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Original article

Evaluation of the application of SIIG index in the selection of barley pure lines with high yield and desirable agronomic characteristics in warm areas of Iran

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Extended abstract

Introduction

Barley is unique among crop plants for being of tremendous importance to agriculture and to science. Advances on both fronts create a positive feedback loop, allowing barley to be in the forefront in meeting the great challenges of climate change and human population growth. In terms of agriculture, barley is the fourth most important cereal crop in the world. Barley grain, in the form of malt, is the perfect nutritional source for yeast and is therefore the base of the brewing industry. Selection index of ideal genotype (SIIG) technique was improved as following method to the selection of favorable genotypes using different morphological traits simultaneously.

Materials and Methods

In order to study the phenotypic diversity of inbred barley lines under heat stress conditions at the end of the season, 108 pure line in the non-repeating Augment design with four controls (Nimroz/Sahra, Norooz, Auxin and WB-95-19) in three blocks, in the Center for Agricultural Research and Education and Natural Resources Fars (Darab), Ahvaz, Sistan (Zabol) and Golestan (Gonbad) were evaluated during 2018-19 cropping year. Plots consisted of six rows that were 6 m long with spacing of 0.20 m between rows. Seeding rate was 300 seeds/m2 at each trial. Agronomic practices including fertilizer application and weed management were carried out as recommended at each location. Following harvest, grain yield (kg ha^{-1}) was determined for each genotype at each testing environment.

Results and Discussion

The results of REML analysis showed that the highest heritability of yield was related to Gonbad (0.952) and Ahvaz (0.530), respectively, and the heritability of grain yield was close to zero in Darab region and 0.111 in Zabol. The results of SIIG index in Darab showed lines number 8, 33, 34, 64, 32, 6, 2, 113, 15, 13, 119, 9, 28, 87, 115, 85, 65, 14,16 22, 86, 3, 10 and 89 were the best lines with the highest value of SIIG index (0.800-600), respectively. In Ahvaz, lines 113, 119, 109, 19, 83, 110, 90, 82, 120, 98, 118, 17, 106,

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102, 40, 42, 23 and 18, with the highest amount of SIIG (0.600-0.600) were the best lines. In Zabol, lines 120, 17, 28, 18, 33, 24, 30, 104, 34, 22, 105, 14, 19, 118, 15, 38, 119 and 16 with the highest value of SIIG index (0.600-0.800) respectively, were the best lines. Lines number 47, 46, 112, 86, 85 and 83 with the highest value of SIIG index (0.900-0.600) were the top lines in this experiment in Gonbad region.

Conclusion

In total, based on the average results of SIIG index in all regions, lines number 113, 33, 104, 119, 17, 2, 18, 23, 28, 120, 106, 112, 86, 34, 102, 47, 15, 85, 16, 19, 57, 118, 103, 46, 24, 98, 105, 40 and 22 with the highest average value of SIIG index (0.700-500), respectively, are the best lines in most regions. This research showed that the SIIG index was able to categorize the genotypes according to the different traits, simultaneously. The SIIG method is comprehensive in the order in which amount of information increases. It is very effective in selection of ideal (best) genotypes using several different traits or indices simultaneously. Therefore we propose that researches use of SIIG method to study of genetic variation and help to choose ideal genotypes using morphological and physiological traits, simultaneously.

***Keywords*:** SIIG index, Ideal genotype, BLUE, REML analysis

جدول ۱. داده‌های هواشناسی ماهیانه در فصل زراعی ۹۸-۱۳۹۷ در مناطق مختلف

Table 1. Monthly meteorological data in cropping season of 2018-19 at different regions

Month	Darab Rainfall (mm)	Darab Tem. (°C) Min	Darab Tem. (°C) Max	Darab Tem. (°C) Mean	Ahvaz Rainfall (mm)	Ahvaz Tem. (°C) Min	Ahvaz Tem. (°C) Max	Ahvaz Tem. (°C) Mean
Oct.	50.2	11.8	35.6	23.9	21.5	20.9	39.8	30.4
Nov.	32.9	6.6	26.8	17	52.3	15.5	26.8	21.1
Dec.	7.5	0.4	23.4	13.3	58.3	11.1	21.9	16.5
Jan.	7.2	-0.6	22.2	13	60.8	7.5	17.7	12.6
Feb.	97.3	0	24.4	12.9	46.0	7.8	20.1	14.0
Mar.	98.4	2.8	24.2	15.6	33.7	8.7	22.8	15.8
Apr.	57	8	30.9	21.8	39.0	14.5	29.3	21.9
May	2.9	13.2	39.2	29.4	23.4	19.4	35.0	27.2
June	2	22.1	39.6	30.1	18.9	25.0	44.2	34.6
Sum	**355.4**				**353.9**			

