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Genotypes Selection on the basis of Periodic Performance - A Reliable Strategy to Maximize Crop Water Use Efficiency and Productivity in Arid Regions

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Abstract: To evaluate drought resistance and adaptability of exotic wheat genotypes to rainfed conditions, a field experiment was performed at Arid Land Agriculture Research Station, King Abdulaziz University during 2012-13 and 2013-14 using randomized complete block design with split plot arrangement. Drought stress was applied as 100% and 50% of total water requirement in main plots while four wheat genotypes viz. Yocoro rojo (YR), Faisalabad (Fsd), Millat and F-50 were planted in sub plots. Drought stress significantly decreased crop growth, yield and yield components while increased water use efficiency, harvest index and stress susceptibility index, however the effect of genotypes was significant for all traits except harvest index. The Fsd throughout growth period presented higher values for leaf area index, dry matter accumulation. Moreover, maximum days to 50% maturity (93 d), water use efficiency (8.88 kg grain ha^{-1} mm^{-1}), harvest index (28.79%), stress susceptibility index (1.23) and stress tolerance index (39%) were recorded for the Fsd. The drought tolerance potential of the genotype resulted in up to 21% increase in final grain yield under drought stress as compared to local genotype YR. Correlation analysis estimated the highest contribution of water use efficiency and stress indices towards genotype drought tolerance that translated in term of final grain yield. So, drought tolerant genotypes selection offered a reliable strategy to maximize crop water use productivity.

Key words: Arid land, drought stress indices, genotype, drip irrigated wheat.

Wheat (*Triticum aestivum* L.) is the most important and major cereal crop of the world including Saudi Arabia. In most parts of the world, wheat is a staple food, which fulfills the need of more than 1/3rd of the world's population by providing 19% of world's food energy and 21% of protein intake is known to be severely affected by drought stress (FAO, 2011; Chaves and Oliveira, 2004).

Human induced climatic variations has predicted significant decrease in fresh water resources and at the same time an increase in mean surface air temperature. This will results in significant drying in some regions of the world. The forthcoming major challenge that will hamper successful crop production is drought stress (Nezhadahmadi *et al*., 2013). Currently, drought stress is affecting about 159 million hectares of wheat cultivation in developing and developed countries globally (Rajaram, 2001). Increasing world population, limited availability of arable land, poor management of resources and abrupt climatic changes have resulted in catastrophic consequences that put more pressure on arid lands to produce food on sustainable bases. In developing countries more than 35% of the total cultivated area is semi-arid and wheat is mostly grown on rain fed areas Drought is a non-uniform phenomenon that influences plant differently, depending on the development stage (vegetative, reproductive) at the time of its occurrence. It adversely affects crop growth and yield by altering normal morpho-physiological phases of wheat crop (Hossain and Da-Silva, 2012). Drought may impede crop growth by changing internal water status by decreasing relative water content that consequently decrease the turgor potential and closure of stomata (Akram, 2011; Aroca, 2012). Drought induced growth reduction is well understood in maize and rice (Lafitte *et al*., 2007) but information is

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lacking in wheat under arid land conditions. Yield in a drought-prone environment may be measured as affected by three components viz., yield potential, appropriate phenology and drought tolerance (Ouk *et al*., 2006). To have a high and sustainable yield in a drought-prone environment, selection of drought-tolerant genotypes are needed. Drought tolerance a complex quantitative trait that involves interaction among many physiological, metabolic and hormonal pathways that are regulated by drought resistant background of the genotypes. The establishment of a standard assessment procedure is important for the screening of drought resistant genotypes where stress tolerance index is considered one of the options (Hao *et al*., 2011). Moreover, for drought tolerance characteristics of genotypes like short duration, efficient water use efficiency and stress tolerance are preferred along with high yield.

Based on previous research and the literature, this study focused on various parameters to evaluate wheat genotypes growth and yield potential at different levels of drought stress under arid land conditions of Saudi Arabia. Moreover the regression analysis were performed for water use efficiency, stress tolerance index and grain yield against crop growth indices to quantify the impact of these variable on wheat productivity.

Materials and Methods

Site description and treatments

Drought resistance potential of four wheat genotypes, YR tall stature and Fsd, Millat and F-50 short stature were evaluated under drip irrigated arid land environment. The experiment was performed under field condition at Hada Al-Sham (HAS) agronomic research station of Arid Land Agriculture Department, King Abdulaziz University, Jeddah, KSA, during two consecutive seasons 2012-13 and 2013-14. Drought stress was applied as 100% (non-stressed) and 50% (stressed) of total water requirement, as calculated from FAO-CROPWAT 8.0 by using last ten year data of agro-ecological, climate, soil and crop phenology parameters (Surendran *et al*., 2015). Experiment was laid out in randomized complete block design with split plot arrangement having three replications. Drought stress was main plot factor while genotypes were sub plot factor. The sub plot size was 1.6 x 2 m^2. Detail of calculated crop water requirement is presented in table 1. A 50% of the total water requirement was used as drought stress treatment at each phenological growth stage.

