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The Determination of Selection Criteria Using Path Analysis in Two Rowed Barley (*Hordeum vulgare L. Conv. Distichon*)

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Abstract

In this study, interrelationships among yield components were determined both by simple correlation and path coefficient analyses of 13 barley cultivars (*Hordeum vulgare* L. conv. *Distichon*) during 2004-2006 under rainfeed condition of Van, Turkey. In the first cropping season, grain yield had a significant positive correlation with number of spike per m^2 (r=0.853**), moreover in the next season, there were found significant positive correlations with number of spike per m^2 (r=0.895**), and harvest index (r=0.323*) between grain yield. Path coefficient analysis revealed that number of spike per square meter showed the highest positive direct effect to grain yield in two years. According to results of correlation and path analysis of this study, it is recommended that spike per square meter ideally and also harvest index can be used as the most selection criteria for improving grain yield in barley breeding program at early generations.

Keywords: Barley, simple correlations, path coefficient analysis

İki sıralı Arpada (*Hordeum vulgare L. conv. Distichon*) Path analizi kullanılarak Seleksiyon Kriterinin Belirlenmesi

Özet

Van'ın kıraç koşullarında 2004-2006 yıllarında yürütülen bu çalışmada, path ve basit korrelasyon analizleri ile on üç adet iki sıralı arpa çeşidinin (*Hordeum vulgare* L. conv. *Distichon*) verim öğeleri arasındaki ilişkiler belirlenmiştir. İlk yılda tane verimi ile metrekarede başak sayısı (r=0.853**) arasında olumlu ve önemli bir ilişki tespit edilmiş olup hatta sonraki yılda da metrekarede başak sayısı (r=0.895**), ve hasat indeksi (r=0.323*) ile tane verimi arasında önemli olumlu ilişkiler bulunmuştur. Her iki yılda da path analizi sonuçları metrekarede başak sayısının tane verimi üzerine direk etkisinin yüksek olduğunu göstermiştir. Çalışmanın korelasyon ve path analizi sonuçlarına göre arpa tane verimi ıslahında erken dönemlerinde ideal olarak metrekarede başak sayısının ve hasat indeksinde en önemli seleksiyon kriteri olarak kullanılabileceği önerilmektedir.

Anahtar kelimeler: Path analizi, basit korelasyon, arpa

Introduction

Barley (*Hordeum vulgare* L. conv. *Distichon*) is one of the most important cereals in the Turkey and the grain is a major source of malt and feeding for animals. The principal aim of barley breeding programs has been developing new cultivars with high grain yield and high quality characters for different soils and climates. The direct selection of newly developed cultivar is necessary for every region. but, the direct selection on the basis of achieved grain yield could be misleading (Toker and Cagirgan, 2003). Therefore, path-coefficient analyses provide more information between variables (Dewey and Lu, 1959). Path coefficient analysis (Wright, 1921) is helpful in determining the direct contribution of yield components, and the indirect contribution of other characteristics, on seed yield. Path coefficient analysis has been used to determine the direct and indirect effects of individual yield components on final seed yields in cereals such as wheat (Sönmez et al., 1999, Garcia Del Moral et al., 2003), similar researches were carried out in barley (Hamid and Grafius, 1978; Riggs et al., 1981, Garcia Del Morel et al., 1991; Balkema-Boomstra and Masterbroek, 1993; Sinebo, 2002; Eshghi et al., 2011)

Grain yield in barley can be improved by understanding the interrelationships among yield, yield components, vegetative growth, and growth durations. Grain yield in barley can be expressed as a function of spikes per square meter, kernels per spike, and kernel weight, which together are referred to as yield components but this principle fluctuates for every region. Especially, many reports showed that the correlation and path coefficient analyses indicated that number of spike per unit area was the major contributors to grain yield (Hamid and Grafius 1978, Riggs *et al*. 1981, Garcı´a del Moral *et al*. 1991, Sinebo 2002). Generally subsequent the major effect on grain yield is kernels per spike (Sinebo 2002). But spikes per square meter have a negative effect on kernels per spike (Garcı´a del Moral *et al*. 1991, Balkema-Boomstra and Master broek 1993). Kernels per spike followed by kernels weight per spike little determined grain yield. But the effects of kernel weight are little on grain yield (Garcı´a del Moral *et al*. 1991, Sinebo 2002). Moreover the correlation of spikes per square meter with kernel weight is either positive (Garcı´a del Moral *et al*. 1991) or negative (Balkema Boomstra and Masterbroek 1993) depend on different regions. Kernels per spike and kernel weight are correlated negatively (Balkema-Boomstra and Masterbroek 1993). Slafer *et al*. (1994) have noted that the increase of number of seeds generated a decrease in the individual grain weight due to a lower quantity of photo-assimilates available for each grain. Moreover, Azimzadeh and Azimzadeh (2013) and Setotaw (2014) reported that the number of seed per spike and the 1000-kernel weight are the most important traits in barley selection in dry land condition.