Month	Zabol Rainfall (mm)	Zabol Tem. (°C) Min	Zabol Tem. (°C) Max	Zabol Tem. (°C) Mean	Gonbad Rainfall (mm)	Gonbad Tem. (°C) Min	Gonbad Tem. (°C) Max	Gonbad Tem. (°C) Mean
Oct.	0	16.0	31.6	23.8	32.8	13.9	28.8	21.3
Nov.	2.6	10.8	24.9	17.8	30.6	9.7	22.3	16
Dec.	0.2	5.0	22.3	13.6	45.1	7.7	17.0	12.3
Jan.	0	3.9	20.0	12.0	40.6	4.9	15.9	10.4
Feb.	11.6	4.5	19.2	11.8	37.2	4.3	15.2	9.7
Mar.	0	8.6	22.2	15.4	61.9	5.2	19.4	12.3
Apr.	25.8	16.4	31.2	23.8	62.8	10.3	20.7	15.5
May	3.6	19.7	34.5	27.1	134.2	13.5	28.2	20.8
June	1	23.6	37.5	30.5	236.1	20.1	36.3	28.2
Sum	**44.8**				**681.3**			

Table 2. Genetic variance, residual variance and hertability in morphological and phonologic triats in different regions

Traits	Regions	δ^2_g	δ^2_{Res}	He^2
Days to heading	**Darab**	0.708	0.216	0.766
	Ahvaz	0.553	0.286	0.659
	Zabol	0.599	0.331	0.644
	Gonbad	0.649	0.292	0.689
Days to maturity	**Darab**	0.349	0.582	0.375
	Ahvaz	0.256	0.657	0.280
	Zabol	0.000	0.980	0.000
	Gonbad	0.550	0.401	0.578
Plant height	**Darab**	0.000	0.941	0.000
	Ahvaz	0.319	0.618	0.340
	Zabol	0.000	0.825	0.000
	Gonbad	0.880	0.091	0.906
1000 kernel weight	**Darab**	0.599	0.385	0.609
	Ahvaz	0.000	1.000	0.000
	Zabol	0.801	0.199	0.801
	Gonbad	-	-	-
Seed yield	**Darab**	0.000	0.988	0.000
	Ahvaz	0.495	0.439	0.530
	Zabol	0.111	0.890	0.111
	Gonbad	1.035	0.052	0.952

Table 3. Results of REML analysis for morphological and phonologic traits of barley lines and check genotypes at four regions

	Inbred lines			
	Days to heading		**Days to maturity**	
S.O.V	**BLUP**	**BLUE**	**BLUP**	**BLUE**
He^2	0.53		0.55	
δ^2_g	2.24		1.20	
δ^2_e	587	587	810	810
δ^2_{ge}	4.53		0.63	
δ^2_{Res}	3.43	2.752	2.29	1.99
$LSD_{0.05}$	2.87	3.96	2.05	2.76
N Env.	4	4	3	3
	Check genotypes			
He^2	0.51		0.50	
δ^2_g	3.89		0.93	
δ^2_e	587	587	810	810
δ^2_{ge}	11.69		0.53	
δ^2_{Res}	3.43	2.75	2.29	1.99
$LSD_{0.05}$	3.98	4.89	1.70	2.10
N Env.	4	4	3	3

Table 3. Continued

	Inbred lines					
	Plant height		**1000 kernel weight**		**Seed yield**	
S.O.V	**BLUP**	**BLUE**	**BLUP**	**BLUE**	**BLUP**	**BLUE**
He^2	0.10		0.00		0.13	
δ^2_g	3.85		0.02		24766	
δ^2_e	204	204	9.13	9.13	2513070	2513070
δ^2_{ge}	31.1		5.39		97828	
δ^2_{Res}	35.48	46.26	2.37	2.45	409165	441250
$LSD_{0.05}$	5.18	15.79	0.36	5.44	409	1078
N Env.	2	2	2	2	3	3
	Check genotypes					
He^2	0.20		0.27		0	
δ^2_g	6.13		1.23		0	
δ^2_e	204	204	9.1	9.1	2513070	2513070
δ^2_{ge}	13.61		4.42		18309	
δ^2_{Res}	35.48	46.26	2.37	2.45	409165	441250
$LSD_{0.05}$	5.88	8.27	2.55	3.67	0.06	248
N Env.	2	2	2	2	3	3

