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Characterization of Iranian bread wheat landraces for morpho-physiological traits associated with drought tolerance

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Abstract

To evaluate the morpho-physiological traits related with drought tolerance in wheat landraces of Iran, 53 selected lines along with 10 cultivars were grown in randomized complete blocks in 2012. Agronomic characters, physiological traits such as relative water content (RWC), cell membrane stability (CMS), chlorophyll fluorescent (Fv/Fm), activity of ascorbate peroxidase (APX), catalase (CAT) and superoxide dismutase (SOD) enzymes were measured. Significant differences were observed among the genotypes in all of the traits. Among the genotypes, 7 lines had higher grain yield than the best yielding variety. Sixty percent of lines had higher seeds/spike than the best control cultivar. Eighteen lines had higher RWC than the best control variety. Thirteen lines had higher APX activity and Fv/Fm than the best control variety. Four lines had higher CAT and SOD activity and CMS than the best control variety. Yield had positive correlation with HI and all of physiological traits except for CMS. In regression analysis, RWC, HI, Fv/Fm along with CAT and SOD activities were entered in the model and 65% of variation of yield was explained.

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Introduction

Drought is a major abiotic stress, limiting crop production in arid and semi-arid climates. Stress resistance in plants is determined by the interactions of many morphological, physiological and biochemical processes. Genetic improvement of yield in crop plants requires the development of suitable methodologies for their measurement in large breeding populations (Bajji *et al.* 2001). Reports in the published literature suggest that further progress in increasing yield of wheat in drought prone areas through the development of drought resistant cultivars can be achieved by selecting for physiological characteristics related to drought resistance (Richards *et al.* 2010). Therefore, measurement of Leaf RWC (Araus *et al.* 2002; Boyer *et al.* 2008); chlorophyll fluorescence parameters such as dark adapted Fv/Fm (Maxwell and Johnson 2000; Baker 2008); activity of antioxidant enzymes such as APX, CAT and SOD (Monneveux *et al.* 2012; Shao *et al.* 2005) and cell membrane thermo-stability (Chandrasekar *et al.* 2000; Blum *et al.* 2001; Sayar *et al.* 2008); have been regarded as promising technics for selecting drought tolerance in wheat. A direct way to exploit novel allelic diversity is to cross elite material with landraces originating in abiotically stressed environments (Reynolds *et al.* 2007). The assumption is that such accessions may provide novel alleles that will complement existing stress-adaptive mechanisms. Iran is one of the world's centers of diversity for wheat; consequently searching among these landraces can lead to finding useful physiological traits for breeding programs. The objective of this study was to evaluate the morpho-physiological traits in Iran's bread wheat landraces and evaluation of their association with yield.

Materials and methods

Bread wheat landraces of northwest of Iran were prepared from national gene bank of Iran and were grown in 2011. Pure lines were extracted among these 160 landraces in 2012. Based on the morphological similarities and Gliadin protein patterns in Acid-PAGE, identical genotypes were excluded from the experiment and 53 pure lines were selected. Ten control varieties were also included in the experiment. Genotypes were grown in a RCB design with 3 replications in rain-fed condition at agriculture research station of Islamic Azad University, Ardabil Iran. Each plot consisted of six 4 m long rows spaced 20 cm apart, With 300 seeds/m2 planting density. Drought was imposed by using a rain exclusion shelter after an thesis.

Measurement of traits

Days to flowering and maturity measured as phonologic traits. Plant height, seeds/spike, 100 kernels weight and number of tillers per plant were measured in 10 randomly selected plants. After maturity, grain yield determined from 1.25 meters of 4 middle rows (1m2 harvested area). The RWC was calculated by the formula given by Barrs (1968). Enzyme extraction was done according to Sairam *et al.* (1998). Activity of SOD was measured according to the method of Giannopolitis and Ries (1977). Catalase was assayed by measuring the initial rate of disappearance of hydrogen peroxide by the method of Chance and Maehly (1955). The assay of APX activity was performed as described by Nakano and Asada (1981). Cell membrane stability under heat induced stress estimated using the method of Blum *et al* (2001). Maximum quantum yield of PSII (Fv/Fm) was measured in flag leaves of 10 randomly selected plants per plot using OS30P fluorometer (readings were done at 10-12 am).

