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The Correlation Study of important Barley agronomic traits and grain yield by Path Analysis

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ABSTRACT: Path analysis was suitable method for direct and indirect effects on yield traits. This study was conducted to study the correlation between the number agronomic performance traits and cause and effect relationships between them in four barley cultivars and lines with three replications in a randomized complete block design in Boyer Ahmad region. During growth and after harvest was recording completed of 10 random tillers per plant traits, heading date, arrival date, plant height, grain weight and yield. After harvesting were determined the grain weight and yield. By analysis of variance and covariance to determine the correlation coefficients between traits and path analysis were used for the correlation coefficient analysis of direct and indirect effects. Analysis showed no significant difference in level 5% between yield treatments. Based on analysis and comparison treatments, superior yield to treatments 2 and 4 (cultivar Valfajr) with average yield 6.520 and 6 490 t/ha. This two lines are features better, including grain yield, plant height and grain weight.

Key words: barley, coefficients, correlation, path analysis, traits.

INTRODUCTION

Barley (*Hordeum vulgar* L.) is the world's fourth most important cereal after wheat, rice, and corn. Barley is in the second place among the cereals after wheat in Iran (Matlubi and Akbari, 1983).Barley has better compatibility than other cereals, and regarding this only the wheat is to close it (Rasmusson, 198).This study investigated the correlation between important agronomic traits and grain yield of barley genotypes to achieve the selection criteria to improve the yield.

According to Food and Agriculture Organization (FAO) data, in 2008, the global production of barley was 141175906 tons with an average yield of 2538kg/ha. Iran, owning 1.45million hectares of planted land with barley, has 2.6 of the world's land area under barley cultivation. Average barley yield in Iran has been 1382kg/ha, and in 2008, its production was estimated two million tons, allocating 4.1% of the world's total production.

The linear relationship between variables is expressed by correlation coefficient, stating the coefficient of common variation of two different traits. The coefficient of correlation measures the relationship between different variables and helps to determine traits which are very important or some what important for selection criteria programs (Gadekar *et al.*, 1990). The coefficient of correlation shows the variations of common traits interactions under study and does not imply causation. The plant breeding experts use path analysis as a tool to determine the importance of effective traits in yield. This method was discussed for the first time by Wright's question (Wright, 1921). PATH system, as a powerful method and having simple changes, is relatively complex in terms of formula and includes all the factors and variables derived from them.

Path coefficient method is obtained to a large extent by formulating a diagram that shows the relationships between variables. In the diagram formation, a series of bi-directional arrows is used to show the relationship between the main factors and the bilateral cooperation. One-way arrows are used to determine the direct direction of a variable's effect on other variable (Dewey and Lu, 1959).And insufficient knowledge of the relationships between different traits and one-way selection of traits reduce the desired results in plant breeding. Path analysis consists of two main components, a diagram of causality and correlation analysis. Path diagrams are capable of showing both direct and indirect effects of one variable on an other variable. To draw the path diagrams, the independent variables should be separated from the dependent variables (Bhatt, 1973). The main components of yield include the number of spikes per square meter, number of grains per spike, and grain weight.

Some researchers reported a positive correlation between grain yield and other traits such as the number of spikes per square meter, number of grains per spike (Evans, 1983), and 1000 seed weight (Evans, 1983;Singhand Rana, 1983).A positive correlation has been reported between grain yield and weight (Singh and Rana, 1983),and between grain yield and spike length.

Also, positive correlations have been reported between the number of tillers and grain yield by several authors (Ozkan *et al,* 1997; Rasmusson, 1985). Morphological traits of the plant and its connection with the yield have been studied by a large number of researchers (Hanson, 1990).Plant height is a morphological trait; studying its relationship with grain yield and other traits of the plant has been of great importance for different researchers. A high number of investigators have reported a positive correlation between plant height and grain yield (Leonard and Martin, 1963; Samaria *et al.,* 1987).Traits such as the number of spikes per square meter, number of fertile tillers, 1000 seed weight, harvest index, leaf area index, crop growth rate after flowering, and dry matter accumulation pattern can be introduced as selection criteria for grain yield improvement (Mohtashami, 2005).