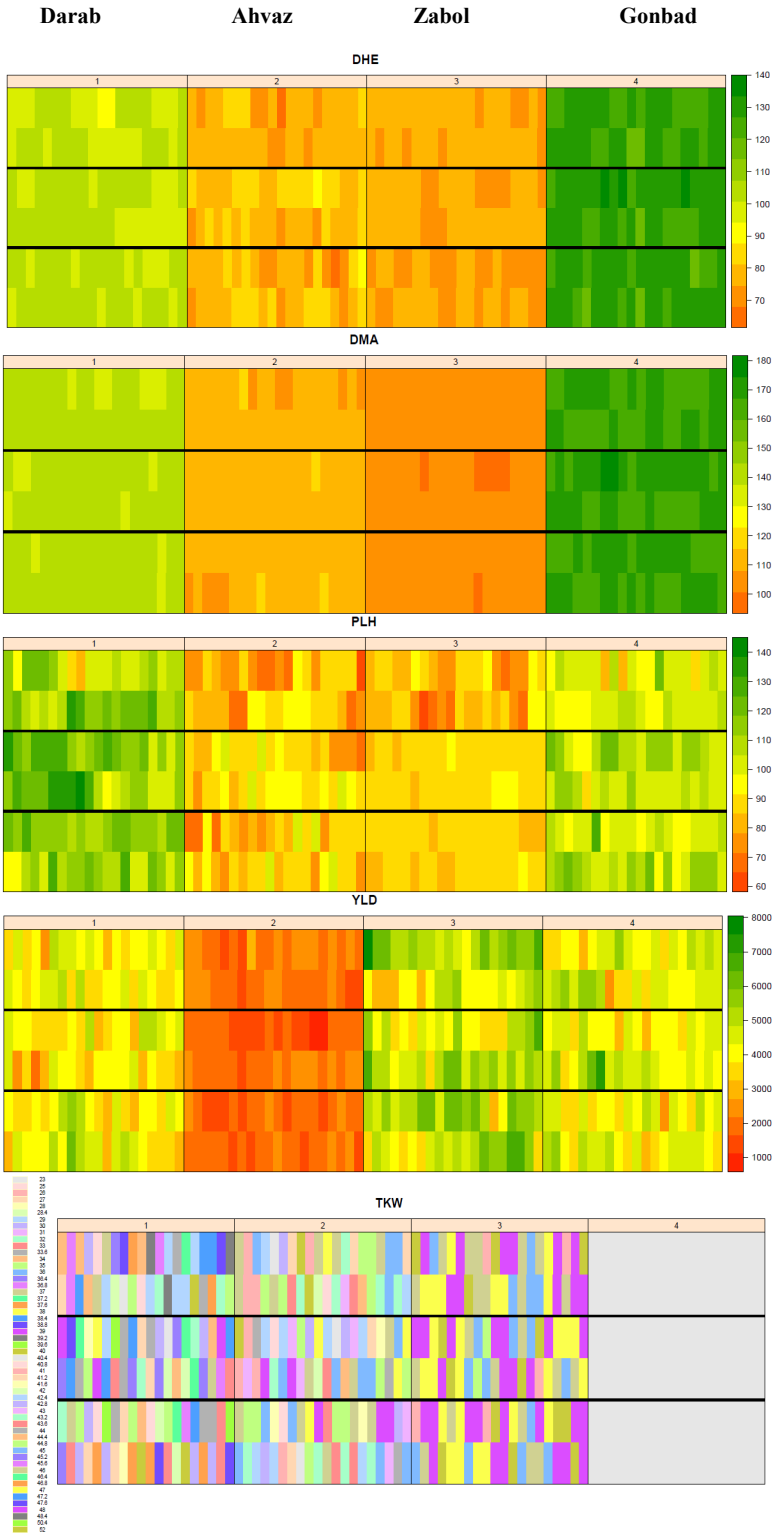

Fig. 1. Phenotypic variation of morphological and phonologic traits of barley genotypes at different regions. DHE: Days to heading; DMA: Days to maturity; PLH: Plant height; TKW: Thousand kernel weight; YLD: Seed yield