Soil texture of experimental site was sandy loam, organic matter was 0.50% and pH was 8.65. Moreover, N was 0.67 mg kg^{-1}, P_2O_5 was 0.28 mg kg^{-1} and K was 2.7 mg kg^{-1}. Agro-climatic data was recoded for both growth seasons that could be summarized as: 15-42°C minimum-maximum temperature, 43-71% minimum-maximum relative humidity and 58 mm annual rainfall.

Site preparation and crop husbandry

Prior to planting, soil of experimental site was ploughed twice with tractor mounted plough and was then left fellow for one week. After that soil was ploughed again and was followed by planking. Manual cleaning of experimental site was also performed for picking stones. Layout of the experiment was sketched and drip irrigation system was installed for different crop water requirements. and the irrigation system was controlled by automatic electronic system (Rain bird Co., Azusa, USA). Wheat was planted at third week of November each year with hand

Table 1. Treatment description and amount of water applied at each phenological growth stage

Water requirement	Genotypes	Amount of applied water (mm)						
		Ger	Til	Joi	Bot	Hed	Gfl	Tot
100%	Yocoro Rojo Faisalabald 2008 Millat F-50	16	29	66	38	98	66	313
50%	Yocoro Rojo Faisalabald 2008 Millat F-50	16	14	34	20	50	24	158

Ger: Germination, Til: Tillering, Joi: Jointing, Bot: Booting, Gfl; Grain filling and Tot: Total amount of applied water.

driven seed drill and line to line distance was maintained at 22 cm. Equal seed rate (160 kg ha^{-1}) was used for all the genotypes. Fertilizers (N:P:K) were applied as 120:100:80 in the form of diammonium phosphate, urea and potassium chloride. Manual weeding was performed twice at third and fifth week after sowing to control weeds where predominant species was *Setaria viridis* weed. No pesticide was used for insect or disease control. Harvesting was done at second week of March.

Data recording

Periodic response of wheat phenological growth, plant height, leaf area index (LAI) and dry matter accumulation (DMA) were recorded at 30, 60 and 90 days after sowing (DAS) following procedures as described by Daur (2013) and Ihsan *et al*. (2016). Varietal difference for days to reach 50% heading were also counted. Grain yield (GY) and yield contributes including number of productive tiller (PT), spike length (SL), grains per spike (GPS), 1000 grain weight (TGW) along with crop biological yield (BY) were also measured. Crop water use efficiency (WUE), harvest index (HI), stress susceptibility index (SSI) and stress tolerance index (STI) were recorded to estimate cultivar response to applied levels of drought stress using the following equations (Ihsan *et al*., 2016; Fischer and Maurer, 1978).

$$SSI = \frac{1 - \frac{Ys}{Yp}}{1 - \frac{\acute{Y}s}{\acute{Y}p}} \quad ...(1)$$

$$STI = \frac{Yp \times Ys}{Y^{\acute{2}}p} \quad ...(2)$$

where, SSI is stress susceptibility index, Ys is grain yield of genotype under drought stress condition, Yp is grain yield of genotype under normal condition, Ýs and Ýp are the mean yield of all genotypes under drought stress and normal conditions (kg ha^{-1}), respectively. STI is stress tolerance index and Ý^{2}p is mean square of yield of all genotypes under stressed condition.

Statistical analysis

Data was analyzed to compute analysis of variance (ANOVA) by using DSTAT software. Two way interaction for drought stress and genotypes were drawn for crop phenological growth, yield and stress indices. Treatments means were compared by using least significant difference (LSD) test with probabilities (P ≤0.05 and P ≤0.01) to find level of significance among treatment means. Curve fitting regression analysis was also performed for maximum

Table 2. Periodic response of wheat genotypes plant height and dry matter accumulation to applied levels of drought stress under drip irrigation system

