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Research Article

CORRELATION, PATH ANALYSIS AND STEPWISE REGRESSION IN YIELD AND YIELD COMPONENT IN WHEAT (*Triticum aestivum* L.) UNDER THE TEMPERATE CLIMATE OF ILAM PROVINCE, IRAN

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ABSTRACT
In order to investigate the correlation between yield and yield components in wheat and some cause and effect relationships between them, a field experiment was conducted to determine the most appropriate level of nitrogen fertilizer and wheat pre-sowing plants during 2013- 2014 sowing season under the temperate climate of Ilam province, IRAN. The experiment was performed in a split plot arrangement based on randomized complete block design with 4 replications. The main plots consisted of 6 pre-sowing plant treatments (control, Perko PVH, Buko, Clover, Oilseed radish and combination of three plants Ramtil, Phaselia, Clover), and sub-plots were allocated to four levels of nitrogen fertilizer (0, 75, 150 and 225 kg ha-1). The results showed that grain yield traits such as the number of fertile spikes, spike weight per unit area, harvest index, biomass. Thousand-grain weight, number of grains per spike, and height plant showed significant positive correlations. Stepwise regression was used to remove the effects of ineffective or low impact on yield traits in the regression model. Important traits for grain yield in this study included; biological yield (biomass), harvest index and weight spike per unit. The model has a coefficient of determination of 0.984. Path analysis showed the most significant and positive direct effect (P= 0.57) by harvest index and grain yield. Harvest index also showed positive indirect effect (P= 0.51) on grain yield. The highest negative direct effect on grain yield was found for the number of fertile spikes (P=-0.449) and the highest negative indirect effect for harvest index (P=-0.35). Finally, the number of fertile spikes was showed the highest impact on grain yield.

Keywords: *Correlated Traits, Path Analysis, Stepwise Regression, Yield Wheat*

INTRODUCTION
Almost 75% of people's food comes from only 12 plant species. Today, only 3 plants of wheat, rice and maize provide about 60% calories and 56% protein world population need, from which rice provides 26%, wheat 23% and maize 7% (Janick, 2001).
Perko varieties were derived from the crosses between tetraploid plants of winter rapeseed (*Brassica napus* L. *var napus*) and Chinese cabbage (*Brassica campestris* L. *var. sensulato*). New plants are superior to their parents in different aspects. Buko variety is a new amphiploid plant obtained by crossing tetraploid winter rapeseed, Chinese cabbage and turnips (*Brassica campestris* L. *var. Rapa*). Oilseed radish with scientific name (*Raphanus sativus* L.) is a genus belong to the Brassica and for various uses, e.g. oil, green manure, feed and fodder (Kashani *et al.*, 1986; Lupashku, 1980; Nasri *et al.*, 2014). Ramtil (*Guizotia abyssinica*) belongs to *Asteraceae* family, Phasilia (*Phacelia tanacetifolia*) to *Boraginaceae* (Marianne, 1994) and clover to *Fabaceae* family which all are grown for feeding (Nasri *et al.*, 2014). Wheat grain yield when is grown after clover is higher up to 200 to 300 kg per hectare. It has been reported that the presence of periodic clover had positive effects on plants (Shahbazian and Allahdadi, 2004).
Nitrogen at different growth stages increased wheat grain yield, number of grains per spike, grain weight, harvest index, protein percentage and increase the efficiency of nitrogen use efficient (Subedi *et al.*, 2007; Semenov *et al.*, 2007; Michael and Adoerge, 2003). According to Rahimizadeh *et al.*, (2011) Crop rotation and nitrogen fertilizer had a significant impact on crop yield biomass, number of spikes per unit area and spike length of wheat. Haddadi and Atai (2013) suggested the application of 225 kg nitrogen per

hectare for wheat growth while was improving yield components (number of spikelets per spike, grain weight per spike). With the increased use of nitrogen fertilizer in wheat improved tiller number, number of ears per square meter, grain weight, grain yield, biological yield and straw yield (Zebart and Sheard, 1992; Mc Donald, 2002; Nasri *et al.*, 2014; Ejaz *et al.*, 2003). Thousand-grain weight number of spikes (m^2), number of spikelets per spike, protein content and grain yield of wheat Pishtaz to significantly higher increased amounts of nitrogen fertilizer. But the harvest index was decreased with increasing nitrogen content (Nasri *et al.*, 2014).

Yield of wheat is complex quantitative character that results in the actions and interactions of various component traits (Singh and Diwivedi, 2002). Correlation and path coefficient analysis could be used as an important tool to bring information about appropriate cause and effects relationship between yield and some yield components (Khan *et al.*, 2003). Selections based on simple correlation coefficients without considering the interactions among yield and yield components may mislead the breeders to reach their main breeding purposes (Garcı´a del Moral *et al.*, 2003). Some researchers reported a positive and significant correlation between plant height, harvest index and yield (Anwar *et al.*, 2009; Akram *et al.*, 2008); however, Tas and Çelik (2011) in their study reported a negative and non-significant correlation between them. In many studies, it has been reported that grain number per spike has a positive effect on yield (Dogan, 2009; Aycicek and Yildirim, 2006). Above ground biomass has been found to have a positive effect on yield (Leilah and Al -Khateeb, 2005).