MATERIALS AND METHODS

To investigate the correlation between agronomic traits and grain yield of barley genotypes, to address these lection criteria of the study, the experiment was conducted in Boyer-Ahmad, Iran with four treatments and three replications in a randomized complete block design. Treatments consisted of three lines of barley: C-81-15, C81-13, C-81-11, and valfajr barley as control.

Sampling was performed from 0-30cm depth of the experiment area. The amount of chemical fertilizers was determined after the chemical analysis of the soil. The experiment area had deep sedimentary calcareous soil with salty clay loam texture with no salinity and PH of 7.6.100kg urea and 150 kg ammonium phosphate was calculated per hectare. All of phosphate fertilizer and half of urea fertilizer were evenly mixed with the soil at planting time, and the rest of urea fertilizer was used as split application at the till erring stage.

Land preparation including plowing, leveling discs, and determining boundaries were performed. Barley seeds were sterilized and planted in 15 cm intervals over 10-meterlength ridges with 450 seeds per square meter (Matlubi and Akbari, 1983). Planting was done by hand with high accuracy. Precipitation level was 1100 mm during June to November, and a total of three irrigations were performed during the growing period. In the third to fifth leaf stage, weed chemical control was performed. During the growth period and after the harvest, note takings and measurements of the yield and yield components were performed according to the standards of CIMMYT as follows:

-**The total number of tillers:** after the spikes' emergence, counting the cultivars' tillers was done by randomly counting10plantsperreplication. The mean of tillers of each cultivar was calculated.

-**The number of fertile tillers:** counting the fertile tillers was done in the milk stage in one square meter for each cultivar and for each replication compared with the number of fertilized and harvested spikes.

-Plant height: in the grain dough stage, the distance between the soil surface and the top end of the spike, regardless of the awn, was measured for 10 plants (in centimeters) randomly in each plot.

-The number of days to heading: the number of days to heading was considered from the onset of the first effective precipitation until 50 percent of the plant had spikes.

-The number of days to maturity: it starts from the first effective precipitation until the day 50% of plant have yellow color in the top stem internodes.

-The number of grains per spike: the number of full grainsper10 spikes from each plot and in each replication was counted after harvest, and the average number of grains per spike was calculated.

-Spike length: the distance between the first node of the spike and the end of the last spikelet was randomly measured in maturity time for10spikes in each plot with a ruler, regardless of the awns, and then the average spike length was determined in centimeters.

-Awn length: when the awns started yellowing down, the average awn length was measured randomly in10 plants in centimeters.

-Grain weight: after collecting a number of 1000 seeds from each cultivar in each replication by a seed counter, the average1000 seed weight was weighted with a sensitive and accurate scale (0.001g).

During the growing season, required note takings were do neon cold damage, lodging, seed abscission, severity and prevalence of pests and diseases. After harvesting and threshing, the genotypes and lines yield were determined. Using MSTATC software, analysis of variance and mean comparisons were done and the best cultivars and lines were selected (1).

The variance components were calculated by expected value and analysis of phenotypes' variance into its constituent components according to the following formula:

$$\sigma^2 ph = \sigma^2 g + \sigma^2 e + \sigma^2 ge$$

Using analysis of variance and the expected mean squares, the genotypic and phenotypic variances were estimated or each trait. Also, estimating the phenotypic and genotypic variances, the general heritability was calculated as follows:

$$H_{bs} = \frac{\delta g}{\delta ph}$$

In this formula, H, $\delta ps, \delta g$ are heritability, phenotypic, and genotypic variances, respectively. Correlations of coefficients were calculated between the traits by formula (Miller *et al.*, 1958).