Water requirement	Genotype	Plant height (cm)						DMA (g m^{-2})					
		2013			2014			2013			2014		
		30	60	90	30	60	90	30	60	90	30	60	90
		DAS											
100%	YR	28 a	55 a	72 a	27 a	48 a	68 a	49 a	306 d	677 c	48 d	422 d	722 d
	Fsd	22 d	47 c	64 c	25 bc	42 b	61 c	42 b	409 a	822 a	64 a	479 a	775 a
	Millat	26 b	51 b	68 b	26 ab	45 ab	65 b	43 b	354 c	694 bc	54 c	449 c	744 c
	F-50	24 c	50 b	71 ab	27 a	44 b	66 b	48 a	374 b	705 b	59 b	462 b	758 b
50%	YR	21 de	40 d	58 d	24 cd	31 c	50 d	16 c	175 f	431 f	19 g	251 h	413 h
	Fsd	19 f	37 f	56 de	21 f	30 c	48 e	15 cd	193 e	566 d	25 e	343 e	581 e
	Millat	20 ef	39 de	55 de	22 ef	30 c	47 e	13 d	162 g	446 f	22 f	271 g	509 g
	F-50	20 ef	38 ef	54 e	23 de	28 c	44 f	15 cd	178 f	504 e	22 f	285 f	557 f
Water req. (WR)		*	*	**	*	**	**	**	**	**	*	**	**
Genotype (G)		ns	**	*	ns	*	*	*	**	*	**	**	**
WR × G		ns	ns	Ns	ns	*	*	ns	**	*	ns	ns	*
CV		6.38	3.41	5.63	7.33	8.10	2.52	7.73	6.13	3.19	2.77	2.26	7.02
RLSD (P ≤0.05)		1.92	1.66	3.77	1.93	3.09	1.59	2.54	20.06	20.06	1.07	18.53	28.01

Values with different letters are statistically significant, *; significant at P ≤0.05, **: significant at P ≤0.01, ns; non-significant, CV; coefficient of variation, RLSD; revised least significant difference, req.; requirement; YR; yocoro rojo, Fsd; Faisalabad-2008, DMA; dry matter accumulation (g m^{-2}) and DAS; days after sowing.

leaf area index, dry matter accumulation and grain yield against crop water use efficiency and stress tolerance index to compute their optimum levels.

Results and Discussion

Wheat growth

Wheat periodic response (30, 60 and 90 DAS) to applied drought stress (different irrigation levels) influenced plant height, dry biomass accumulation and leaf area index indicated significant (P ≤0.05) effect of water stress in both the years (Table 2 and 3). Effect of genotype was also highly significant (P ≤0.01) on all the above mentioned parameters at 60 and 90 DAS while its effect on plant height and leaf area index was non-significant at 30 DAS . Interaction of water requirement × genotype was non-significant during first year for plant height while significant during second year for 60 and 90 DAS. Leaf area index was significant for water requirement and genotype during first year except for 30 DAS during first year while interaction of water requirement × genotype was thoroughly significant except 90 DAS. DMA was thoroughly significant for water requirement and genotype while for their interaction it presented mixed trend but was significant at 90 DAS in both years. The highest values for these traits were observed where full water requirement was applied while reducing water quantity resulted in gradual decline in these growth traits. Genotype expressed variably to applied drought stress as recorded for both years. The genotype YR attained the maximum plant height at each studied interval but differences among genotypes for plant height was least at maturity. Likewise, the genotype Fsd documented the highest dry matter accumulation and the maximum value (822 g m^{-2}) was recorded during first year of study at 90 DAS. The recorded differences for dry biomass accumulation between drought stress levels was very high compared to genotypes at 30 DAS while at later stages the differences between genotypes also gradually increased. The highest leaf area index (5.59) was attained at 60 DAS for Fsd under non-stressed conditions. Periodic responses of genotypes for leaf area index were variable as under non-stressed condition YR presented the maximum value for leaf area index while under drought stressed condition Fsd produced the maximum value at 30 DAS during both years. However, Fsd reproduced the higher

Table 3. Periodic response of wheat genotypes leaf area index along with days to complete 50% maturity and biological yield to applied levels of drought stress under drip irrigation system

Water req.	Genotype	LAI						D50%M		BY (kg ha^{-1})	
		2013			2014			2013	2014	2013	2014
		30	60	90	30	60	90	d	d		
		DAS									
100%	YR	1.95 a	5.48 b	2.22 b	1.94 a	5.31 b	1.49 cd	99 d	93 d	8893 c	7658 c
	Fsd	1.82 c	5.59 a	2.72 a	1.81 b	5.53 a	2.24 a	108 a	105 b	10171 a	9245 a
	Millat	1.75 d	4.95 c	1.89 c	1.63 c	5.11 c	1.22 f	101 c	100 c	9784 b	8894 b
	F-50	1.88 b	5.47 b	2.61 a	1.84 b	5.43 ab	1.89 b	105 b	107 a	9942 ab	8993 b
50%	YR	1.22 g	3.63 f	1.37 d	1.22 f	3.44 e	1.33 ef	78 h	80 g	4893 f	4267 g
	Fsd	1.41 e	4.50 d	1.74 c	1.49 d	4.39 d	1.58 c	93 e	85 e	5567 d	4969 d
	Millat	1.35 f	3.10 g	1.08 e	1.15 g	3.18 f	1.03 g	84 g	78 h	5136 ef	4521 f
	F-50	1.45 e	4.11 e	1.48 d	1.39 e	4.26 d	1.45 de	88 f	81 f	5249 e	4765 e
Water req. (WR)		*	**	*	*	**	*	*	*	**	**
Genotype (G)		Ns	**	*	ns	**	**	ns	*	**	**
WR × G		**	*	Ns	*	**	*	ns	ns	ns	**
CV		2.49	3.82	8.99	7.74	5.28	7.48	7.25	3.41	3.92	14.57
RLSD (P ≤0.05)		0.05	0.54	0.18	0.10	0.18	0.12	3.82	2.11	298	118