Khan *et al.*, (2003) showed significant and positive correlation between grain yield and number of tillers per plant. Correlations themselves express only the degree of traits interrelationships, while path analysis developed by Wright (1921) and applied by Dewey and Lu (1959), is used to separate the correlation coefficients to their direct and indirect effects through other traits. Path analysis procedure was used by number of researchers in wheat. It can provide useful information about affectability form of traits to each other and relationships between them.

Correlation coefficient is an important statistical procedure to evaluate breeding programs for high yield, as well as to examine direct and indirect contribution of the yield variables (Mohamed, 1999). Path analysis has been used in many studies on wheat (Mohamed, 1999; Leilah and Al-Khateeb, 2005). Stepwise multiple linear regressions proved to be more efficient than the full model regression to determine the predictive equation for yield (Naser and Leilah, 1993; Mohamed, 1999).

Mollasadeghi *et al.*, (2011) indicated that number of grain per spike, grain weight, 1000 kernel weight and biological yield had the most direct and positive effect on grain yield. In additional, stepwise regression is a method that is used to estimate the value of a quantitative variable regarding its relation with one or some other quantitative variables. This relation is such that it is possible to predict other changes using one variable. Many investigators have used this technique on wheat such as Mohamed (1999), Pržulj and Momcilovic (2011), Soleymanifard *et al.*, (2012). The present study was conducted to establish the inter - relationship and direct and indirect effects of various wheat components among themselves and with yield under rainfed conditions

Continuous operation and the lack of agricultural practices and crop rotation principles of organic matter is degraded lands so that the organic matter is given minimal in the dry areas (less than 0.3%). To recognize ways to improve soil organic matter, the research to understand the effects of the crops cultivated plants of pre-sowing plants and nitrogen fertilizer level on yield and yield components.

MATERIALS AND METHODS

Experimental Site and Design

The field experiment was conducted from 2013 to 2014 at the Karezan region of Ilam, Iran (42º33′N, 33º46′ E) on a Silty- Clay with low organic carbon (1.26%and slightly alkaline soil (pH= 7.9). Other soil test parameters are presented in Table 1.This site characterized by temperate climates with 370 mm annual precipitation.

Table 1: Results of soil tests implementation of experimental site

Soil depth $_{(cm)}$	Soil Texture	P $_{(ppm)}$	K$_{(ppm)}$	N%	OC%	pH	EC$_{(ds/m)}$
0-30	Silty- Clay	10.5	760	0.11	1.26	7.9	0.58
31-60	Silty- Clay	4.4	420	0.07	0.76	7.8	0.58

Design and Application of Treatments

The experiment was arranged in a split plot based on randomized complete block design with four replications. The main plots consisted of 6 pre-sowing plant treatments (control, Perko PVH, Buko, Clover, Oilseed radish and combination of three plants Ramtil, Phasilia, clover), and Sub plots were four N fertilizer rates including no fertilizer N(Control), 50% lower than recommended N rate, recommended N rate and 50% more than recommended N rate.

Winter wheat (Cv. Pishtaz) was planted on mid-November with arrow spacing of 15 cm and a seeding rate 200 kgha-1. Weeds were controlled by 2,4-D and Clodinafop-propargyl herbicides. Soil samples were taken after harvest of each crop from the 0 to 30 cm and 30 to 60 cm soil depths using a soil Auger. Wheat grain yield (14% moisture) obtained by harvesting the center 3 m by 10 m with a plot combine, but yield components were determined from two randomly selected areas ($2m^2$) within each plot. Plant samples collected at harvest were separated into grain and straw and oven-dried at 60°C for 72hr. In this experiment was determined grain yield, yield components (number of spikes per square meter, number of spikelets per spike, number of grains per spike, thousand grain weight gain weight per spike), harvest index and biological yield.

Statistical Analysis

The differences between the treatments were determined using analysis of variance (ANOVA). Statistical analyses were performed using Duncan's multiple range test procedures by the SAS software. Correlation coefficients between each pairs of the traits were computed according to Snedecor and Cochran (1981). In path analysis, grain yield used as dependent variable, and the other studied traits were use as predictor variables. The stepwise regression analysis was also carried out for the data obtained to test the significance of the independent variables affecting the grain yield. To determine the used to SAS software for stepwise regression and path analysis software was used to analyze causality.

