Stability of Safflower genotypes through nonparametric methods

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Abstract
The objectives of this study were to identify safflower genotypes that have both high and stable yield performance across different environments through apply nonparametric measures. Yield data of 16 safflower genotypes selected from Iran/ICARDA joint project grown in 18 rain-fed environments during 2003-05 in Iran was collected. Results of nonparametric tests of G×E and a combined ANOVA across environments indicated the presence of both crossover and usual crossover interactions, and genotypes varied significantly for grain yield. According to rank-sum (RS), three genotypes viz.G2, G14 and G16 were the best. TOP is a non parametric superiority measure for general adaptability that is the proportion of sites at which the cultivar occurred in the top third of the mean yield ranks, high value of TOP indicates widely adapted genotype, according to TOP measure the genotypes G7 followed by G4 and G16 were relatively adapted. Regarding to RS and TOP, G16 (PI-537598) was the best genotype, which has high TOP value and low RS value also has the highest yield. It could be selected as an adapted and stable genotype among all genotypes, although according to other nonparametric measures G16 wasn't selected as stable genotype.

Key words: Safflower - multi environment trials - nonparametric measures - stability

Introduction

Parametric and nonparametric methods for estimating genotype x environment interactions and phenotypic stability are used in plant breeding programs. Stability measures based on ranks require no statistical assumptions about the distribution of the phenotypic values. Nassar and Huehn (1987) proposed four nonparametric measures of phenotypic stability (1) $S_i^{(1)}$ is the mean of the absolute rank differences of a genotype over the n environments, (2) $S_i^{(2)}$ is the variance among the ranks over the n environments, (3) $S_i^{(3)}$ and (4) $S_i^{(6)}$ are the sum of the absolute deviations and sum of squares of ranks for each genotype relative to the mean of ranks, respectively. Kang (1988) assigned ranks for mean yield, with the genotype having the highest yield receiving the rank of 1, and ranks for the stability variance of Shukla, with the lowest estimated value receiving the rank of 1. The sum of these two ranks provides a final index, in which the genotype with the lowest rank-sum is regarded as the most desirable. Fox *et al*. (1990) used stratified ranking of the cultivars and ranking was done at each environment separately: the proportion of sites at which the cultivar occurred in the top, middle and bottom third of the ranks was computed to form the nonparametric measures TOP, MID and LOW, respectively. A genotype that occurred mostly in the top third (high value of TOP) was considered as widely adapted genotype. Thennarasu (1995) proposed the nonparametric statistics $NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$ and $NP_i^{(4)}$ based on ranks of adjusted mean of the genotypes as those whose position in relation to the others remained unaltered in the set of environments assessed as stability measures.

The objectives of this study were to (i) identify safflower genotypes that have both high yield and stable yield performance across different environments and (ii) apply nonparametric tests to investigate the crossover and noncrossover interaction in multi environment trials (MET)

Materials and Methods

This study was carried out with 16 safflower genotypes in 18 environments (year-location combinations during 2003-2005) including six dryland agricultural research stations viz. Sararood (Kermanshah province), Ardebil (Ardebil province), Ghamlo (Kordestan province), Gonbad (Golestan province), Shirvan (North Khorasan province), during 2003-05(Table1). Experiments were conducted in Randomized Completely Block Design (RCBD) with four replications in each environment. Sowing was done by hand in 1.5m × 4m plots, consisting of five rows with 30 cm row spacing. Seeding rate was 30 seeds m^{-2} for each location. Fertilizer application was 40 kg ha-1 Nitrogen and 60 kg ha-1 P_2O_5at planting and 40 kg ha-1 Nitrogen as top dressing in early spring.

In this paper two nonparametric statistical procedures namely Bredenkamp method (Bredenkamp, 1974, Huehn and Leon, 1995) and van der Laan-de Kroon method (de Kroon and van der Laan, 1981, Huehn and Leon, 1995) were applied.The four nonparametric stability statistics ($S_i^{(1)}$, $S_i^{(2)}$, $S_i^{(3)}$,and $S_i^{(6)}$) that combine mean yield and stability have been described in detail by Nassar and Huehn (1987), and Mohammadi *et al.* (2007). Other nonparametric stability measures that proposed by Thennarasu ($NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$ and $NP_i^{(4)}$)described in detail by Thennarasu (1995) and Mohammadi *et al.* (2007) . Kang's (1988) rank-sum (RS) and parameters of Fox *et al*. (1990) (TOP, MID and LOW) are other nonparametric stability procedure that were calculated in this study.