Values with different letters are statistically significant at P ≤0.05, *: significant at P ≤0.05, **: significant at P ≤0.01, ns: non-significant, CV: coefficient of variation, RLSD: revised least significant difference, req.: requirement; YR: yocoro rojo, Fsd: Faisalabad-2008, LAI: leaf area index, D50%M: days taken to complete 50% maturity and BY: biological yield (kg ha^{-1}).

leaf area index at 90 DAS in both stressed and non-stressed conditions. Days to 50% maturity varied significantly (Table 3), genotype Fsd took maximum days (108) to mature at 100% water requirement during first year that was followed by F-50 which took maximum days (107) to mature during second year of the study. A significant reduction in number of days to complete crop maturity were observed with application of drought stress. Yocoro rojo and Millat were the early maturing genotypes under severe drought stress (50% WR).

Previous studies revealed that wheat phenological attributes have direct relation with final grain yield (Ihsan *et al*., 2016). Under drought stress, a pronounced reduction in these attributes has resulted, based on the stress intensity and duration (Hossain and Da-Silva 2012; Alghabari *et al*., 2016). Most significant reduction was associated with short stature, declined leaf area, lower biomass accumulation, early flowering and short anthesis period (Zhang *et al*., 2004). Genotypic differences for drought tolerance and sensitivity also played vital role in modulating plant growth and adjusting the size of each phenological growth stage when tested under moisture deficit conditions. Akram (2011) reported genotypic difference for stress tolerance in terms of leaf relative water content, crop growth and yield components. Our results presented significant genotypic variations as genotype Fsd showed greater tolerance to applied stress in term of plant growth, yield and water use efficiency. Under water stress conditions, the genotypes that initiated their reproductive stage earlier than late flowering genotypes, have mostly produced higher yield as they adjusted well between pre anthesis and post anthesis water use by balancing water availability for longer period of time to continue grain filling under unfavorable conditions (Khakwani *et al*., 2011; Ihsan *et al*., 2016). The genotype Fsd and F-50 took maximum days to mature and presented greater leaf area index at 90 DAS that contributed in grain filling by increasing the grain filling duration. Kilic and Yagbasanlar (2010) also reported the importance of phenological studies as they influence final grain yield. Genotypes possessing early flowering, longer grain filling period and late maturity are desirable for selection against drought stress.

Yield and yield contributors

Statistical analysis for grain yield and yield contributing parameters showed significant (P≤0.05) effect of water requirement (irrigation) on number of productive tillers, grains spike^{-1}, thousand grain weight, grain yield and

Table 4. Genotypic response to applied drought stress as measured in term of productive tillers, spike length, grains per spike, thousand grain weight and grain yield

Water requirement	Genotype	PT		SL		GPS		TGW		GY	
		2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
100%	YR	313 c	298 b	10.96 a	9.66 a	35.83 a	29.32 b	35.76 a	37.95 a	2518 c	2325 d
	Fsd	354 a	329 a	9.62 b	9.48 a	36.7 a	34.32 a	34.64 ab	32.95 b	2835 a	2632 a
	Millat	327 bc	312 ab	9.58 b	9.2 a	32.15 c	32.15 ab	33.15 b	33.45 b	2614 b	2456 c
	F-50	339 ab	315 ab	10.11 ab	9.23 a	34.15 b	31.65 ab	34.15 ab	35.64 ab	2789 a	2518 b
50%	YR	142 f	116 d	8.63 c	7.66 b	29.33 d	24.66 c	24.26 c	20.68 c	1541 g	1517 h
	Fsd	204 d	144 c	7.84 cd	6.69 c	31.25 c	21.99 c	24.64 c	23.11 c	1869 d	1851 e
	Millat	158 f	121 cd	7.68 d	6.34 c	28.54 d	22.34 c	22.1 c	22.1 c	1659 f	1745 g
	F-50	178 e	128 cd	7.64 d	6.31 c	30.94 c	22.85 c	23.14 c	20.34 c	1746 e	1789 f
Water requirement (WR)		**	**	*	ns	**	*	*	*	**	**
Genotype (G)		*	ns	*	ns	*	ns	ns	ns	**	**
WR × G		ns	ns	*	*	ns	ns	*	*	*	ns
CV		7.65	10.98	9.32	8.16	3.70	12.10	8.37	9.41	12.62	10.12
RLSD (P ≤0.05)		19.92	25.03	0.87	0.68	1.26	3.42	2.60	2.77	61.55	26.29