Statistical analysis

Randomized complete blocks design with 3 replications was used for ANOVA. Mean comparisons were done by Duncan's multiple range test at 5% probability level. Relations of traits were evaluated by simple correlation coefficients and Stepwise multiple regression method.

Results

ANOVA and mean comparisons

In ANOVA table, highly significant differences were observed among genotype in all of the traits, indicating the genetic diversity among the genotypes. (Table 1).

Yield and yield components

Mean comparison of genotypes revealed that lines 11031 and 12078(1) had the highest grain yield with 459 and 433 gr/m2 respectively. Lines 12197, 11490(1), 11024, 12078(2) and 10523 were grouped in second rank. Superiority of landraces over modern genotypes under stress conditions have been reported in some studies (Ceccarelli 1989; Akçura *et al.* 2011). In harvest index, 47 lines grouped in first rank, amongst them we can refer to lines 11031, 11198 and 11486(2). Genes that affect a greater relative partitioning of assimilates to the sink, resulting in a higher HI, would be expected to improve yield under drought (Monneveux *et al.* 2012). Plant height of genotypes ranged from 64.4cm (in 10429) to 130cm (in 11042), however 85% of lines were taller than 90cm. Under growing conditions with limited nitrogen availability, wheat landraces with a taller growth habit absorb and translocate more nitrogen into the grain than modern varieties, presumably due to greater pre-anthesis uptake and an increased buffering capacity in genotypes with high vegetative biomass. Lines 11198, 11479(2), 12078(4), 10335(1) and Konya2002 had higher 100 kernels weight. Since larger seeds can be sawn deeper in dry soils, larger seeds have been regarded as selection criteria for drought resistance in germination stage (Richards *et al.* 2010). Landraces under study had in general high tiller numbers and 43 of 53 lines had tiller numbers above 10, meanwhile lines 10425, 10429, 10523(2), 11039(3) and11203(1) had controlled tillering. Results also showed that lines 11063, 11028, 12187(2), 11042(2), 11072(2), 10523(2) and 12197 with 72.5 to 78.5 seeds/spike, had the highest seed numbers.

Phonologic traits

Lines under study had in general late flowering and maturity. Earliness is one of the most important mechanisms of scape. However if the pattern of water deficit is predictable in a given region, selection for a flowering date that does not coincide with the period of water deficit is a very effective way of improving drought adaptation (Araus *et al.* 2002). It seems that native landraces under study have adapted to use from late season rain falls of this region. Passioura and Angus (2010) suggested that one successful strategy to gain yield under drought is choosing a slow-developing cultivar and sowing early.

Antioxidant activity

Among the genotypes, lines12187 (2), 10425, 11072 (2) and 11024 had the highest SOD activity, in the case of CAT enzyme, lines 11031, 12197, 11025, 11024 and Trakia had the highest activity. In APX enzyme, 11031, 12078(1), 11024, 11036, 11030, 11501, 11015 and 11039(2) lines had the highest activity.

Chlorophyll fluorescence

Results also showed that lines 11024 and 11204 had the highest Fv/Fm. The most easily measured and hence the most commonly used fluorescence parameter in stress studies is dark adapted Fv/Fm (Baker 2008).

Cell membrane thermo-stability

Under heat stress (induced by warm water), genotypes 11031, 10429, 10523(2), 11072(6) and Trakia had the most stable cell membranes. Relative water content: RWC of lines ranged from 75.8 (in 11492) to 89.05 (in 11028) and 39 of them had the highest RWC, considering that 18 lines had higher RWC than the best control variety (cv. Alamout). Leaf RWC is proposed more important indicator of water status than other water potential parameters under drought stress conditions (Araus *et al.* 2002). Since the traditional method of RWC measurement is not valid if osmotic adjustment has occurred, the Traditional method therefore was modified here according to Boyer *et al* (2008), so that leaves are rehydrated by eliminating transpiration (e.g. by predawn sampling).

Table 1. Mean squares of traits in randomized complete block design.