To study the significance of the correlation coefficient between pairs of traits, the proposed correlation coefficient was used. For statistical analysis, ANOVA, analysis of covariance, and means comparisons were done using Duncan method by MSTAT-C and SAS software. To draw graphs, computer software (EXELL) was used.

RESULTS AND DISCUSSION

Analysis of variance was carried out based on the data obtained from the grain yield and mean comparison using Duncanmulti-grain test (Table 1). The data show that treatment 2 with a mean yield of 6.520 and the control with yield of 6.490 ton have the highest grain yield and are significantly different from other genotypes at 5%. Genotypes 2 and 4 had the highest grain weight, respectively, and genotypes 3and1had the lowest grain weight. There was a positive and significant correlation between the grain yield and 1000 grain weight. A positive weak correlation has been reported by some authors between the grain yield and 1000 grain weight (Samaria *et al.*, 1987).Genotypes 3 and 4 had the maximum plant height and treatment 2 had the lowest height. The results show that there is a significant difference among genotypes regarding grain yield at 5% which implies the existence of genetic variation among genotypes studied. The experiment has a coefficient of variation of cv = 15.37, indicating the accuracy of the experiment (Table 1). Estimation of variance components and heritability of important agronomic traits of barley genotypes is reflected in Table 2.

Table 1: The mean ofagronomic traits andgrainyieldof response genotypes.

No	Tiller number	Plant height	1000 grain weight	Average yield	Genotype
1	21 ^{c}	95 ^{c}	37 ^{b}	6.010 ^{b}	C-81-11
2	23 ^{b}	89 ^{b}	40 ^{a}	^{a}6.520	C81-13
3	22 ^{b}	104 ^{a}	35 ^{c}	^{b}5.950	C-81-15
4	26 ^{a}	103 ^{a}	39 ^{a}	^{a}6.490	Valfajr

The means in each colum followed by same letters are not significantly different at 5% level Cv: 15.37

Table 2: Estimates of variance components, heritability, and genetypic and phenotypic variation coefficients of important agronomic traits of barley.

Traits	Genotypic variance	Phenotypic variance	Coefficient of genotypic variation	Coefficient of phenotypic variation	Heritability
Number of days toheading	5.64	7.55	3.59	4.22	42.3
Number of days to maturity	4.15	8.34	2.72	2.88	51.2
Total number of tillers	1.11	1.87	8.35	11.32	58.14
Number of fertile tillers	0.54	0.93	28.58	47.29	26.83
Number of grains per spike	3.22	14.26	7.41	13.34	8.65
Plant height	12.64	22.47	6.36	9.72	52.38
Spike length	1.78	2.52	2.77	6.12	35.37
Awn length	2.43	3.86	11.35	18.56	44.25
1000 grain weight (g)	5.32	9.14	8.92	11.53	51.67
Grain yield	1.18	1.62	15.58	22.84	45.62

Genotypic and phenotypic coefficients of variation of grain yield were 15.58 and 22.84percent, respectively, and the heritability was 45.62 percent. The heritability of 1000 grain weight was 51.67, and genotypic and phenotypic coefficients of variation were 8.92 and 11.53 percent, respectively. Genotypic and phenotypic variation coefficients of number of grains per spike were 13.34 and 7.41, respectively, its heritability was 8.65, and phenotypic and genotypic variations were 3.22 and 14.26, respectively. Genotypic and phenotypic coefficients of variation of number of days to heading were 3.59 and 4.22, respectively, and the heritability of this trait was 42.3.Regarding the number of days to maturity, the phenotypic and genotypic variation coefficients were 2.72 and 2.88 percent, respectively, and its heritability was 51.2percent.Genotypic and phenotypic coefficients of variation of the total number of tillers were8.35 and 11.32, respectively. The general heritability was 58.14 percent. Phenotypic and genotypic coefficients of variation of the number of fertile tillers were 28.58 and 47.29 percent, respectively, and the general heritability of the traitwas26.83.Genotypicand phenotypic coefficients of variation and heritability of the plant height of different genotypes were 2.77, 6.12, and 35.37, respectively. Genotypic and phenotypic coefficients of variation of the plant height were 6.36 and 9.72 percent, respectively, and the heritability was 52.38 percent. Genotypic and phenotypic coefficients of variation of the awn length were 11.35 and 18.56 percent, respectively. And the general heritability was estimated 37.45 percent (Table 2).

