Journal of Animal and Veterinary Advances 10 (Supplement): 3363-3367, 2011
ISSN: 1680-5593

Paraquat Tolerance of Bread Wheat (*Triticum aestivum* L.) Genotypes

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Abstract: The drought stress in one of the most significant environmental stress limiting the plant production over the agricultural lands of the world. Since, the stress caused by the pesticide paraquat (1, 1-dimenthyl-4, 4 bipyridilium dichloride) is similar to water stress which decreases the chlorophyll content of the leaves, paraquat tolerance is successfully used to determine the wheat genotypes resistant to drought. This study was carried to determine the Paraquat (PQ) tolerance of 64 bread wheat genotypes. The parameters of SPAD values before and after paraquat treatments, chlorophyll loss caused by paraquat and correspondingly calculated Paraquat Sensitivity Indexes (PSI) was investigated in this study. Significant differences were observed among the wheat genotypes with regard to all of the investigated parameters. SPAD values of genotypes before PQ treatment varied between 33.6-51.3 and varied between 28.8-47.0 after PQ treatment. Chlorophyll loss of genotypes due to PQ treatments was between 2.0-23.3%. PSI values of genotypes were found to be between 0.18-2.10. The varieties Cetinel, 2000, Alparslan, Sultan 95, Karahan and Kirmizi Yerli were found to be the most tolerant and Ankara 093/44, Ak 702, Haymana 79 and Conkesme varieties were found to be the most sensitive genotypes.

Key words: Wheat, paraquat tolerance, SPAD, chlorophyll loss, genotypes

INTRODUCTION

Wheat is strategical crop being the most important nutrient source for humankind. The fact that wheat is produced in dry farming conditions in Turkey and problems related to its production due to drought increase importance of researches about development of drought resistance genotypes.

Drought has various physiological and biochemical impacts over plant like regression in cell growth due to decrease in cell division, change in amount of chlorophyll, stoma close-up and decrease in photosynthesis (Jamaux *et al*., 1997; Tabaeizadeh, 1998).

Water deficiency causes also oxidative stress in plants (Foyer *et al*., 1994; Moran *et al*., 1994). Active oxygen formation rate in chloroplasts may increase or antioxidant defense activity may be hindered during water stress (Smirnoff and Colombe, 1988). These impacts of water stress are similar to the stress caused by paraquat (herbicide) over the plants (Dodge, 1971). Free radicals with high toxicity are formed by reactions between oxygen in chloroplasts and paraquat radicals during photosynthesis. Therefore, there is a close relationship between plant tolerance to water stress and plant paraquat tolerance (Altinkut *et al*., 2001).

One of the main objectives of plant breeding is to develop genotypes having high and stable yield under drought stress conditions. Therefore, wild forms, local genotypes being source of genetic variation and cultivars should be characterized based on components of drought adaptation. Proper progenitors that can used in breeding programs should be determined and breeding programs should be also planned based on wheat developmental stages which drought is harmful.

There are several drought elimination tests based on different plant characteristics to classfy the plants with regard to drought resistance during early plant development stages of populations or to identify the best offspring to be used in breeding programs (Gavuzzi *et al*., 1997; Dhanda *et al*., 2004). Altinkut *et al*. (2001) used paraquat tolerance test successfully to identify the drought resistant wheat varieties during the early plant development stages.

Leaf total chlorophyll content can rapidly be measured by a portable SPAD-502 chlorophyll meter. Researches revealed close relationships between leaf SPAD value and real amount of chlorophyll determined by spectrometric methods (Yadava, 1986; Campbell *et al*., 1990; Shaper and Chacko, 1991). SPAD measurements today are widely used as an indicator of leaf chlorophyll

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contents (Lopez-Bellido *et al*., 2004) and they are able to provide information to researchers about the nitrogen state of the plants. SPAD values increase with increasing nitrogen uptake (Singh *et al*., 2002).

This study was carried out to determine paraquat tolerance of 64 common wheat genotypes.

MATERIALS AND METHODS

A total of 64 bread wheat genotypes composed of registered and local varieties constituted the plant material of this study. Bezostaja 1 and Karasu 90 recommended for irrigated agricultural lands were included into experiments as the control genotypes.