Varieties with late heading time has low grain yield in growth limiting environments (Sinebo 2002). The correlation coefficient of 1000-grain weight with grain yield was positive or non-significant, with number of grains per spike mainly negative and with volume weight it was positive (Hadjichristodoulou 1990).

The aim of the present study was to determine the correlations between yield and other characteristics in two rowed barley varieties selected for varying agronomic composition and to determine the direct and indirect contributions using path coefficient analysis in rainfed condition. The results that determined in the present study might be used to adopt selection criteria in further studies. It may increase the selection efficiency.

Materials and Methods

Materials

Field experiments were conducted during the 2004-2005 and 2005-2006 winter growing seasons at one site in Van Province in eastern Turkey (38° 55’ N, 42° 05’ E, 1.725 m above sea level). Thirteen two rowed barley cultivars were selected for this study (Tokak 157/37, Tarm-92, Orza-96, Bülbül-89, Yesevi-93, Aydanhanım, Kalaycı-97, Karatay-94, Efes-3, Efes 98, Anadolu 98, Çıldır-02 and Zeynel Ağa). Seed materials were determined from the central research institute of field crops, the institute of Anatolia agriculture research, the institute of international agriculture research of Bahri Dağdaş and the Anatolia beer and malt industry.

Soil and Climatic Description

Soil analysis has been described in detail by Kacar (1995). Soil samples were taken from the surface layer of the experimental area (0-20 cm). Analysis showed the soil to have a sandy-clay-loamy texture with low organic matter (1.15%) and nitrogen (0.15%) content, high potassium (185.6 kg/da) and lime (29.5%) content, medium phosphorus (5.48 mg/kg) content and slight alkalinity (pH: 7.35) (Kaçar, 1995).

The region has a terrestrial climate that having cold in winter seasons and water limited in summers. Table 1 shows the average temperatures, rainfall and humidity for both the 2004-2005 and 2005-2006 growing seasons as well as long-term (1929-2006) averages for the region.

Methods

Each plot contained 8 rows 6 m in length and row spaced 0.20 m (9.6 m^{-2}). Seeds were hand-drilled at depths of 4 to5 cm and spaced approximately 1 cm apart along each row. The seeding rate was adjusted for a density of 500 viable seeds m^{-2}.

Fertilizer was applied by hand and mixed into the top 1-5 cm of soil at sowing time. Barley was fertilized at planting with 150 kg di ammonium phosphate ha^{-1} (N 18%- P 46%), and 200 kg ammonium sulfate ha^{-1} (N 21%) was applied as a top dressing before ear emergence.

The data included in the correlation and path analyses were grain yield (kg da^{-1}), spike density (number of spike per meter square), plant height (cm), spike height (cm), kernels (number of kernel per spike), kernels weight (number of kernel weight per spike), 1000 kernel weight (g), harvest index (%) and heading time (days). Data for these traits were obtained from the inner four rows by 3.2 m^2 of each sampling plots.

Statistical *Analysis*

Correlation coefficients and the path coefficient analysis was conducted following the procedure developed by Wright (1921) and applied by Dewey and Lu (1959). Grain yield (kg da^{-1}) was kept as resultant variable and all other component characters as causal variables. The SAS (SAS Inst., 1997) procedures and programs were used for these calculations.

Results

The results showed that yield and yield components were affected differently in two years such as grain yield, number of spike m^{-2}, stem height, spike height, number of kernel per spike, weight of kernel weight per spike, 1000 kernel weight, harvest index and heading time. The amounts of all traits were significantly ($p<0.01$) higher in 2004-2005 year than in 2005-2006 except heading time (Table 2). The difference can be related to the different environments affected to plant growth such as mean rainfall, temperatures and relative humidity (Table 1). Generally, autumn and winter rainfall is important for recharging soil water and is necessary in rainfed cropping system. Mean rainfall was slightly (16.5 %) higher during the 2004-2005 growing season than during the 2005-2006 growing season (Table 1).

