	33.8	36.2	13.4	13.4	13.4	38.5	45.0	41.8
MEAN	**37.3**	**33.9**	**35.6**	**13.4**	**13.7**	**13.5**	**39.4**	**50.7**	**45.1**
LSD=	ns	ns	-	ns	ns	-	ns	7.2*	-
LSD=	L**, 1.2		G, ns	L, ns		G, ns	L**, 3.1		G, ns
(Aegilops juvenalis) Selkirk / Dagdas-94	40.5	35.8	38.1	13.0	13.6	13.3	32.0	43.0	37.5
(Ae. cylindrica) Selkirk / Dagdas-94	36.9	33.0	35.0	13.4	13.4	13.4	28.5	36.0	32.3
(Ae. variabilis) Selkirk / Dagdas-94	38.2	33.4	35.8	13.2	13.3	13.3	36.5	37.0	36.8
(Ae. uniaristata) Selkirk / Dagdas-94	38.5	35.2	36.8	13.0	13.6	13.3	25.0	33.0	29.0
(Ae. ventricosa) Selkirk / Dagdas-94	36.1	32.8	34.5	13.5	13.5	13.5	29.5	39.5	34.5
MEAN	**38.0**	**34.0**	**36.0**	**13.2**	**13.5**	**13.4**	**30.3**	**37.7**	**34.0**
LSD=	3.5**	2.7*	-	0.4*	Ns	-	7.3**	8.4**	-
LSD=	L**, 0.8		G**, 2.8	L*, 02		G, ns	L**, 3.4		G**, 7.6
OVERALL MEAN	**36.2**	**33.1-**	**34.7**	**13.1**	**13.3**	**13.2**	**35.4**	**45.6**	**40.5**
RANGE	29.8-40.5	29.2-35.9	29.5-38.1	12.5-13.7	12.4-14.0	12.5-13.8	25.0-40.5	33.0-57.0	29.0-47.5
LSD WITHIN LOCATION	5.8**	5.3**	-	1.1**	1.2**	-	9.6**	12.9**	-
GENERAL LSD	**L**, 0.6**		**G**, 3.9**	**L, ns**		**G**, 0.4**	**L**, 1.2**		**G**, 8.4**
COEFFICIENT OF VARIATION	6.0	6.4	**6.5**	3.6	3.5	**5.2**	12	11.0	**12.7**

*, **: Significant at p=0.05 and 0.01 level, respectively, ns: non-significant L : Location G: Genotype

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