Source of variation	d.f.	Grain yield	Harvest Index	Plant Height	Tiller Numbers	100 kernels weight	Seeds per spike	Days to Flowering
		Mean squares						
Replication	2	412.3 ^{ns}	9.2 ^{ns}	0.24 ^{ns}	0.31 ^{ns}	2.7 ^{ns}	28.5 ^{ns}	0.04^{ns}
genotype	62	13705**	50.5**	651.8**	91.8**	102.6**	450.1**	42.1**
Error	124	471.9	12.0	14.2	2.16	8.5	13.5	3.6
CV		7.4	11.1	3.93	11.4	6.5	6.6	0.2

^{ns}, * and ** are non-significant and significant at 5% and 1% probability levels respectively.

Table 1. Continued.

Source of variation	d.f.	Days to Maturity	RWC	APX activity	CAT activity	SOD activity	Cell Membrane Stability
		Mean Squares					
Replication	2	0.39^{ns}	16.07 ^{ns}	1.02 ^{ns}	358.37 ^{ns}	6.03 ^{ns}	0.65 ^{ns}
genotype	62	41.7**	30.53**	5.00**	5345.27**	2.08**	18.17**
Error	124	3.6	2.24	0.61	470.16	0.45	0.75
CV		0.29	1.80	12.94	20.57	29.27	24.95

Table 2. Mean comparisons of genotypes by Duncan's method at 5% probability level.