Table 1. Climatic data for Van Province from - 2004-2005, 2005-2006 and, long-term (LT) averages

Months	Temperature (^{0}C)			Rainfall (mm)			Relative humidity (%)		
	2004-05	2005-06	LT	2004-05	2005-06	LT	2004-05	2005-06	LT
October	12.0	11.2	10.3	48.1	35.4	49.6	64.1	56.9	63.2
November	4.6	4.6	4.3	102.4	29.3	47.5	75.1	69.1	67.0
December	-3.7	1.9	-1.1	41.0	34.3	32.1	73.8	69.0	69.0
January	-3.3	-3.1	-3.6	34.4	90.4	41.9	77.1	73.7	69.0
February	-4.0	-1.3	-3.5	27.2	47.7	35.4	73.7	74.2	64.0
March	2.5	3.0	0.5	59.1	45.7	46.2	70.9	77.5	57.0
April	8.9	9.8	7.0	55.9	39.6	57.5	64.1	66.5	50.0
May	13.3	14.6	13.0	35.8	35.4	40.5	62.5	54.0	44.0
June	18.7	21.5	17.8	13.0	0.1	16.8	55.4	41.9	41.0
Total				416.9	357.9	323.4			

Table 2. Range in mean values for the investigated characters of the study in 2004-2006

Years	2004-2005						2005-2006					
Traits	Means	Std. Dev.	Ranges		Mean squares		Means	Std. Dev.	Ranges		Mean squares	
			Min.	Max.	Varieties	Error			Min	Ma.	Varieties	Error
GY (kg da^{-1})	283.0	32.52	219.3	350.2	5663.4**	36.105	230.2	42.43	165.2	305.2	7892.5**	40.12
SPM	395.5	83.34	270.0	620.0	29498.9**	108.391	329.4	74.73	214.0	530.0	23599.3**	26.086
MSH (cm)	61.95	4.28	51.6	70.7	79.9**	1.577	54.8	4.54	47.20	61.30	76.268**	0.304
SH (cm)	6.86	0.54	5.9	8.0	0.919**	0.052	6.0	0.43	5.15	7.00	0.698**	0.030
KPS	20.33	1.70	15.8	24.5	8.826**	0.700	16.7	1.28	14.50	19.40	6.531**	0.205
KWPS	0.92	0.10	0.68	1.2	0.045**	0.001	0.76	0.068	0.60	0.87	0.018**	0.001
TKW	45.44	3.54	35.8	50.1	17.124**	1.705	41.1	3.18	31.41	46.32	13.123**	1.077
HI (%)	33.85	3.90	21.4	38.6	55.670**	2.421	32.8	3.89	22.44	37.95	59.811**	1.041
HT (days)	181.8	3.23	176.0	190.0	41.692**	0.829	185.1	3.45	180.0	191.0	50.125**	0.386

Grain Yield (GY); Spike per m^2 (SPM); Mature stem height (MSH); Spike height (SH); Kernels per Spike (KPS); Kernels weight per Spike (KWPS); 1000 kernel weight (TKW); Harvest index (HI); Heading time (HT)
** Indicates significance at P < 0.01

Correlation coefficient analysis

The correlation statistic among the traits was separately presented in Table 3 for each year (*n* =52). The results showed that, there were significant positive correlations (Table 3) between grain yield and number of spike per m^2 (r =0.853**) or significant negative correlations with mature stem height(r=-0.288*), kernel weight per spike (r = -0.401**) and 1000 kernel weight (r = -0.275*) in the first year of study. In the next year of the cropping seasons, grain yield had significant positive correlation (Table 3) with number of spike per m^2 (r= 0895**) and harvest index (r= 0.323*) or significant negative correlations with mature stem height(r= -0.593**) and heading time (r= -0.333*) that were obtained.