Genotypic and phenotypic correlation coefficients of different traits with grain yield and among each other are given in Tables 3 and 4. There is a strong positive genotypic and phenotypic correlation between grain yield and1000 grain weightat1%.The correlation between the grain yield and the number of grains per spike was negative and non-significant. A weak positive correlation was established between the number of grains per spike and the spike length. There was a weak negative correlation between1000 grain weight and the number of grains per spike.

The phenotypic correlation of the grain yield with the trait of number of grains per spike was negative and non-significant, and it was positive and significant with 1000 grain weight trait.

The phenotypic correlation between1000 grain weight and the number of grains per spike was negative and non-significant, and regarding the number spikes per square meters, it was negative and significant. On the other hand, the phenotypic correlation between the number of grains per spike and 1000 grain weight was negative and non-significant.

Table 3: The genotypic correlation coefficients between important agronomic traits of barley genotypes.

Traits	Number of days to heading	Number of days to maturity	Total number of tillers	Number of fertile tillers	Number of grains per spike	Plant height	Spike length	Awn length	1000 grain weight	Grain yield
Number of days toheading	1	0.75**	-0.17	0.29	.036	-0.38	0.42*	0.59**	0.33	0.27
Number of days to maturity		1	0.18	0.16	0.33	0.28	0.31	0.53**	0.27	0.31
Total number of tillers			1	0.61**	-0.10	0.03	0.15	0.11	0.11	0.35*
Number of fertile tillers				1	0.18	0.14	0.3	0.16	0.34	0.63**
Number of grains per spike					1	-0.04	0.12	-0.05	-0.25	-0.08
Plant height						1	0.24	0.11	0.21	0.16
Spike length							1	-0.11	-0.04	-0.07
Awn length								1	0.29	-0.10
1000 grain weight									1	0.58**
Grain yield										1

There was a high significant positive correlation between the number of days to heading and the number of days to maturity. The genotypic correlation between the total number of tillers and the grain yield was positive, moderate, and significant, and the phenotypic correlation regarding the grain yield was positive, weak, and non-significant. There was a very positive and significant genotypic and phenotypic correlation between the total number of tillers and the number of fertile tillers.

The number of fertile tillers had a highly significant and positive genotypic and phenotypic correlation with the grain yield, and a positive, weak, and non-significant correlation with the number of grains per spike. The genotypic correlation of the spike length and the number of days to maturity, plant height, and the total number of tillers was also positive. The genotypic and phenotypic correlation of the awn length and the number of days to heading was positive and highly significant but non-significant and positive regaring 1000 grain weight (Table 4).

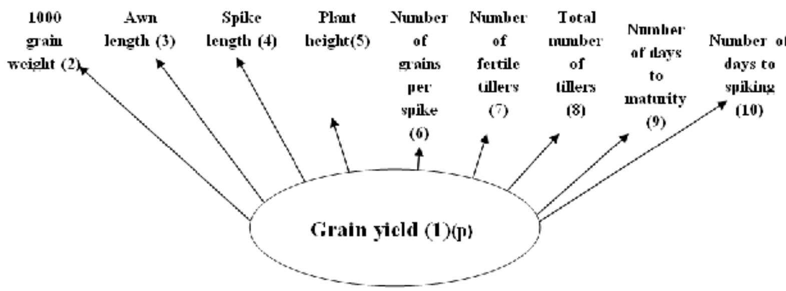

Fig. 1. Path analysis diagram of important agronomic traits of barley genotypes.

Table 4: Phenotypic correlation coefficients between important agronomic traits of barley genotypes.