Table 4. Amounts SIIG index and seed yield in cultivars and lines of barley at Darab, Ahvaz, Zabol and Gonbad regions

	SIIG					Seed yield				
Lines	**Darab**	**Ahvaz**	**Zabol**	**Gonbad**	**Mean**	**Darab**	**Ahvaz**	**Zabol**	**Gonbad**	**Mean**
L2	0.676	0.513	0.520	0.531	0.560	4722	2120	5276	5346	4175
L3	0.614	0.387	0.462	0.259	0.430	4587	1788	5040	3788	3466
L4	0.569	0.503	0.391	0.193	0.414	4482	2172	4637	3288	3293
L5	0.595	0.472	0.257	0.530	0.463	4555	2002	3832	5147	3588
L6	0.684	0.324	0.385	0.448	0.460	5564	1583	4609	4634	3537
L7	0.561	0.371	0.259	0.397	0.397	4240	1720	3859	4392	3252
L8	0.764	0.294	0.440	0.487	0.496	6287	1622	4970	4946	3774
L9	0.667	0.496	0.538	0.291	0.498	5269	1924	5498	3654	3620
L10	0.610	0.371	0.483	0.195	0.414	4959	1670	5109	3299	3287
L12	0.429	0.488	0.463	0.090	0.367	3539	2056	5068	2879	3262
L13	0.669	0.499	0.502	0.241	0.478	4889	2110	5443	3088	3475
L14	0.645	0.374	0.627	0.301	0.487	5194	1541	6359	3991	3892
L15	0.671	0.424	0.613	0.420	0.532	4894	1800	6248	4386	4073
L16	0.631	0.438	0.600	0.440	0.527	4600	1940	6215	4604	4181
L17	0.505	0.646	0.709	0.413	0.568	3854	2350	7276	4627	4679
L18	0.511	0.604	0.685	0.391	0.548	3999	1983	7040	4476	4427
L19	0.520	0.682	0.619	0.269	0.522	3812	2417	6148	3814	4054
L20	0.483	0.395	0.264	0.261	0.351	3550	1310	3748	3454	2765
L22	0.631	0.401	0.640	0.352	0.506	4879	1760	6082	4056	3894
L23	0.497	0.611	0.589	0.489	0.547	3742	2234	5776	4876	4223
L24	0.549	0.577	0.670	0.259	0.514	4122	2038	6387	3459	3889
L25	0.579	0.461	0.335	0.347	0.430	4642	1526	4318	3948	3192
L26	0.383	0.332	0.230	0.399	0.336	3424	1680	3595	4264	3108
L27	0.469	0.503	0.521	0.166	0.415	4002	1883	5470	2499	3212
L28	0.661	0.478	0.697	0.348	0.546	5180	2042	6762	4203	4263
L29	0.420	0.396	0.596	0.474	0.472	3457	1410	5998	4857	4016
L30	0.461	0.458	0.667	0.318	0.476	3652	1850	6582	3716	3977
L32	0.694	0.545	0.424	0.244	0.477	5215	1876	4748	3314	3241
L33	0.762	0.544	0.679	0.354	0.585	5754	1992	6415	4018	4069
L34	0.729	0.437	0.659	0.311	0.534	5652	1517	6568	3728	3865
L35	0.570	0.360	0.487	0.185	0.400	4500	1713	5387	3453	3445
L36	0.488	0.283	0.560	0.437	0.442	3909	1330	5734	4584	3811
L37	0.572	0.475	0.466	0.217	0.432	4422	1616	5109	3106	3205
L38	0.488	0.356	0.612	0.238	0.424	3899	1377	6082	3116	3453
L39	0.483	0.513	0.408	0.413	0.454	3659	1812	4859	4466	3640
L40	0.468	0.624	0.570	0.370	0.508	4169	2290	5665	4254	3998
L42	0.286	0.614	0.387	0.582	0.467	1947	2172	4595	5747	4250
L43	0.435	0.477	0.386	0.238	0.384	3423	1741	4665	3607	3416
L44	0.248	0.522	0.247	0.306	0.331	1565	2051	3707	4011	3334
L45	0.339	0.356	0.319	0.537	0.388	2427	1741	3984	5007	3656
L46	0.534	0.481	0.357	0.694	0.517	4278	1966	4290	6120	4203
L47	0.450	0.425	0.432	0.824	0.533	3703	1606	4818	7577	4745
L48	0.468	0.544	0.189	0.484	0.421	3847	2106	3082	4940	3454
L49	0.389	0.518	0.382	0.539	0.457	3255	1690	4484	5209	3872
L50	0.331	0.555	0.593	0.461	0.485	2832	2136	5957	4962	4430