Values with different letters are statistically significant at P ≤0.05, *: significant at P ≤0.05, **: significant at P ≤0.01, ns: non-significant, CV: coefficient of variation, RLSD: revised least significant difference, YR: yocoro rojo, Fsd: Faisalabad-2008, PT: productive tiller m^{-2}, SL: spike length (cm), GPS: grains per spike, TGW: 1000 grain weight (g) and GY: grain yield (kg ha^{-1}).

biological yield during both years except spike length was non-significant during second year (Table 4). Effect of genotype was significant for grain yield and biological yield during both years while for productive tiller, spike length and grains spike^{-1} during first year. Interaction of water requirement × genotypes was non-significant for productive tillers and number of grains spike^{-1}. Application of drought stress suppress produce productive tiller, grains spike^{-1}, thousand grain weight, grain yield and biological yield. However, some genotype coped drought stress by producing higher biological yield that insured continuous supply of photosynthates to plant parts especially grains under severe drought stress conditions at reproductive stages. At water stress, drought resistant genotype Fsd secured 10-31% higher productive tiller, grains spike^{-1} and grain yield as compared to drought sensitive genotype YR, during the experiment. Genotype YR produced the longest spike under both stressed and non-stressed conditions. 1000-grain weight was higher for YR that was statistically non-significant with Fsd and F-10 at 100% water requirement while under drought stress all genotypes produced non-significant value for 1000-grain weight. Interaction of Fsd to water requirement produced maximum final grain yield that was followed by F-10 for both stressed and non-stressed conditions.

The above results are supported by Blum (2005), who studied significant effect of drought stress on number of grains spike^{-1}, fertile tillers m^{-2}, 1000 grain weight, awn length and grain