case	Landrace code	GY (gr/m²)	H I (%)	PH (cm)	TN	KW(gr)	SSP	DF	DM	SOD unit/gFw	CAT unit/gFw	APX unit/grFw	Fv/Fm (%)	CMS (%)	RWC (%)
1	10325	266p-y	31d-q	93n-s	16g-i	45.4e-o	67c-h	224hi	266lm	2.5d-k	116f-q	7.2b-g	78c-m	4.4f-m	80g-n
2	10333(1)	186z	30e-q	85t-u	11m-q	33.7wx	54 l-q	230b	269hi	2.3d-k	91j-u	5.4f-p	75no	5.2e-h	82b-m
3	10335(1)	166z	31d-q	77v-x	11m-q	54.6abc	32z	222lm	265no	0.68k	28v	3.5p	77e-n	5.9e-g	76mn
4	10425	332e-m	32b-m	77v-x	6.5s-w	32.9x	65e-i	227e	268jk	4.5ab	120e-o	6.3d-m	78e-n	2.2m-w	82c-n
5	10427	220yz	35a-h	89r-t	14.5i-l	49.6c-h	37z	220pq	262rst	1.8f-k	62p-v	5.6e-o	77f-o	1.4p-w	77lmn
6	10429	286l-w	24qrs	64y	5.5u-x	42.9i-t	72b-e	228d	265mn	1.5g-k	111f-r	5.3f-p	76i-o	11.5b	82c-n
7	10523	382b-f	31d-q	89k-o	16.5f-i	43.9g-s	47r-z	228d	269hi	2.2d-k	136c-l	6.1d-n	81bcd	5.0f-j	82c-n
8	10523(2)	274n-y	22rs	94n-s	6.5s-w	39.5p-v	78ab	228d	269hi	1.5g-k	85k-u	6.4d-m	77e-n	9.1c	85a-i
9	11015	363c-h	32c-m	82uv	8.5q-t	45.9e-n	56k-p	223jk	266lm	1.6g-k	121e-o	7.6a-e	79b-j	4.2f-n	84a-j
10	11022	219yz	34a-k	81u-w	13j-l	42.4j-t	53m-s	230b	273ab	2.2d-k	69o-v	7.2b-f	76j-o	1.9o-w	85a-i
11	11024	384b-e	33a-l	85tu	10n-r	47.7d-l	48q-y	221no	263pqr	3.8a-d	177a-d	9.1ab	85a	1.8o-w	86a-g
12	11025	321g-p	33b-m	99j-o	16g-i	39.8o-v	58i-n	229c	265mn	2.1d-k	185abc	6.0d-o	80b-i	2.9j-t	88a-d
13	11028	316h-q	33a-l	87s-u	8.5q-t	46.2e-m	74abc	229c	272bcd	2.6c-j	76m-v	5.1g-p	80b-t	2.4l-w	89a
14	11030	333e-m	36a-f	110ef	17f-i	42.3k-t	57j-o	227e	270fgh	2.0e-k	165b-g	8.9abc	78e-n	0.1w	83a-l
15	11031	459a	40a	105f-l	28.2a	47.9d-k	40z	220op	268jk	3.7b-e	219a	9.2a	76j-o	13.5a	88ab
16	11036	331e-m	35a-h	98l-o	21.5c	37.5t-x	51n-u	226ef	264opq	1.5g-k	88k-u	9.0ab	77e-n	2.5l-v	88abc
17	11037	326g-o	35a-g	96m-q	9.50-r	45.3e-p	69c-g	226f	269hi	2.4d-k	140b-k	5.1h-p	77e-n	0.4uvw	85a-i
18	11039(2)	347d-j	32b-m	92o-t	17.5e-h	43.9h-s	51n-u	225g	273ab	2.7c-j	131c-m	7.3a-f	78e-n	1.0s-w	84a-k
19	11039(3)	355c-j	36a-e	96m-r	4.5wx	52.6bcd	63g-k	225g	270fgh	2.3d-k	50s-v	5.8d-o	79b-l	3.1h-s	86a-h
20	11042(2)	263q-y	28h-s	131a	25b	40.7m-u	78ab	230b	265mn	1.9e-k	101h-s	6.1d-n	75l-o	0.7t-w	85a-i
21	11063	203z	24p-s	118b-d	21.5c	41.3m-u	73a-d	229hi	269hi	1.8f-k	81l-v	5.7d-o	76j-o	6.1def	86a-g
22	11064	251t-z	27d-s	100h-n	11m-q	34.5vwx	65e-i	228cd	272abc	1.7f-k	145b-j	6.2d-n	77f-o	3.7h-p	81d-n
23	11072(2)	312h-q	36a-f	116c-d	15h-k	48.3d-j	78ab	231a	271cde	4.3abc	87k-u	4.8i-p	78e-n	1.4p-w	84a-k
24	11072(6)	245u-z	25o-s	123b	19c-f	45.3e-p	68c-h	227e	266lm	1.8f-k	35uv	4.6j-p	78c-m	8.0cd	84a-j
25	11074(1)	298j-u	31d-p	90p-t	8r-u	34.9vwx	56k-p	229c	269hi	1.9e-k	128d-n	5.9d-o	78c-m	4.8f-j	85a-i
26	11076	278m-x	26l-s	100h-n	13j-m	41m-u	56j-p	232a	272abc	1.4h-k	113f-q	6.1d-n	76g-o	2.5k-u	84a-k
27	11078	254s-z	26m-s	108fg	12l-o	40.1n-v	58i-n	230b	267kl	2.6c-j	100h-s	4.3m-p	79b-j	3.4h-q	86a-g
28	11198	232w-z	39ab	97m-p	18.5d-g	59.1a	42yz	218s	264no	1.7g-k	55r-v	5.1h-p	76k-o	2.3l-w	77k-n
29	11200	244u-z	25n-s	100i-n	9.50-r	49.3c-h	44u-z	223jk	266lm	2.8c-j	122b-t	5.8d-o	76k-o	1.90-w	77lmn
30	11203(1)	224xyz	25o-s	98m-p	6t-x	44.2g-r	63f-j	225gh	268ij	2.7c-j	74m-v	6.2d-m	78e-n	1.60-w	87a-f
31	11204	341e-l	34a-k	66m-p	9.50-r	41.9l-t	43v-z	232a	266kl	2.8c-j	166b-f	6.8d-i	82ab	2.4l-w	84a-j
32	11205(1)	298j-u	31c-o	119bc	12l-o	43.9g-r	61h-l	225g	269a	1.6g-k	46s-v	4.3m-p	79b-k	3.1h-s	83a-l
33	11479(2)	254s-z	27a-e	99j-n	12.5k-n	55.7ab	40z	223kl	262hi	2.2d-k	89j-u	4.0op	79b-l	1.4p-w	79i-n
34	11483	255r-z	33a-l	101h-n	9.50-r	44.3g-r	46s-z	223jk	265ab	1.9e-k	124d-o	7.0d-h	79b-l	5.3e-h	79i-n
35	11486(2)	305i-t	38abc	106f-j	21.5c	47.4d-l	50o-v	223jk	266hi	1.8f-k	80l-v	5.7d-o	76g-o	1.70-w	82b-l
36	11490(1)	400bcd	34a-j	100h-n	18.5d-g	35.7u-x	67c-h	227e	273pqr	3.0b-h	79l-v	7.2b-f	80b-g	2.9j-t	85a-j
37	11490(3)	343e-k	32c-m	112d-f	12.5k-n	38.1s-x	70c-f	228d	269hi	2.7c-j	71n-v	4.7i-p	75mno	3.8g-o	84a-j