Table 3. Correlations among traits in two rowed barley

		GY	SPM	MSH	SH	KPS	KWPS	TKW	HI	HT
2004-2005	GY	1.000	0.853**	-0.288*	-0.048	-0.240	-0.401**	-0.275*	0.152	0.070
	SPM		1.000	-0.500**	-0.305*	-0.526**	-0.759**	-0.409*	0.084	-0.204
	MSH			1.000	0.307*	0.217	0.545**	0.443**	0.065	0.009
	SH				1.000	0.380**	0.581**	0.392**	-0255	0.346*
	KPS					1.000	0.582**	-0.122	-0.026	0.563**
	KWPS						1.000	0.611**	0.063	0.302*
	TKW							1.000	-0.076	-0.070
	HI								1.000	-0.002
	HT									1.000
2005-2006	GY	1.000	0895**	-0.593**	-0.068	-0.007	0.144	0.098	0.323*	-0.333*
	SPM		1.000	-0.495**	-0.171	-0.192	-0.071	0.053	0.226	-0.417**
	MSH			1.000	0.332*	0.230	0.051	0.212	0.040	0.272
	SH				1.000	0.130	0.109	0.488**	0.080	0.343*
	KPS					1.000	0.615**	-0.050	-0.055	0.492**
	KWPS						1.000	0.066	0.302*	0.481**
	TKW							1.000	0.348*	0.091
	HI								1.000	0.248
	HT									1.000

Grain Yield (GY); Spike per m^2 (SPM); Mature stem height (MSH); Spike height (SH); Kernels per spike (KPS); Kernels weight per spike (KWPS); 1000 kernel weight (TKW); Harvest index (HI); Heading time (HT)
* Indicates significance at P < 0.05, ** Indicates significance at P < 0.01.

Path coefficient analysis

The direct and indirect effects of traits were dedicated in Table 4. In 2004-2005, path coefficient analysis revealed that number of spike per m^2 and kernel weight per spike showed the positive highest direct effect on grain yield. In addition, traits such as mature stem height (MSH) and heading time (HT) which showed moderately positive direct effect to grain yield in same cropping year. In same year, some traits which showed moderately negative direct effect to grain yield involved spike height, kernels per spike, 1000 kernels weight and harvest index.

Negative indirect effects of the number of spikes per square meter on grain yield, via stem height, via kernels weight per spike, via harvest index and heading time reduced the final values of the correlations; but positive indirect effects of number of spike per m^2 on grain yield via spike height, via kernel per spike and 1000 kernel weight increased the final values of the correlations.

Some traits have a direct effect on grain yield, although a high degree of positive; negative correlation between traits and grain yield were determined. Therefore path-coefficient analyses provide more information between traits. Moreover path coefficient analysis has been used to determine the direct and indirect effects of individual yield components on final seed yields. Although the direct effect of kernel weight was significantly higher on grain yield, the correlations were negative between grain yield and kernel weight. The positive and direct effect of kernel weight per spike on grain yield were masked by some other traits such as SPM, SH, KPS, TKW, HI. The negative effects of SPM on kernel weight per spike was higher that was reduced the correlation between KWPS and grain yield (Table 4).

Moreover the data further indicated that the total positive effect of kernel weight per spike on grain yield was the result of positive and indirect effect of MSH and HT. Moreover, negative indirect effects of the KWPS on grain yield, via SH, via KPS, via TKW, via HI reduced the final values of the correlations in 2004-2005.

Table 4. The direct, indirect, contribution of various traits to grain yield in two rowed barley.

		Direct effect	Indirect effects								
	Traits		SPM	MSH	SH	KPS	KWPS	TKW	HI	HT	Correlation
2004-2005	SPM	1.351		-0.062	0.015	0.010	-0.479	0.055	-0.002	-0.035	0.853**
	MSH	0.124	-0.676		-0.015	-0.004	0.344	-0.060	-0.002	0.001	-0.288*
	SH	-0.049	-0.412	0.038		-0.007	0.367	-0.053	0.008	0.060	-0.048
	KPS	-0.020	-0.711	0.026	-0.018		0.367	0.016	0.000	0.097	-0.240
	KWPS	0.631	-1.026	0.067	-0.028	-0.011		-0.083	-0.002	0.052	-0.401**
	TKW	-0.136	-0.553	0.055	-0.019	0.002	0.386		0.002	-0.012	-0.275*
	HI	-0.033	0.114	0.008	0.012	0.000	0.039	0.010		0.000	0.152
	HT	0.173	-0.276	0.001	-0.017	-0.011	0.190	0.009	0.000		0.070
2005-2006	SPM	0.664		0.163	-0.030	-0.051	-0.004	-0.000	0.051	0.103	0.895**
	MSH	-0.330	-0.329		0.060	0.061	0.003	-0.000	0.009	-0.067	-0.593**
	SH	0.180	-0.113	-0.109		0.034	0.006	-0.000	0.018	-0.084	-0.068
	KPS	0.267	-0.127	-0.076	0.023		0.039	0.000	-0.012	-0.121	-0.007
	KWPS	0.063	-0.047	-0.016	0.019	0.164		0.000	-0.079	-0.118	0.144
	TKW	-0.001	0.035	-0.070	0.088	-0.013	0.004		0.078	-0.022	0.098
	HI	0.225	0.150	-0.013	0.014	-0.014	0.022	-0.000		-0.061	0.323*
	HT	-0.247	-0.276	-0.089	0.062	0.131	0.030	-0.000	0.056		-0.333*