Results

The $S_i^{(1)}$ and $S_i^{(2)}$ statistics are based on ranks of genotypes across environments and they give equal weight to each environment (Table 3). Genotypes with fewer changes in rank are considered to be more stable (Becker and Leon, 1988). Nevertheless, these two statistics ranked genotypes similarity for stability. Two other nonparametric statistics $S_i^{(3)}$ and $S_i^{(6)}$ combine yield and stability based on yield ranks of genotypes in each environment. G2 followed by G8 and G14 were the most stable according to these parameters, respectively. Mean yield of G6 followed by G5 were the lowest among the genotypes tested. The highest mean yield observed for G16 followed G1 and G9 (Table 2). According to $NP_i^{(1)}$ genotypes G2 followed by G8 and G14 were stable in comparison with the other genotypes. These three genotypes had the lowest value of $NP_i^{(2)}$ and were stable. $NP_i^{(3)}$, identified G2 as the most stable genotype. The next most stable genotypes were G14 and G8 which had low mean yield performance. Stability parameter $NP_i^{(4)}$ identified G2 as a stable genotype, followed by G14 and G8; but like $NP_i^{(3)}$, identified G7, G15 followed by G16 as unstable. According to the RS statistic, G2 followed by G14 and G16 had the minimum value for RS and therefore were stable genotypes with high yield (Table 2). According to TOP parameter the genotypes G7 followed by G4, G16 and G11 relatively adapted. Regarding to RS and TOP, G16 is the best genotype which has high TOP value and low RS value also has the highest mean yield, so could be selected as an adapted and stable genotype among all genotypes, although relative to other genotypes G16 is an unstable genotype, the reason is, other nonparametric measures indicate stability and high yield hasn't any effect on their value.

Discussion

The stability statistics of ($S_i^{(1)}$, $S_i^{(2)}$ and $S_i^{(3)}$) and the $NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$ and $NP_i^{(4)}$ parameters represent static concepts of stability, and are not correlated with mean yield. Therefore, these stability statistics could be used as compromise methods to select genotypes with moderate yield and high stability. According to these measures, G2, G8 and G14 can be selected. In our study, positive significant correlation between RS and mean yield (P<0.05) indicated that RS was the best parameter to identify high yielding genotypes. A low value of RS indicates the combination of high yield and high stability. According to RS, G2, G14 and G16 were the best genotypes. Consequently, we recommend use of RS as the best parameter to select superior genotypes.

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Table1. Code, cropping season, names and origin of genotypes and rainfall for each environment

Env	Cropping season	Station	Province	precipitation (mm)	Code of genotypes	Genotype	Origin
1	2002-03	Sararood	Kermanshah	424.4	G1	CH-5	America
2	2002-03	Ardebil	Ardebil	274.0	G2	PI-250537	World Bank of Safflower
3	2002-03	Ghamloo	Kordestan	354.0	G3	Syrian	Syria
4	2002-03	Gonbad	Golestan	444.7	G4	CW-74	America
5	2002-03	Shirvan	North Khorasan	301.0	G5	Dincer	Turkey
6	2002-03	khoram abad	Lorestan	335.4	G6	Zarghan279	Iran
7	2003-04	Sararood	Kermanshah	588.0	G7	LRV-55-245	Iran
8	2003-04	Ardebil	Ardebil	282.0	G8	PI-198290	World Bank of Safflower
9	2003-04	Ghamloo	Kordestan	425.0	G9	Hartman	America
10	2003-04	Gonbad	Golestan	492.8	G10	Gila	America
11	2003-04	Shirvan	North Khorasan	251.0	G11	Kino-76	ICARDA
12	2003-04	khoram abad	Lorestan	466.7	G12	Yenice	Turkey
13	2004-05	Sararood	Kermanshah	431.5	G13	PI-537636	World Bank of Safflower
14	2004-05	Ardebil	Ardebil	286.2	G14	PI-537636-s	World Bank of Safflower
15	2004-05	Ghamloo	Kordestan	333.7	G15	LRV-51-51	Iran
16	2004-05	Gonbad	Golestan	700.6	G16	PI-537598	World Bank of Safflower
17	2004-05	Shirvan	North Khorasan	242.2			
18	2004-05	khoram abad	Lorestan	482.9			

Table 3. Ranks of 16 safflower genotypes after yield data from 18 environments were analyzed for G x E interaction and stability using 10 different nonparametric methods