Experiments were carried out in randomized complete block design with 3 replications in plant growth chamber and laboratories of Ataturk University, Agricultural Faculty, Field Crops Department. Genotypes were sown into 75×100×12 cm peat filled boxes at a rate of 50 seeds per genotype with 2 cm spacing >2 cm deep furrows and they were buried and irrigated. A 5 cm spacing was provided between genotype rows. Plants were grown in growing chamber at 23°C, 16 h light and 8 h dark conditions until they have 5-6 leaves. Second leaves from the top were sampled randomly from 10 plants during this period (Altinkut *et al*., 2001), total chlorophyll contents were determined with SPAD chlorophyll meter and before paraquat SPAD values were determined. These leaves were floated for 24 h within sterilized water containing 100 μM Paraquat (PQ) under 1200 lux light for paraquat treatment (Altinkut *et al*., 2001) and chlorophyll contents after paraquat treatment were measured again with SPAD chlorophyll meter. These measurements were used to determine percent chlorophyll loss of genotypes, chlorophyll loss of each genotype after paraquat treatment was divided by population mean chlorophyll loss and in this way Paraquat Sensitivity Indexes (PSI) were determined (Cakmak, 1994).

Data were statistically analyzed by using SAS (SAS Inst, Cary, NC, USA) statistical analysis software in accordance with the experimental design, variance analyses were performed and LSD test was used to evaluate the differences among genotypes at 1% significance level.

RESULTS AND DISCUSSION

Mean SPAD values of genotypes before and after paraquat treatment were shown in Table 1. Differences among wheat genotypes with regard to SPAD values before and after paraquat treatment were found to be significant. SPAD values of genotypes before paraquat treatment varied between 33.6-51.3 and varied between 28.5-47.0 after paraquat treatment. While Soyer 02, Sonmez 2001, Ozlu bugday and Sultan 95 genotypes had the highest SPAD values before paraquat treatment (respectively, 51.3, 50.2, 48.8 and 48.5), the genotypes Atli 2002 (33.6), Alparslan (33.9) and Aksel 2000 (36.6) had the lowest values. Similar to findings of the current study, Bulut (2009) carried out a study on Dogu 88 and Kirik varieties and observed significant differences between the varieties with regard to SPAD values and found out the SPAD values of the varieties as 44.7 for Dogu 88 and 46.1 for Kirik. Giunta *et al*. (2002) stated that under limited nitrogen uptake conditions, the variations in SPAD values were mostly due to genetic characteristics and genetic variations were related to variations in leaf nitrogen content, number of leaves and area of a single leaf. Babar *et al*. (2006) indicated varying SPAD values due to genetic characteristics of varieties. Among the researchers stating variations in SPAD values of wheat with regard to varieties, Giunta *et al*. (2002) observed SPAD values as between 42.5-50.6 and Fois *et al*. (2009) as between 35.9-39.7. Order of genotypes with regard to SPAD values after paraquat treatment was almost similar to SPAD values before paraquat treatment. While the genotypes Sultan 95 (47.0) Ozlu Bugday (46.3) Sonmez 2001 (46.2) and Soyer 02 (44.8) had the highest SPAD values after paraquat treatment, the genotypes Atli 2002 (28.5) Bolal 2973 (29.4), Bayraktar 2000 (30.8) Aytin 98 (31.0) and Aksel 2000 (31.7) had the lowest values. Decreases in leaf chlorophyll contents due to water stress after paraquat treatment caused to have lower SPAD values.

Chlorophyll losses due to paraquat treatment and consequently calculated Paraquat Sensitivity Indexes (PSI) were shown in Table 1. Differences among wheat genotypes of this study with regard to chlorophyll loss after paraquat treatment and paraquat sensitivity indexes were found to be significant. Chlorophyll loss ratios of genotypes after paraquat treatment varied between 2.0-23.3% and some had lower and the other had higher loss. The highest chlorophyll loss ratio was determined at genotype Ankara 093/44 (21.3%), followed by Ak 702 (21.6%), Haymana 79 (21.3%) and Conkesme (21.2%). The differences between these genotypes and the other 60 genotypes were found to be significant. The lowest chlorophyll loss ratios were obtained from the genotypes of Cetinel 2000, Alparslan, Sultan 95, Karahan 99 and Kirmizi Yerli and the ratios were 2.0, 3.0, 3.1, 3.1 and 3.2%, respectively. Aydin *et al*. (1999) also carried out a study on seedling period drought tests for some wheat genotypes grown under Central Anatolian conditions and stated varying paraquat-related chlorophyll losses with genotypes they used as the plant material of the study. The researchers