Traits	Number of days to heading	Number of days to maturity	Total number of tillers	Number of fertile tillers	Number of grains per spike	Plant height	Spike length	Awn length	weight of 1000 grain	Grain yield
Number of days to heading	1	0.69**	-0.13	0.31	.034	-0.45*	0.45*	0.55**	0.30	0.26
Number of days to maturity		1	0.19	0.18	0.34	0.28	0.36	0.54**	0.29	0.38*
Total number of tillers			1	0.56**	-0.07	0.06	0.12	0.11	0.09	0.27
Number of fertile tillers				1	0.15	0.11	0.32	0.19	0.38*	0.61**
Number of grains per spike					1	-0.08	0.13	-0.11	-0.33	-0.12
Plant height						1	0.23	0.11	0.20	0.14
Spike length							1	-0.13	0.02	-0.09
Awn length								1	0.26	-0.12
weight of 1000 grain									1	0.49*
Grain yield										1

Genotypic and phenotypic correlation analyses of important agronomic traits of barley with regard to direct and indirect effects are illustrated in Fig.1, on the basis of causality relationships; the results are shown in Table 5.

Path Way effects	Genotypic rG	Phenotypic rph
Effects of 1000 grain weight on grain yield:		
Direct effect (21)	**0.41**	**-0.33**
Indirect effect through:	[redacted]	
Awn length	**0.04**	**0.08**
Spike length	**0.01**	**0.07**
Plant height	**-0.26**	**-0.18**
Number of grains per spike	**0.13**	**-0.03**
Number of fertile tillers	**0.37**	**0.28**
Total number of tillers	**0.16**	**0.01**
Number of days to maturity	**0.07**	**-0.02**
Number of days to heading	**-0.03**	**-0.09**
Effect of Awn length on grain yield:		
Direct effect (31)	**0.38**	**0.33**
Indirect effect through:	[redacted]	
1000 grain weight	**0.22**	**0.29**
Spike length	**-0.11**	**-0.03**
Plant height	**-0.07**	**-0.09**
Number of grains per spike	**0.16**	**0.12**
Number of fertile tillers	**0.33**	**0.18**
Total number of tillers	**0.25**	**0.13**
Number of days to maturity	**-0.14**	**-0.18**
Number of days to heading	**-0.08**	**-0.02**
Effect of Spike length on grain yield:		
Direct effect (41)	**0.14**	**0.03**
Indirect effect through:	[redacted]	
Weight of 1000 Grain	**0.03**	**0.01**
Awn length	**0.08**	**0.1**
Plant height	**-0.37**	**-0.32**
Number of grains per spike	**0.09**	**-0.04**
Number of fertile tillers	**0.16**	**0.14**
Total number of tillers	**0.13**	**0.09**
Number of days to maturity	**-0.01**	**-0.01**
Number of days to heading	**-0.11**	**-0.09**
Effect of Plant length on grain yield:		
Direct effect (51)	**-0.14**	**-0.33**
Indirect effect through:	[redacted]	
Weight of 1000 Grain	**0.12**	**0.08**
Awn length	**0.13**	**0.11**
Number of grains per spike	**-0.05**	**-0.14**
Number of fertile tillers	**0.11**	**0.04**
Total number of tillers	**-0.15**	**-0.19**
Number of days to maturity	**-0.07**	**-0.09**
Number of days to heading	**-0.16**	**-0.06**
Effect of Number of grains per spike on grain yield:		
Direct effect (61)	**0.27**	**0.09**
Indirect effect through:	[redacted]	
Weight of 1000 Grain	**-0.11**	**-0.15**
Awn length	**0.05**	**0.1**
Spike length	**0.22**	**0.17**
Plant Height	**-0.16**	**-0.14**
Number of fertile tillers	**0.11**	**0.07**
Total number of tillers	**0.13**	**0.18**