Spike per m^2 (SPM); Mature stem height (MSH); Spike height (SH); Kernels per Spike (KPS); Kernels weight per spike (KWPS); 1000 kernel weight (TKW); Harvest index (HI); Heading time (HT)

* Indicates significance at $P < 0.05$; ** Indicates significance at $P < 0.01$

The mature stem height (MSH) showed moderately positive direct effect to grain yield in same cropping year. Negative indirect effects of the mature stem height (MSH) on grain yield, via SPM, via SH, via KPS, via TKW and via HI reduced the final values of the correlations; but positive indirect effects of the mature stem height (MSH) on grain yield via KWPS via HT increased the final values of the correlations.

The heading time (HT) showed moderately positive direct effect to grain yield in 2004-2005. Negative indirect effects of the heading time (HT) on grain yield via SPM, via SH and via KPS reduced the final values of the correlations; but positive indirect effects of the mature stem height (MSH) on grain yield via MSH, via KWPS, via TKW and via HI increased the final values of the correlations.

In the second year, path coefficient analysis revealed that number of spike per m ^{2} showed the highest direct effect to grain yield positively. The negative indirect effects of the number of spikes per square meter on grain yield, via kernel weight, via spike height, via kernels per spike and via 1000 kernel weight reduced the final values of the correlations; but positive indirect effects of number of spike per m^2 on grain yield via mature stem height, via harvest index and heading time increased the final values of the correlations.

In this study, in spite of vegetative duration (heading time) is correlated negatively with grain yield in 2005-2006, in contrast, heading time was not correlated with grain yield in 2004-2005. The reason of this result may be that rainfall at flowering and grain filling stage was slightly lower in 2005-2006 than that of 2004-2005.

The positive and direct effects of spike height on grain yield were also masked by some other traits such as SPM, MSH, KPS, TKW and HI. These traits reduced the correlation between spike height and grain yield (Table 4)

The negative indirect effects of number of kernels per spike on grain yield, via SPM, via MSH, via HI, via HT reduced the final values of the correlations; but positive indirect effects of number of kernels per spike on grain yield via SH and via KWPS increased the final values of the correlations.

The positive and direct effect of harvest index on grain yield was also masked by some other traits such as MSH, KPS and HT. These traits reduced the correlation between harvest index and grain yield (Table 4). Although the direct effects of harvest index on grain yield was moderately positive but there were highly positive correlation between grain yield and harvest index. Especially the positive indirect effects of harvest index on grain yield, via SPM, via SH and KWPS increased the final values of the correlations.

Discussion

There were differences in number of spike square meter between two years. This can be related to the uncertainty of rainfall is immediately after plant emergence, leading to early season drought in rainfed farming systems (El-Hafid et al., 1998). Many work showed that early drought affects seedling establishment negatively and the uniformity of plant density with negative effects on yield (Debaekea and Aboudrareb, 2004). But in two years, grain yield was strongly positive correlated with number of spike per m^2. Previous paper had mentioned barley grain yield as the most important function of number of spike per square meter (Sinebo, 2002). In drought and cold conditions, varieties have more number of spike per square meter has higher grain yield.