Table 1: SPAD values before and after paraquat application of bread wheat genotypes, chlorophyle loss (%), index of sensitivity to Paraquat (PSI)

Genotype names	SPAD values before PQ application	SPAD values after PQ application	Chlorophyle loss (%)	Paraquat Sensitivity Index (PSI)	Genotype names	SPAD values before PQ application	SPAD values after PQ application	Chlorophyle loss (%)	Paraquat Sensitivity Index (PSI)
Aksel 2000	36.6	31.7	13.4	1.21	Sonmez 2001	50.20	46.20	7.90	0.71
Alparslan	33.9	32.9	3.0	0.27	Sultan 95	48.50	47.00	3.10	0.28
Altay 2000	37.1	33.1	10.4	0.94	Suzen 97	47.20	43.90	7.00	0.63
Atli 2002	33.6	28.5	15.0	1.35	Tosunbey	46.40	43.30	6.70	0.60
Aytin 98	35.6	31.0	13.1	1.18	Turkmen	44.90	40.20	10.40	0.94
Bagci 2002	40.1	35.6	11.3	1.02	Uzunyayla	40.10	35.80	10.80	0.97
Bayraktar 2000	35.8	30.8	14.0	1.26	Yakar 99	44.90	39.30	12.60	1.14
Bolal 2973	35.1	29.4	16.3	1.47	Zencirci 2002	43.00	38.70	10.10	0.91
Cetinel 2000	39.1	38.3	2.0	0.18	Ak-702	38.30	30.00	21.60	1.95
Dagdas 94	42.8	37.0	13.6	1.23	Ak bugday	45.50	39.60	13.10	1.18
Demir 2000	41.1	39.1	4.9	0.44	Ankara 093/44	43.50	33.40	23.30	2.10
Dogankent 1	39.3	34.8	11.6	1.05	Conkesme	42.90	33.80	21.20	1.91
Dogu 88	40.1	35.8	10.6	0.95	Haymana 79	44.00	34.70	21.30	1.92
Gerek 79	40.4	38.2	5.5	0.50	Hawk (Sahin)	40.50	35.30	12.90	1.16
Gun 91	41.9	39.5	5.7	0.51	Kilciksiz bugday	43.80	38.00	13.40	1.21
Harmankaya 99	45.6	39.0	14.5	1.31	Kirik	46.60	42.60	8.50	0.77
Ikizce 96	43.9	41.2	6.2	0.56	Kirmizi Kilcik	46.70	38.20	18.10	1.63
Izgi 2001	44.5	39.9	10.3	0.93	Kirmizi Yerli	42.10	40.70	3.20	0.29
Karahan 99	43.5	42.2	3.1	0.28	Koca bugday	46.30	42.90	7.40	0.67
Kate A-1	42.4	37.0	12.8	1.15	Kose 220/39	45.10	43.00	4.70	0.42
Kirac 66	40.4	38.7	4.4	0.40	Orso	43.10	39.90	7.60	0.68
Kirgiz 95	40.9	39.0	4.8	0.43	Ozlu bugday	48.80	46.30	5.10	0.46
Kirkpinar 79	41.9	38.6	7.8	0.70	Polatli Kosesi	43.90	36.20	17.60	1.59
Kutluk 94	44.0	38.6	12.1	1.09	Sert bugday	45.90	40.40	12.10	1.09
Lancer	44.2	38.4	13.1	1.18	Surak 1593/51	43.80	39.70	9.50	0.86
Mizrak	41.9	38.3	11.1	1.00	Tir	41.40	37.00	10.70	0.96
Mufitbey	47.7	40.0	16.2	1.46	Yayla 305	41.50	36.90	11.30	1.02
Nenehatun	47.3	41.4	12.6	1.14	Zerin	46.30	40.40	12.80	1.15
Palandoken 97	46.3	38.8	16.1	1.45	Bezostaja 1	48.50	40.80	15.80	1.42
Pamukova 97	43.1	34.0	21.1	1.90	Karasu 90	45.50	36.10	20.80	1.87
Pehlivan	45.2	42.8	5.4	0.49	Mean	43.10	38.30	11.10	0.98
Prostor	47.6	45.0	5.6	0.50	F-value (Genotypes)	5.89**	8.03**	45.31**	45.31**
Seri 82	45.3	40.9	9.7	0.87	LSD	5.90	5.50	2.90	0.26
Soyer02	51.3	44.8	12.5	1.13	C.V (%)	6.40	6.70	12.10	12.1