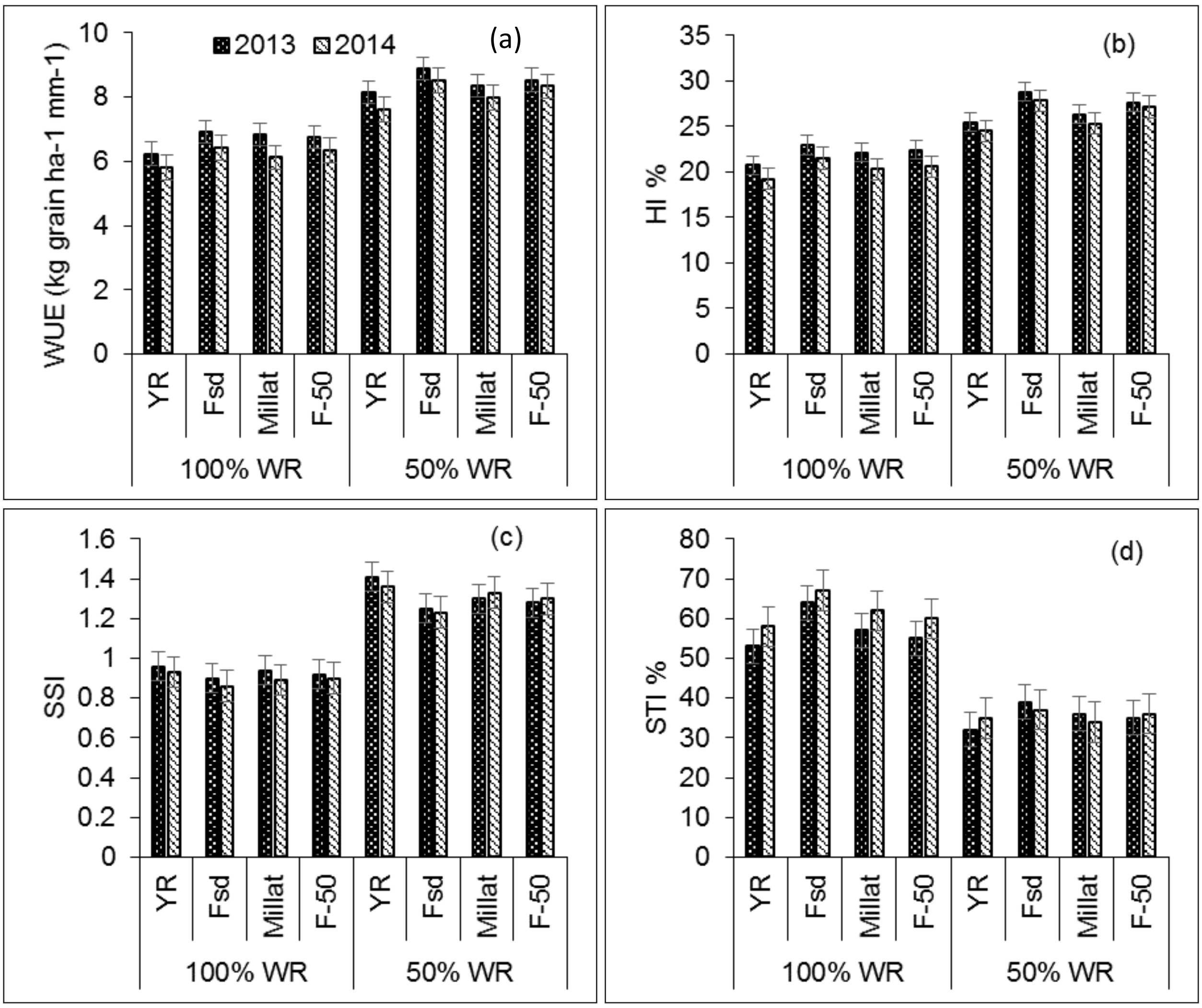

Fig. 1. Response of different wheat genotypes to drought stress in term of (a) water use efficiency WUE, (b) harvest index HI%, (c) stress susceptibility index SSI and (d) stress tolerance index STI. LSD values for a, b, c and d were 0.56, 1.73, 0.08 and 6.92, respectively.

weight spike^{-1}. Negative consequences of water stress during anthesis stage has previously studied in wheat and genotypes behaved variable with increasing drought and heat stress treatments (Alghabari *et al*., 2015). Chen *et al*. (2012), calculated a significant reduction in grain number, in individual grain weight and in final grain yield of drought stressed plots. Our study demonstrated almost similar results for applied drought stress to genotypes with different backgrounds. The percentage of aborted tillers and grain numbers spike^{-1} were the chief contributors in final grain yield and were significantly affected by imposed water stress. This reduction may be attributed to grain abortion and reduced grain filling capacity under drought stress that decreased sink strength to adjust under reduced source capacity (Yang *et al*., 2001). This decline in sink strength to adjust under drought stress was observed in term of shrunk grains under drought stress in our experiment. Abiotic stresses including salinity and heat are predominant under arid land conditions. The recorded maximum temperature during grain filling stage crossed 40°C that resulted in early crop maturity and caused significant shrinkage of grains.

Water use efficiency, stress indices and curve fitting regression line

Genotypic response to applied drought stress was also measured in term of water use efficiency, harvest index, stress susceptibility index and stress tolerance index. Drought stress significantly ($P \leq 0.05$) increased crop water use efficiency, harvest index and stress susceptibility index while stress tolerance index was decreased. Genotypes response was significant for water use efficiency and stress tolerance index while effect was non-significant for harvest index and stress susceptibility index (Fig. 1). Interaction of water requirement × genotype was non-significant for all studied indices except for stress tolerance index that was highly significant for both years. Drought stress favored water use efficiency by 30%, harvest index by 25% and stress susceptibility index by 23% while stress tolerance index was reduced by 69% as compared to non-stressed conditions. Under drought stress genotype YR reported higher stress susceptibility index while Fsd produced higher stress tolerance index, water use efficiency and harvest index. These stress indices produced parallel results for 2013 and 2014. Nevertheless, first year produced higher values for water use efficiency (8.88 kg grain ha^{-1} mm^{-1}), harvest index (28.79%), stress susceptibility index (1.41) and stress tolerance index (39%) under severe drought stress condition.

Curve fitting regression equations were estimated for leaf area index and dry matter accumulation at 30, 60 and 90 DAS against final grain yield (Fig. 2). For that trend lines were drawn where polynomial and linear relation got fitted for leaf area index and dry matter accumulation respectively. Coefficient of determination predicted strong relation of these variables at each growth stage and the highest value were obtained for leaf area index (R^2=0.896) at 60 DAS and for dry matter accumulation (R^2=0.790) at 90 DAS. It further concluded from the predicted values that leaf area index contributed almost in similar way throughout the growth period while dry matter accumulation was least fit (R^2=0.646) at 60 DAS (Fig. 2). It may be due to enhanced demand for biomass to fulfil vegetative growth requirements than to contribute in grain filling at early growth stages. Under drought stress condition, sensitive genotype spend all their energy to contribute in vegetative requirements hence resulted in lower grain yield and less 1000-grain weight. Curve fitting regression analysis were also estimated for maximum leaf area index, dry matter accumulation and grain yield against independent variables of water use efficiency and stress tolerance index for two years recorded data (Fig. 3). These three studied variables predicted medium (-0.703) to strong (0.897) correlation with both water use efficiency and stress tolerance index. The predicted relationship was negative for water use efficiency and positive for stress tolerance index. The highest estimated negative correlation was between dry matter accumulation and water use efficiency while the highest positive correlation was between leaf area index and stress tolerance index. The stress tolerance index presented positive while water use efficiency denoted negative correlation to final grain yield.