Table 4. Continued

	SIIG					Seed yield				
Lines	**Darab**	**Ahvaz**	**Zabol**	**Gonbad**	**Mean**	**Darab**	**Ahvaz**	**Zabol**	**Gonbad**	**Mean**
L52	0.530	0.491	0.363	0.551	0.484	3682	2159	4332	5284	4003
L53	0.449	0.518	0.481	0.459	0.477	3775	2412	5207	4722	4192
L54	0.543	0.563	0.375	0.378	0.465	3957	2390	4568	4286	3826
L55	0.533	0.590	0.513	0.355	0.498	4060	2656	5457	4159	4168
L56	0.363	0.459	0.325	0.353	0.375	2570	2011	4345	4227	3606
L57	0.575	0.557	0.504	0.440	0.519	3982	2496	5429	4617	4259
L58	0.492	0.574	0.334	0.326	0.431	3445	2191	4387	4049	3620
L59	0.493	0.570	0.506	0.403	0.493	3455	2482	5262	4467	4148
L60	0.352	0.546	0.460	0.314	0.418	2675	2436	4984	3907	3854
L62	0.576	0.438	0.469	0.459	0.486	3992	1706	5068	4794	3934
L63	0.581	0.451	0.425	0.330	0.447	4255	1722	4929	4142	3676
L64	0.710	0.420	0.391	0.384	0.476	4913	1986	4665	4494	3793
L65	0.649	0.159	0.232	0.223	0.316	4900	735	3401	3547	2639
L66	0.318	0.217	0.225	0.330	0.273	2920	986	2929	4066	2738
L67	0.436	0.337	0.205	0.347	0.331	3628	1596	3179	4261	3090
L68	0.479	0.266	0.276	0.320	0.335	3933	1388	3901	4139	3221
L69	0.382	0.302	0.231	0.166	0.270	3243	1674	3762	3281	2983
L70	0.325	0.266	0.463	0.374	0.357	2572	1460	5095	4326	3705
L72	0.424	0.290	0.301	0.205	0.305	3455	1553	3984	3354	3042
L73	0.516	0.359	0.277	0.312	0.366	3868	1581	3776	4174	3255
L74	0.373	0.350	0.336	0.327	0.347	3310	1664	4123	4236	3419
L75	0.394	0.330	0.207	0.297	0.307	3293	1633	3304	3916	3029
L76	0.334	0.374	0.276	0.543	0.382	3152	2066	3734	5145	3727
L77	0.410	0.332	0.232	0.323	0.324	3480	1726	3151	3842	2984
L78	0.475	0.550	0.418	0.444	0.472	3513	1864	4776	4665	3847
L79	0.506	0.540	0.264	0.449	0.440	3767	1988	3832	4834	3629
L80	0.531	0.449	0.558	0.351	0.472	4133	1686	5498	4355	3925
L82	0.522	0.666	0.186	0.531	0.476	4064	2258	3089	5123	3483
L83	0.462	0.680	0.155	0.644	0.485	3317	2293	2769	5747	3596
L84	0.562	0.528	0.144	0.461	0.424	4087	1875	2825	4660	3113
L85	0.656	0.563	0.246	0.651	0.529	4735	1928	3852	5770	3843
L86	0.625	0.556	0.307	0.655	0.536	4554	1889	3936	5895	3900
L87	0.660	0.436	0.342	0.541	0.495	4920	1465	3075	5245	3255
L88	0.386	0.480	0.395	0.152	0.353	3489	1965	4214	2442	2866
L89	0.601	0.585	0.463	0.265	0.479	4814	2075	4866	3700	3540
L90	0.420	0.667	0.570	0.223	0.470	3420	2210	5269	3370	3609
L92	0.451	0.459	0.282	0.291	0.371	4030	1840	3936	3667	3140
L93	0.529	0.504	0.341	0.462	0.459	4162	2125	4241	4742	3696
L94	0.591	0.522	0.287	0.445	0.461	4634	2065	4158	4722	3641
L95	0.409	0.520	0.290	0.330	0.387	3427	1993	4033	4024	3343
L96	0.548	0.478	0.402	0.361	0.447	4427	1750	4769	4184	3561
L97	0.478	0.555	0.342	0.353	0.432	3920	2290	4061	4162	3497
L98	0.510	0.657	0.432	0.454	0.513	3715	1998	4352	4755	3695
L99	0.450	0.381	0.409	0.391	0.408	3475	1147	4991	4373	3497
L100	0.550	0.400	0.539	0.419	0.477	4214	1570	5866	4632	4016