The harvesting times for all varieties were similar in this study due to lower rainfall and higher temperature at grain filling stage. Therefore, varieties with earlier heading time have longer grain filling periods, resulting significant heavier kernel weight and 1000 kernel weight and also higher grain yield than the others. Varieties with shorter heading time had higher grain yield in second year. Conversely, in 2004-2005 there was non-significant positive correlation between grain yield and heading time. This result showed that the shorter heading time was important trait on grain yield under drought condition. In other words, heading time was the most important trait under stress condition; it was not important trait for grain yield under less stress condition. Moreover this was explained that varieties with longer heading time faced moisture stress during grain filling that resulted in a negative association of grain yield with heading time in 2005-2006. Donald and Hamblin (1976) reported that there were negative correlations between heading time and grain yield under stress conditions. Moreover our results were correlated with findings of van Oosterom and Ceccarelli (1993) that reported non significant trait for grain yield under non-stress condition. Sinebo (2002) reported that the late maturing genotypes faced moisture stress during grain filling and performed relatively poorly. Donald and Hamblin (1976) reported that there was negative correlation in grain yield with heading time under stress conditions. And also similar finding was reported by Gonzalez (1999) that yield was negatively correlated with heading time in barley varieties under drought. Simane et al. (1998) reported that path-coefficient analysis revealed that longer vegetative periods were associated with reduced grain-filling periods and negatively associated with drought resistance.

In this study individual kernel weight was lower and kernel weight negatively correlated with grain yield. Because of this situation could have been that higher number of spike per square meter reduced individual grain weight. Generally, the increase of number of spikes decreases individual grain weight due to a lower quantity of photo-assimilates available for each grain in limited environment (Hamid and Grafius, 1978, Balkema Boomstra and Masterbroek, 1993). Moreover, in the study, kernels per spike and 1000 kernel weight are correlated negatively (Hamid and Grafius, 1978; Balkema-Boomstra and Masterbroek ,1993; Sinebo, 2002). Slafer et al. (1994) have noted that the increase of number of seeds generated a decrease in the individual grain weight due to a lower quantity of photo-assimilates available for each grain. Hamid and Grafius (1978), Balkema Boomstra and Masterbroek (1993) reported that the correlation of spikes per square meter with kernel weight was negative.

The direct effect of number of spikes per square meter on grain yield was positive and significant. However, the indirect effect via number of kernels per spike and kernel weight was negative in the previous work. Traits which showed moderately positive direct effect to grain yield involved spike height, number of kernels per spike, kernel weight per spike and harvest index. There were negative direct effects of some traits on grain yield such as stem height, 1000 kernels weight, and heading time characters. Simane et al. (1998) had similar findings in wheat with the present study.

According to the results of two years, the direct effects of spikes per m^2 on grain yield were higher in 2004-2005 (1.351) than in 2005-2006 (0.664). Moreover the indirect effects of spike number on grain yield via traits were little in 2005-2006 than in 2004-2005 (Table 4). This result may be obtained due to good seedling establishment in 2004-2005 compared to years of 2005-2006. Consequently the most effective trait on grain yield was number of spike per m^2 in our region. The results were reported that under similar region correlated with our findings such as Garcı´a del Moral *et al*. (2003) reported that the direct effects obtained in the path analysis showed that spikes per square meter had a significant influence on grain yield, mainly under rainfed conditions. Moreover, the results obtained in this present study were in agreement with the findings of Garcı´a del Moral et al. (1991). In addition, the results of present study agrees with previous report that conducted under same region, that spike number per m^2 used as a selection criterion increased grain yield in wheat (Sönmez et al., 1999). The most effective character on grain yield was spike per square meter that might be used as the most selection criteria in barley breeding program in Van condition. In addition varieties with earlier heading time (Sinebo, 2002) and higher harvest index might be selected for this region. Although the direct effect of kernel per spike and kernel weight per spike on grain yield was positively higher that the correlations between grain yield and kernel per spike and kernel weight per spike was found highly negative. The effects of the number of spikes per square meter masked the effects of kernels weight per spike and kernel per spike on grain yield that was obtained significantly. Higher number of spikes per square meter reduced the final values of the correlations between grain yield and kernels weight per spike and also kernel per spike. Moreover, higher spike per square meter reduced stem height due to limited water and therefore varieties having shorter mature stem height had higher grain yield, the reduction in mature stem height is associated with progress made in barley breeding for grain yield (Riggs et al., 1981).

Conclusions

Generally, grain yield in barley can be expressed as a function of spikes per square meter, kernels per spike, and kernel weight, which together are referred to as yield components but this principle fluctuates for every region. Especially, the correlation and path coefficient analyses indicated that number of spike per unit area was the major contributors to grain yield in our region. Therefore it is recommended that spike per square meter ideally and also harvest index can be used as the most selection criteria for improving grain yield in barley breeding program at early generations.

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