Early researchers have also correlated water use efficiency, stress tolerance index and yield index to final grain yield and attributed it for screening genotypes (Mohammadi *et* *al*., 2012; Mahmood *et al*., 2015). Significant positive correlation of yield contributing traits with geometric mean productivity was also established by Khakwani *et al*. (2011). Higher positive correlation of drought tolerant genotypes was documented to mean productivity while it was negative to stress susceptibility index under drought stress. Thus, drought resistant genotypes could be selected based on higher values of their stress tolerance index and lower values of stress susceptibility index (Dorostkar *et al*., 2015). Yield of drought

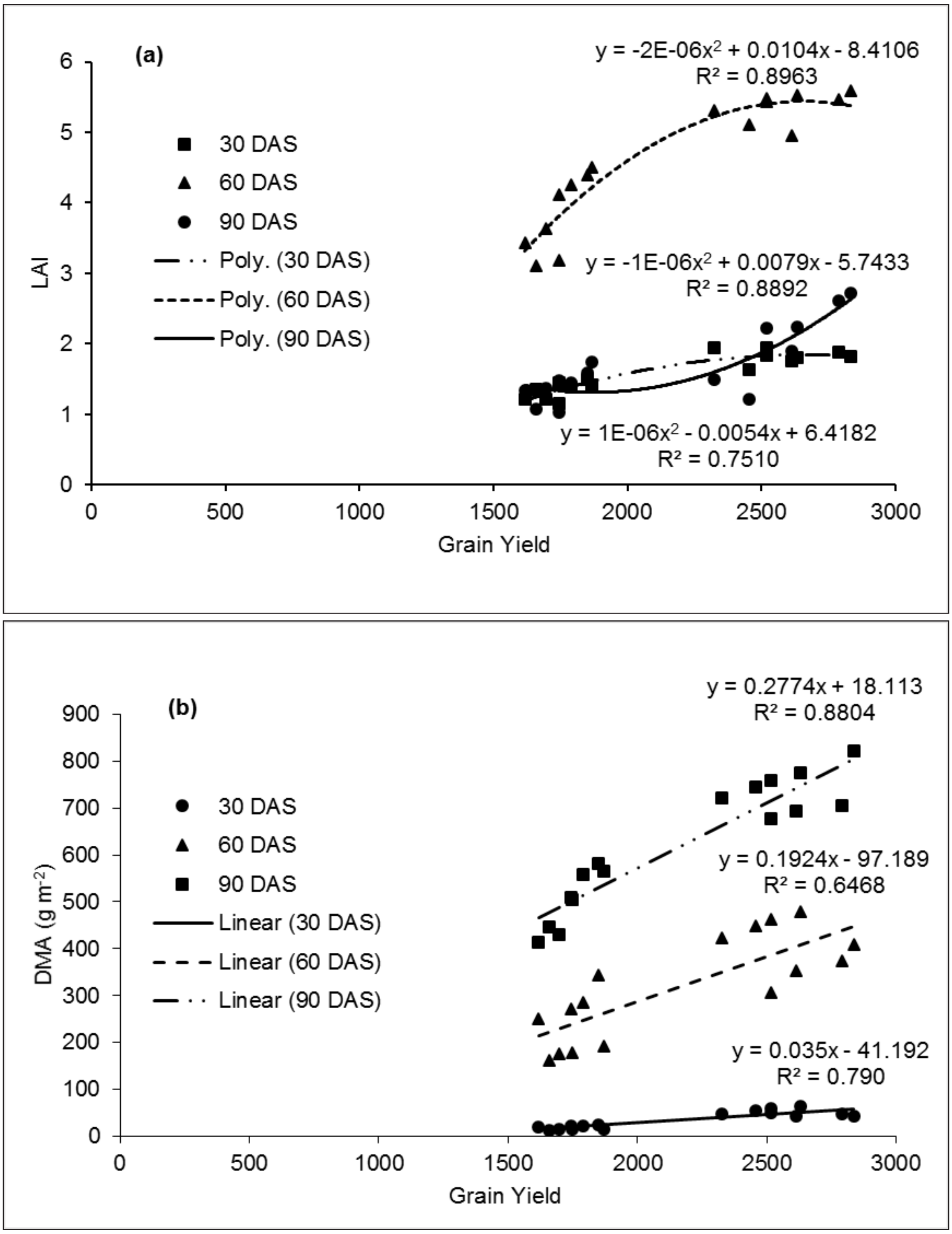

Fig. 2. Curve fitting regression equation for leaf area index LAI (a) and dry biomass accumulation DMA (b) at 30, 60 and 90 DAS for two years pooled data against final grain yield. Trend lines are polynomial and linear for LAI and DMA, respectively.