38	11490(4)	358c-i	27i-s	101g-m	10n-r	33.5wx	56j-p	227e	273ab	1.8f-k	83k-v	4.6j-p	81b-e	6.1def	85a-j
39	11490(5)	218yz	31d-q	94n-s	9 p-s	53.0bcd	52n-t	228d	269hi	2.7c-j	59q-v	4.6k-p	76j-o	4.5f-l	87a-f
40	11492	187z	31d-q	97m-p	18.5d-g	47.3d-l	40z	224ij	263pqr	0.93jk	46s-v	4.1nop	77f-o	0.2vw	76n
41	11498	329f-n	32b-m	106f-k	14.5i-l	44.8f-p	69c-g	228d	269hi	2.1d-k	156b-n	6.7d-j	78d-m	2.3l-w	87a-e
42	11501	365c-h	31d-q	99k-o	21cd	47.7d-l	46s-z	222lm	263pqr	2.9b-h	151b-i	7.7a-d	79b-k	2.5k-u	87a-g
43	12074	199z	28f-r	106f-l	18.5d-g	39.90-v	59i-m	229c	269hi	1.9e-k	119f-p	6.6d-k	79b-l	5.2e-i	78j-n
44	12076(1)	165z	31d-q	89q-t	12l-o	43.2i-t	63g-k	222mn	268ij	1.8f-k	87k-u	6.0d-o	79b-m	1.4p-w	81e-n
45	12076(2)	310h-s	31d-q	108f-h	17f-i	40.7m-u	62g-k	230b	271cde	3.3b-g	155b-n	6.6d-k	79b-l	3.2h-s	86a-g
46	12078(1)	433ab	34a-k	108f-h	10n-r	52.7bcd	72b-e	229c	266lm	2.5c-j	159b-g	9.1ab	82bc	3.3h-r	88ab
47	12078(2)	384b-e	36a-f	107f-i	17.5e-h	51.0b-e	44s-z	228d	263pqr	2.6c-j	97i-t	6.0d-o	80b-h	3.8g-o	83a-l
48	12078(3)	191z	21s	99k-o	16.5f-i	38.8q-w	66d-h	225g	266lm	2.2d-k	71n-v	4.8i-p	80b-f	1.9n-w	81d-n
49	12078(4)	2700-y	28g-s	115c-e	11.5m-p	54.7abc	41yz	224hi	265mn	1.9e-k	86k-u	5.1h-p	78c-m	3.4h-q	86a-g
50	12187(2)	360c-i	29e-q	112d-f	20c-e	47.8d-k	74abc	225g	270efg	5.3a	76m-v	7.1c-h	78d-m	3.0i-t	85a-i
51	12196(2)	2700-y	30e-q	102g-m	16g-i	46.6e-m	500-w	228d	270efg	3.2b-h	93j-t	5.7d-o	79b-m	3.0h-s	81e-n
52	12197	406bc	30e-q	101g-m	12.5k-n	43.3i-t	79a	232a	272abc	2.7c-j	192ab	6.4d-m	81b-e	3.3h-s	86a-g
53	12198	254s-z	35a-h	96m-r	15.2h-k	45.7e-o	44v-z	230b	271def	1.1ijk	160b-g	6.4d-m	78e-n	4.8f-j	81e-n
54	Sabalan	231w-z	31c-p	89r-t	7.6r-v	49.5c-h	36z	220pq	261tuv	2.9b-i	121d-o	6.5d-l	77e-n	2.9j-t	81e-n
55	Azar2	291k-v	30e-q	95m-r	11.5m-p	48.7d-i	52m-t	221no	264nop	3.5b-f	74 m-v	5.0h-p	77e-n	1.3q-t	82b-n
56	Trakia	375c-g	35a-g	96m-r	14.5i-l	48.3d-j	51n-u	219r	260v	2.8c-i	175a-e	6.2d-n	79b-j	7.2cde	85a-i
57	Pishtaz	353c-j	36a-e	67y	5.5u-x	47.9d-k	44v-z	2210p	262qrs	2.6c-j	73n-v	6.1d-n	75mno	1.30-w	85a-i
58	Alvand	221yz	27j-s	75wx	4.9v-x	50.5b-f	43w-z	219qr	261stu	1.7f-k	41tuv	5.1g-p	76 h-o	1.0r-w	80f-n
59	Alamout	311h-r	32c-n	73x	6.3s-x	44.5g-q	54m-r	221no	261tuv	1.7f-k	70n-v	5.6e-o	78 c-m	4.3f-m	85a-i
60	Rasad	278m-x	35a-f	95m-r	15.5h-j	49.8c-g	49p-x	220pq	264nop	1.9e-k	89j-u	5.3f-p	73 o	3.8g-o	84a-j
61	Garak79	284m-w	38a-d	77v-x	4.5wx	38.5r-w	42yz	223jk	262rst	1.5g-k	124d-o	6.2d-m	77 e-n	4.7f-k	79h-n
62	Konya	325g-o	35a-i	65y	3.5x	54.5abc	42x-z	220qr	260uv	2.0e-k	113f-q	7.0d-h	78 e-n	2.2m-w	82b-n
63	Sultan95	236v-z	24a-k	65y	3.5x	42.5j-t	45t-z	224hi	262rst	1.5g-k	109g-r	4.4l-p	77 f-o	3.3h-r	85a-i