Number of days to maturity	**0.21**	**0.18**
Number of days to heading	**0.11**	**0.19**
Effect of Number of fertile tillers on grain yield:		
Direct effect (71)	**0.59**	**0.53**
Indirect effect through:		
Weight of 1000 Grain	**0.26**	**0.21**
Awn length	**0.15**	**0.12**
Spike length	**0.11**	**0.07**
Plant Height	**-0.19**	**-0.14**
Number of grains per spike	**0.14**	**0.13**
Total number of tillers	**-0.13**	**-0.11**
Number of days to maturity	**-0.12**	**-0.15**
Number of days to heading	**-0.09**	**-0.08**
Effect of Total number of tillers **on grain yield:**		
Direct effect (81)	**0.37**	**0.33**
Indirect effect through:		
Weight of 1000 Grain	**0.21**	**0.11**
Awn length	**0.11**	**0.07**
Spike length	**0.08**	**0.04**
Plant Height	**-0.28**	**-0.26**
Number of grains per spike	**0.06**	**0.03**
Number of fertile tillers	**0.12**	**0.08**
Number of days to maturity	**-0.25**	**-0.22**
Number of days to heading	**-0.14**	**-0.23**
Effect of Number of days to maturity on grain yield:		
Direct effect (91)	**0.31**	**0.26**
Indirect effect through:		
Weight of 1000 Grain	**0.18**	**0.16**
Awn length	**0.09**	**0.07**
Spike length	**-0.12**	**-0.08**
Plant Height	**-0.22**	**-0.17**
Number of grains per spike	**0.05**	**0.01**
Number of fertile tillers	**-0.11**	**-0.09**
Total number of tillers	**-0.14**	**-0.21**
Number of days to heading	**0.24**	**0.23**
Effect of Number of days to heading on grain yield:		
Direct effect (101)	**0.44**	**0.36**
Indirect effect through:		
Weight of 1000 Grain	**0.27**	**0.22**
Awn length	**0.15**	**0.14**
Spike length	**-0.17**	**-0.21**
Plant Height	**-0.28**	**-0.32**
Number of grains per spike	**0.15**	**0.13**
Number of fertile tillers	**0.09**	**0.04**
Total number of tillers	**-0.14**	**-0.21**
Number of days to maturity	**0.16**	**0.15**

Correlation analysis shows that the 1000 grain weight had direct positive genotypic effect on grain yield while its direct phenotypic effect on the grain yield was negative. The indirect genotypic and phenotypic effect of this trait was high and positive through the number of fertile tillers per plant.1000 grain weight had an indirect positive and non-significant genetic and phenotypic effect through the spike length on the grain yield.1000 grain weight effect on grain yield was negative and significant through the indirect genotypic effect of the number of days to heading.1000 grain weight effect on grain yield through the indirect phenotypic effects of quantitative traits, except for the number of fertile tillers per plant, regarding other traits was negligible.1000 grain weight had a direct genotypic effect and indirect genotypic effect through the number of fertile tillers and the number of grains per spike on grain yield. Also1000 grain weight had an indirect negative genotypic and phenotypic effect of plant height on yield.

The highest indirect negative effect of 1000 grain weight on yield was through the plant height. The direct genotypic and phenotypic effect of the awn length on grain yield was positive and high. The indirect effect of the awn length through the indirect effect of the number of fertile tillers on grain yield was positive.

The indirect negative genotypic and phenotypic effects of other traits through the positive indirect effects of 1000 grain weight, the number of fertile tillers per plant, and the number of grains per spike were hiden, causing the direct and relatively high effect of the awn length on grain yield. The indirect effect of plant height and the number of days to maturity in both phenotypic and genotypic levels was negative on grain yield such that the indirect genotypic effect of these two traits is considerable and their phenotypic effect is negligible.