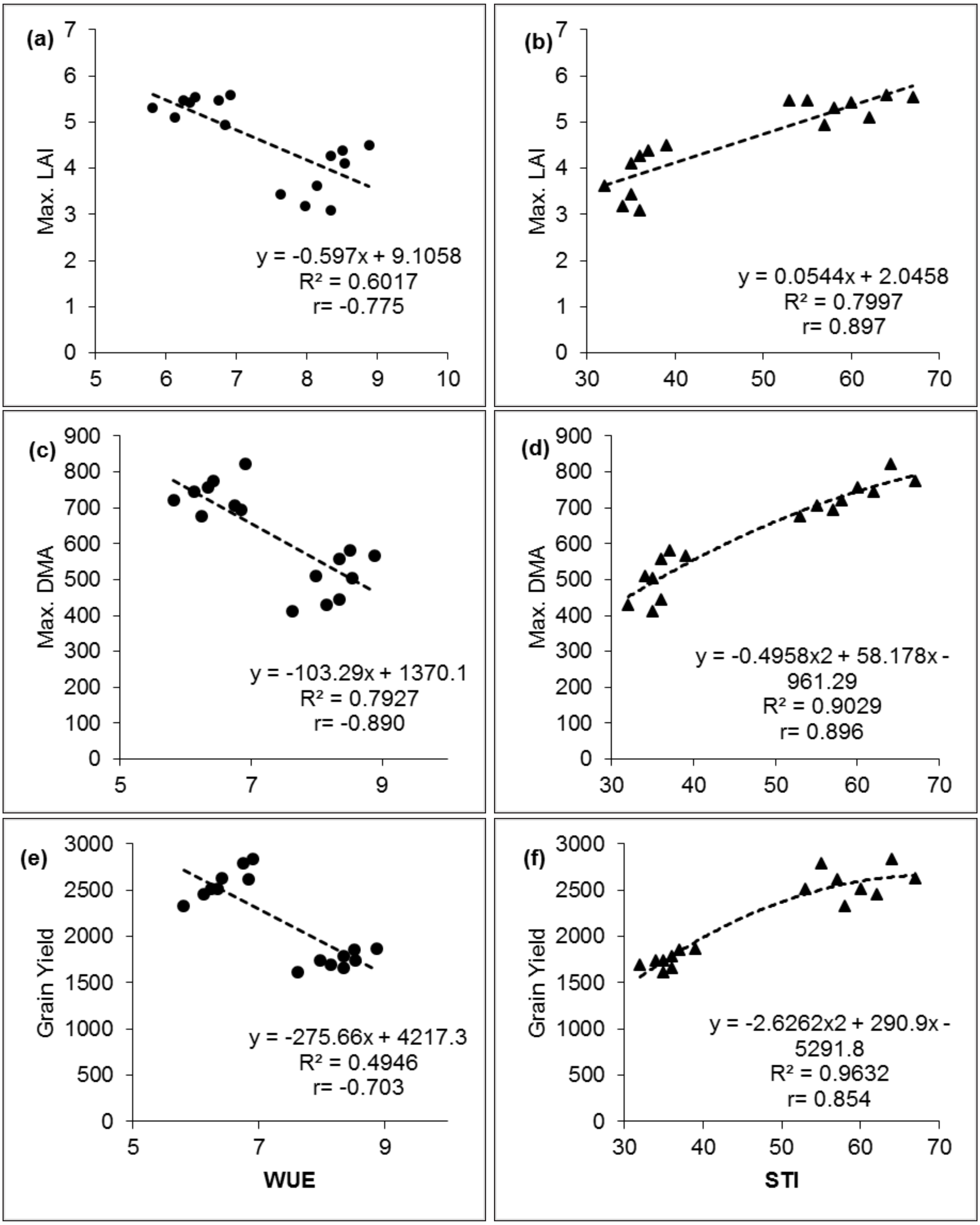

Fig. 3. Curve fitting regression analysis for (a, b) maximum leaf area index (LAI), (c, d) dry matter accumulation (DMA) and (e, f) grain yield against independent variables of water use efficiency (WUE) and stress tolerance index (STI) for two years combine data, respectively.

stressed plots were positively correlated with productivity and stress tolerance index. These estimated correlations confirmed that genotypes with higher stress tolerance index are superior under drought stress condition. Plant drought tolerance assessment criteria for wheat genotype screening, based on stress tolerance index and productivity was more suitable as it have higher positive correlation with final grain yield under both stressed and non-stressed conditions (Reynolds *et al*., 2007). Positive significant correlation of stress tolerance index presented that its effect was stronger than stress susceptibility index for genotype screening based on drought tolerance (Mardeh *et al*., 2006). Among studied interactions, leaf area index presented maximum positive correlation to final grain yield and the screened drought resistant genotype Fsd confirmed this prediction as it produced higher leaf area index throughout crop growth period especially under severe drought stress.

Conclusions

The study determined some new genotypes (Fsd and F-50) with significant potential to replace the existing indigenous ones in the area. The genotype Fsd ascribed the greater adaptability to local climate as it produced significantly higher grain yield, water use efficiency and stress tolerance index under both stressed and non-stressed conditions. Correlation studied positive contribution of genotype water use efficiency and stress tolerance towards final grain yield. Moreover, the study underline good assessment procedure for selection of varieties. All these depicts that managing successful crop production in arid lands is possible through selection of proper genotypes which is more reliable and economical approach to increase crop yield.

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