Numbers inside parenthesis in Landrace code represents the line number extracted, GY: Grain yield, HI: Harvest Index, PH: Plant Height, TN: Tiller numbers, KW: 100 Kernels weight, SSP: Seeds per spike, DF: Days to flowering, DM: Days to maturity.

Correlations

Among the agronomic traits studied, yield had positive correlation only with HI (Table 3.). In many studies yield under drought was interpreted mainly by HI (Monneveux *et al.* 2012; Araus *et al.* 2002; Reynolds *et al.* 2007). HI represents the combined effect of a number of genetically more simple traits and therefore was positively correlated with 100 kernels weight, negatively with seeds per spike and days to maturity. Grain yield had positive correlations with all of physiological traits except for cell membrane stability. Decreased stomatal conductance in response to drought leads to warmer leaf temperature and insufficient CO2 to dissipate incident radiation, both of which increase the accumulation of harmful oxygen radicals and photo-inhibitory damage. The effect of photo-inhibition can be alleviated by antioxidants such as SOD and APX (Monneveux *et al.* 2012). So activity of antioxidant enzymes have been regarded as promising techniques for screening of drought tolerance in some studies (Shao *et al.* 2005). Correlation of yield with RWC has been pointed out repeatedly in published literature. Regardless of high correlations between membrane thermo-stability and grain yield in some reports Chandrasekar *et al.* 2000; Blum *et al.* 2001); CMS didn't show significant correlation with yield. Fv/Fm showed significant correlation with yield. Loggini *et al.* (1999) found that drought caused a more pronounced inhibition in photosynthetic rates in sensitive cultivars compared with tolerant cultivars. Fv/Fm also had significant correlation with APX and CAT activities. RWC had positive correlations with enzymatic activity, indicating that activity of enzymes under study depends on water status of leaf tissue. Retention of higher water content due to ABA regulated stomatal conductance might be responsible for the maintenance of higher activity of enzymes (Chandrasekar *et al.* 2000). The correlation between SOD, APX and CAT activity was significant. It seems that a higher H2O2 production (as a result of scavenging of superoxide radicals by higher SOD activity), promotes the activity of APX and CAT to scavenge H2O2 more efficiently.