Genotype	Y	$S_i^{(1)}$	$S_i^{(2)}$	$S_i^{(3)}$	$S_i^{(6)}$	$NP_i^{(1)}$	$NP_i^{(2)}$	$NP_i^{(3)}$	$NP_i^{(4)}$	TOP	RS
G1	2	13	16	15	7	12	8	10	8	5	6
G2	4	1	1	1	13	1	1	1	1	6	1
G3	7	9	9	8	12	7	10	10	9	4	5
G4	10	8	7	9	5	5	10	12	10	2	6
G5	14	5	5	5	14	4	3	7	6	6	7
G6	15	4	4	4	15	4	2	5	5	5	7
G7	11	10	12	16	13	8	12	14	12	1	9
G8	12	2	2	2	1	2	2	3	3	5	4
G9	3	12	15	10	10	9	4	8	7	5	6
G10	8	12	14	11	6	10	5	9	8	5	8
G11	9	7	8	7	4	6	6	4	4	3	6
G12	11	6	6	6	3	5	6	6	6	4	6
G13	6	12	13	12	9	11	7	11	9	5	7
G14	5	3	3	3	2	3	1	2	2	7	2
G15	13	10	10	13	8	7	9	13	11	4	9
G16	1	11	11	14	11	9	11	13	11	3	3

Table 2. Mean values (Y) and nonparametric stability parameters for grain yield and tests of nonparametric stability measures (Z_1 and Z_2) for 16 safflower genotypes across environments

Genotype	Y	$S_i^{(1)ж}$	$Z_1^{ж}$	$S_i^{(2)ж}$	$Z_2^{ж}$	$S_i^{(3)}$	$S_i^{(6)}$	$NP_i^{(1)\dagger}$	$NP_i^{(2)\dagger}$	$NP_i^{(3)\dagger}$	$NP_i^{(4)\dagger}$	$TOP^{\ddagger}$	$MID^{\ddagger}$	$LOW^{\ddagger}$	$RS^{¥}$
G1	869	6.549	3.925	32.928	5.986	56.607	10.472	5.278	0.556	0.564	0.662	28	17	56	18
G2	791	3.752	6.255	10.889	4.712	22.514	13.743	2.444	0.306	0.390	0.456	22	50	28	5
G3	744	5.438	0.040	21.294	0.000	45.250	12.548	4.056	0.624	0.561	0.680	33	44	22	16
G4	711	5.157	0.062	19.441	0.144	46.116	9.770	3.722	0.620	0.598	0.720	44	39	17	17
G5	624	4.758	0.789	16.706	0.906	35.500	14.310	3.167	0.422	0.497	0.595	22	56	22	20
G6	547	4.647	1.137	16.448	1.012	33.779	18.727	3.222	0.379	0.476	0.561	28	61	11	20
G7	689	6.033	1.332	27.899	1.940	64.188	13.696	4.444	0.988	0.695	0.816	56	22	22	24
G8	682	3.961	4.691	12.118	3.660	26.870	7.357	2.667	0.381	0.441	0.517	28	56	17	15
G9	814	6.235	2.186	28.941	2.596	50.897	11.793	4.500	0.429	0.541	0.645	28	22	50	18
G10	737	6.157	1.830	28.353	2.214	51.643	10.391	4.556	0.456	0.554	0.660	28	22	50	22
G11	723	5.085	0.133	19.477	0.138	35.904	8.024	4.000	0.500	0.465	0.551	39	22	39	17
G12	689	4.863	0.519	17.242	0.705	35.649	7.784	3.722	0.496	0.491	0.591	33	44	22	17
G13	753	6.196	2.004	28.340	2.206	52.878	11.397	4.667	0.519	0.568	0.680	28	28	44	19
G14	778	4.477	1.792	16.016	1.202	29.000	7.537	3.056	0.306	0.414	0.477	11	50	39	8
G15	634	5.961	1.079	26.105	1.034	54.712	10.647	4.111	0.587	0.612	0.735	33	39	28	24
G16	994	6.052	1.405	26.941	1.422	54.960	12.029	4.500	0.692	0.605	0.726	39	28	33	12
Sum			29.180		29.877										

Test statistics

$E(S_1^{(1)})= 5.31$	$E(S_2^{(2)})= 21.25$
$Var(S_1^{(1)})= 0.389$	$Var(S_2^{(2)})= 22.78$
X^2 Sum ¥ = 25	X^2 Z_1 , Z_2 ¥ = 3.84

Grand mean= 736 kg/ha

ж $S_1^{(1)}$ statistics measures the mean absolute rank difference of a genotype over environments, and $S_2^{(2)}$ is the common variance of the ranks ; the Z-statistics are measures of stability. ; ¥ X^2 Z_1, Z_2: Chi-square for $Z_1^{(1)}$, $Z_2^{(2)}$; X^2 Sum: chi-square for sum of $Z_1^{(1)}$, $Z_2^{(2)}$
† NP= nonparametric stability parameters; ‡ TOP, MID and LOW are the parameters of Fox *et al.* (1990); ¥ RS is the rank-sum of Kang (1988)