The spike length having a positive direct effect on grain yield showed positive indirect effects through the number of fertile tillers, total number of tillers, and awn length. The indirect genotypic effect of spike length on yield was positive and relatively high through the number of fertile tillers, and through the plant height it was negative and relatively high. The spike length effect on yield through the indirect genotypic and phenotypic effects of awn length was positive and high. Accumulation of positive and negative effects caused no significant correlation between grain yield and spike length.

The results show that the plant height through the indirect negative genotypic and phenotypic effects of the spike length, number of days to heading, total number of tillers, and the number of grains per spike had a negative effect on grain yield. The effect of plant height on grain yield through the indirect genotypic effect of 1000 grain weight was positive and relatively high; however, the indirect effect of this phenotypic trait was negligible, indicating the negative effect of tall plant height on grain yield. The indirect genotypic effects of the number of grains per spike and the number of days to maturity on plant height were negative, but negligible. Also the direct effect of the plant height on grain yield was negative and negligible. It seems that the negative effect of plant height on grain yield was due to the high indirect negative effects of the spike length, the number of days to heading, and the number of grains per spike on plant height.

The direct genotypic effect of the number of grains per spike was positive and significant on grain yield, and the phenotypic effect of this trait on grain yield was noticeable but negligible. The indirect effect of the number of grains per spike on grain yield by genotypic and phenotypic effects of spike length and the number of days to maturity was positive and high. The indirect genotypic effect of the number of grains per spike on yield through 1000grain weight and plant height was relatively high and negative. The indirect effect of the number of grains per spike through the awn length was very small and negligible. The indirect genotypic effect of the number of grains per spike through the total number of tillers and the number of days to heading was positive and significant on yield. The indirect phenotypic effects of the awn length and the number of fertile tillers considering the number of grains per spike on grain yield was positive but insignificant.

The number of fertile tillers had the maximum direct phenotypic and genotypic effect on grain yield. The maximum indirect genotypic effect of the number of fertile tillers on grain yield was by 1000 grain weight and awn length. The indirect phenotypic effects of spike length on yield was positive but not significant. The indirect effect of fertile tillers on grain yield due to plant height, total number of tillers, and the number of days to maturity was negative, but these effects were neutralized because of indirect positive impacts of 1000grain weight and the awn length. The direct effect of the total number of tillers on grain yield was positive and high at both levels. The indirect effect of the total number of tillers on grainyieldregarding1000 grain weight and the number of fertile tillers was positive and high. The indirect effect of total number of tillers number was negative on grain yield taking into account the plant height, number of days to maturity, number of days to heading at both phenotypic and genotypic levels. The indirect phenotypic effect of the total number of tillers on grain yield was positive but negligible through all indirect phenotypic effects. The direct genotypic and phenotypic effect of the number of days to maturity was positive on grain yield.

The number of days to maturity with a positive direct effect on grain yield had indirect high negative effects through the plant height and the total number of tillers. The indirect effect of the number of days to maturity was positive by1000 grain weight and the number of days to heading on grain yield in phenotypic and genotypic levels. The direct effect of the number of days to heading was high and positive on grain yield in both phenotypic and genotypic levels. The indirect effect of the number of days to heading on grain yield through 1000 grain weight and the number of fertile tillers was positive and high. The indirect phenotypic and genotypic effect of the number of days to heading was negative through the plant height, spike length, and the total number of tillers in either phenotypic or genotypic levels on grain yield. The low effects of the remaining parameters are indicative of correlation among agronomic traits of barley and their impact on grain yield.

It is concluded that the positive correlation between the number of days to maturity and the grain yield is

due to the indirect negative effect of the plant height and the total number of tillers and the considerable positive effect of 1000grainweightandthenumber of days to heading. In the present study, this trait showed a positive indirect effect through the awn length on the grain yield. Due to the indirect highly positive phenotypic and genotypic effect of the number of fertile tillers per plant, this trait can be used as a suitable criterion for selection in increasing grain yield. Based on the results, genotypes 2and 4 have favorable traits such as grain yield, plant height, and 1000 grain weight, thus recommended for irrigated areas of the province.

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