Table 3. Simple correlation coefficients among traits under study.

	GY	HI	PH	TN	KW	SSP	DF	DM	RWC	MTS	FV/FM	CAT	APX
HI	0.401**	1											
PH	0.085	-0.168	1										
TN	0.116	0.104	0.663**	1									
KW	-0.011	0.332**	-0.040	-0.023	1								
SSP	0.165	-0.389**	0.403**	0.080	-0.421**	1							
DF	0.065	-0.310*	0.324**	0.124	-0.541**	0.573**	1						
DM	0.108	-0.193	0.362**	0.178	-0.434**	0.543**	0.689**	1					
RWC	0.571**	0.029	0.194	0.069	-0.166	0.438**	0.323**	0.247*	1				
MTS	0.133	-0.160	-0.022	0.064	-0.124	0.056	0.053	0.018	0.111	1			
FV/FM	0.433**	-0.021	0.053	-0.051	-0.047	0.109	0.177	0.087	0.234	-0.059	1		
CAT	0.534**	0.219	0.002	0.139	-0.188	0.024	0.185	0.073	0.301*	0.169	0.35**	1	
APX	0.547**	0.261*	-0.005	0.234	-0.112	0.046	0.009	0.068	0.355**	0.050	0.275*	0.62**	1
SOD	0.452**	0.115	0.150	0.124	0.014	0.242	0.048	0.181	0.325**	-0.112	0.219	0.256*	0.288*

GY: Grain yield, HI: Harvest Index, PH: Plant Height, TN: Tiller numbers, KW: 100 Kernels weight, SSP: Seeds per spike, DF: Days to flowering, DM: Days to maturity.

Regression analysis

In regression analysis, RWC, HI, Fv/Fm, CAT and SOD were entered stepwise in the regression model and the above 5 variables remained in the final model. R2 value of the final model indicated that 65% of the variation of yield was explained by these traits. Positive and significant regression coefficients of the traits suggest that increase in their values will lead to increase in the yield (Table 4.). Based on the standardized regression coefficients it can be concluded that RWC and HI have the highest direct effect on yield.

Table 4. Unstandardized and Standardized regression coefficients in final model.

	Unstandardized Coefficients	Std. Error	Standard Coefficients	T
(Constant)	-1226.976	261.067	----	-4.7**
RWC	8.113	1.827	0.382	4.4**
HI	5.366	1.337	0.326	4.0**
FVFM	8.114	2.980	0.233	2.7**
CAT	0.350	0.143	0.219	2.4**
SOD	14.906	6.895	0.184	2. 2*

Discussion

Evaluations showed that native landraces of Iran are a valuable source of variation for traits associated with drought tolerance. Among the landraces under study, favorable genotypes were found for RWC, CMS, Fv/Fm, antioxidant activity and agronomic traits. So it would be worthwhile to search these landraces for more useful traits for drought tolerance breeding programs. Despite the spectacular improvements in molecular technologies, fast and accurate phenotyping remains the major bottleneck to enhancing yield gains in water-limited environments (Richards *et al.* 2010), therefore detailed phenotyping of landraces of arid and semi-arid regions with new and rapid methods remains necessary. Crossing of elite cultivars with landrace accessions, originating in abiotically stressed environments (such as Iran) is one important way to increase allelic diversity in bread wheat breeding. Candidates for crossing with elite check cultivars include landraces that showed relatively high biomass under drought combined with favorable expression of physiological traits (Reynolds *et al.* 2007), characteristics for which favorable genes may be found in wheat landraces of this country. Significant correlations between yield and physiological traits, suggest that physiological traits under study could be useful for screening of native landraces of wheat for drought tolerance in this region. Results of regression analysis suggested that RWC, HI, Fv/Fm, CAT and SOD can be regarded as indirect criteria for selection of post anthesis drought tolerance.

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