Table 4. Continued

	SIIG					Seed yield				
Lines	**Darab**	**Ahvaz**	**Zabol**	**Gonbad**	**Mean**	**Darab**	**Ahvaz**	**Zabol**	**Gonbad**	**Mean**
L102	0.424	0.636	0.533	0.542	0.534	3402	2441	5866	5377	4554
L103	0.510	0.573	0.569	0.415	0.517	3935	2148	5380	4528	4012
L104	0.543	0.584	0.660	0.549	0.584	4320	2167	6019	5085	4417
L105	0.550	0.524	0.635	0.338	0.512	4189	1953	5686	4032	3883
L106	0.542	0.644	0.521	0.459	0.542	4230	2385	5269	4748	4127
L107	0.375	0.521	0.543	0.297	0.434	3249	2390	6075	3827	4090
L108	0.532	0.559	0.429	0.409	0.482	4034	2375	5047	4718	4040
L109	0.393	0.702	0.271	0.346	0.428	2727	2049	4089	4007	3375
L110	0.507	0.676	0.341	0.334	0.465	3805	2325	4477	3844	3542
L112	0.531	0.502	0.443	0.674	0.537	3750	2065	4686	5762	4164
L113	0.674	0.876	0.475	0.437	0.615	4464	2875	5130	4683	4223
L114	0.544	0.325	0.469	0.484	0.455	4284	1443	5186	4640	3749
L115	0.657	0.426	0.491	0.322	0.474	4844	1665	5491	3927	3687
L116	0.293	0.288	0.483	0.192	0.314	2670	1368	5144	3197	3229
L117	0.507	0.466	0.462	0.319	0.439	4032	1927	5130	3975	3671
L118	0.422	0.656	0.614	0.381	0.518	3349	2046	6186	4315	4175
L119	0.669	0.717	0.612	0.291	0.572	4594	2388	6172	3815	4118
L120	0.492	0.660	0.765	0.258	0.544	3725	2352	7547	3342	4407
Nimrooz	0.575	0.614	0.425	-	0.538	4212	2436	4862	-	3944
Auxin	0.508	0.564	0.658	0.430	0.540	3988	2495	6293	4608	4305
Norooz	0.587	0.522	0.565	0.404	0.520	4263	2000	5760	4449	4300
WB95-19	0.622	0.571	0.484	0.448	0.531	4542	2069	5149	4705	3889
Sahra	-	-	-	0.440	0.440	-	-	-	4661	4114

0.9≤SIIG<0.8
0.8≤SIIG<0.7
0.7≤SIIG<0.6
0.6≤SIIG<0.5
0.5≤SIIG<0.4
0.3≤SIIG<0.3
0.3≤SIIG<02
0.2≤SIIG<0.1
0.1≤SIIG<0.0

Table 5. Correlation of SIIG index with morphological and phonologic traits at Darab, Ahvaz, Zabol and Gonbad

	SIIG index				
traits	**Darab**	**Ahvaz**	**Zabol**	**Gonbad**	**All of regions**
DHE	-0.081	-0.700**	-0.043	-0.241*	-0.242*
DMA	-0.231*	-0.293**	-0.053	-0.244**	-0.441**
PLH	-0.287**	0.019	0.085	0.282**	-0.414**
TKW	0.079	0.853**	0.189*	-	0.373**
YID	0.947**	0.716**	0.972**	0.977**	0.891**