**Signed F-values significant at 0.01

investigated the variations in leaf chlorophyll contents of 20 bread wheat varieties after 15 h paraquat treatment and while they observed average chlorophyll content of 4.40 mg g^{-1} in control treatments, the chlorophyll content of paraquat treated leaves as 2.06% with a 53.2% decreases. Altinkut *et al.* (2001) determined that decrease in chlorophyll content of wheat with paraquat treatment was much higher in drought-sensitive Sultan 95 variety than drought-resistant Kirac 66 variety. The stress condition created by paraquat treatment to leaves and consequent chlorophyll loses provide information about tissue tolerance of genotypes (Cakmak *et al*., 1993). Paraquat sensitivity indexes of genotypes varied between 0.18-2.10. Ankara 093/44 (2.10) was found to be the most sensitive genotype against paraquat. This genotype was followed by Ak 702 (1.95), Haymana 79 (1.92) and Conkesme (1.91) genotypes among which the differences were not significant. Genotype Çetinel 2000 was observed to have the lowest PSI (0.18). The other tolerant genotypes against paraquat were respectively found to be the genotypes of Alparslan (0.27), Sultan 95 (0.28), Karahan 99 (0.28) and Kirmizi Yerli (0.29). The other most tolerant genotypes against paraquat were respectively found to be the genotypes of Alparslan (0.27), Sultan 95 (0.28), Karahan 99 (0.28) and Kirmizi Yerli (0.29). The other genotypes not placed in the highest and the lowest level sensitivity group was placed in medium level groups. As it can be seen from the Table 1, the genotypes with higher chlorophyll losses due to paraquat treatments had higher paraquat sensitivity index values. Aydin *et al.* (1999) compared the wheat varieties with regard to paraquat sensitivity indexes and obtained varying sensitivity indexes with genotypes. The researchers determined the varieties of Partizanka, Gun 91, Zitarka, Gerek 79, Kirgiz 95, Bolal 2973 and Dagdas 94 as resistant to paraquat and the varieties of Sertak 52, ES 14, Atay 85, Ak 702, Kutluk 94 and Kirac 66 as sensitive to paraquat. Altinkut *et al.* (2001) successfully used the paraquat tolerance to determine the drought-resistant lines wheat and barley populations; they observed significant relationships between paraquat tolerance and some drought resistance parameters such as leaf sizes, leaf water content. Ekmekci and Terzioglu (2005) exposed wheat varieties to different paraquat concentrations and observed impaired photosynthesis mechanism and chlorophyll losses at high paraquat concentrations, impaired membrane stability and increased water losses. Researchers stated the variety Harran-95 as tolerant to oxidative stress created by PQ treatment and stated the reason as the increase in antioxidant enzyme production.

CONCLUSION

The results of this study carried out with several registered and local varieties, most of which are proper for dry farming conditions, revealed significant variations among genotypes with regard to response to paraquat treatment. The genotypes with lower chlorophyll loss with paraquat treatment yielded lower paraquat sensitivity index values and higher paraquat tolerance values. The varieties of Cetinel 2000, Alparslan, Sultan 95, Karahan and Kirmizi Yerli were found to be the most tolerant and the varieties Ankara 093/44, Ak 702, Haymana 79 and Conkesme were found to be the most sensitive varieties.

ACKNOWLEDGEMENT

This research was supported by The Scientific and Technological Research Council of Turkey (Project No: 108 O 511).

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