RESULTS AND DISCUSSION

Yield and Yield Components of Wheat

Grain Yield

The results showed that there was a significant difference between the main plot of the grain yield $p \leq 0.05$ (Table 2). Thus pre-sowing plants caused creating changes in grain yields were compared with the controls, so that the new plants Perko, Buko, Oilseed radish and combination of three plants (Ramtil, Phasilia, and Clover) were in a statistical level and Clover and control (Fallow) were included in the statistics. Grain yield production that Perko and Buko as a pre-sowing planting treatment were killed with an average of 7020 and 6863 kgha-1 high production and control treatment produced the lowest grain yield with an average of 4969 kgha-1 (Table 3). The results showed that there was a significant difference between the Levels of sub-plots of the grain yield (Table 2), The highest wheat production at a rate of 6488.8 kgha-1, the treatment of 75 kg of nitrogen and the lowest production rate of 5287 kgha-1 treatment control (N0 fertilizer) belongs (Table 3). Among interactions the treatment pre-plant Perko and 75 kg nitrogen per hectare highest production the amount 8393 kgha-1 and the lowest production of the control treatment (Fallow) and zero fertilizer production was 3562 kg per hectare. Other researchers were confirmed also excels as a pre-sowing brassica varieties to increase yield and quality of wheat (Mc Donald, 2002; Lehrsch and Gallian, 2010; Nasri *et al.*, 2014).

Thousand Grain Weight

Analysis of variance showed no significant differences between main plot levels of seed weight. But the subplot levels of seed weight was significant differences $p \leq 0.01$(Table 2). The highest of thousand grain weight observed in Boko pre-sowing plants treatment in an average 35.87 grams and the lowest produced

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thousand grain weight control treatment with 33.54 g seed respectively. The mean comparison levels of sub-plots showed that the control treatments (no nitrogen) with thousand grains weight 36.56 grams of the highest and treated with 225 kg N treatments with produced 33.45 g had the lowest thousand grain weight. Seed weight decreased with increasing nitrogen due to increased number of grains per spike and grain weight per spike. Other researchers have also reduced thousand grain weight have confirmed the effect of increasing nitrogen (Nasri *et al.*, 2014). But the results contradict the results of this research, some researchers have nitrogen has caused thousand grain weight (Haddadi and Ataei, 2013; Ayoub *et al.*, 1994; Bulman and Smith, 1993).

The results indicate that thousand grain weights were not affected pre-sowing plants treatments and interactions of nitrogen fertilizer and pre-sowing plants. The greater part of the genetic characteristics of the cultivar and the environment will be less affected. On the other hand seem to preserve the plants, environmental unfavorable conditions thousand seed weight, seed production with high growth potential by reducing the number of grains or change the allocation of assimilates. This component performance is less affected by environmental conditions. The results based are on the research (Rahimzada *et al.*, 2011).

Number of Fertile Spike

The results indicate that the number of fertile spike was not influenced by pre-sowing plants treatments and interactions pre- sowing plants and fertilizer nitrogen. However, nitrogen levels on yield and nitrogen rate had a significant effect on the number of spikes per unit area increased. Because nitrogen has a positive impact on increasing the number of tillers and fertile tillers first prerequisite to achieve optimal performance (number of spikes) at the unit level. Other researchers have also declared the nitrogen yield mainly by increasing the number of spike increases (Ayoub *et al.*, 1994; Gharangeik and Ghaleshei, 2001; Mc Donald, 2002; Giovanni *et al.*, 2004). Non-application of nitrogen fertilizer with an average of 639.7 heads had the least effect on the trait, and by increasing the use of nitrogen fertilizer and 225 kg N ha with an average of 689.7 spikes accounted for the highest production (table 3).

Harvest Index

According to the results of data analysis, there was a significant difference the main plots levels (pre-sowing plants) at the one percent level of statistical probability, but there was significant difference between nitrogen levels of the harvest index at the five percent level of statistical probability (Table 2). The Highest of harvest index-owned pre-sowing plants treatment Buko rate of 41% and the lowest harvest index belonging to the control treatment (no pre-sowing plants), respectively. The highest of harvest index-owned at a rate of 41%, the treatment of 75 kg of nitrogen and the lowest harvest index-owned rate of 36% treatment of 225 kg of nitrogen belongs. With increasing nitrogen harvest index decreased from the lowest harvest index to the highest fertilizer rate, 36% respectively (Table 3). Other researchers have also confirmed the reduction in harvest index of nitrogen fertilizers has increased (Nasri *et al.*, 2014; Ayoub *et al.*, 1994; Zebart and Sheard, 1992).

Table 2: The mean squares of grain yield, harvest index, thousand grain weight, and number of fertile spikes

S.O.V	df	M.S.			
		Grain yield	Harvest index	Thousand grain weight	Number of fertile spikes
Replication	3	463242	0.0135	64.08	148161
Rotation(A)	5	103311*	0.0067**	11.08ns	24642.4 ns
E(a)	15	43639	0.0039	17.57	14603
Fertilizer N rate(B)	3	61024*	0.0078*	27.58*	17605.2 *
AB	15	18072ns	0.0009ns	7.19ns	6305 ns
E(b)	54	13350	0.0024	8.03	5528
%CV	-	19.34	12.81	8.08	10.96

**Significant at 0.05 probability level. ** Significant at 0.01 probability level.ns, non-significant.*

Table 3: Mean comparisons of grain yield, harvest index, thousand grain weight, and number of fertile spikes of wheat at rotations and N rates

	Grain yield (kg/ha)	**Harvest index (%)**	**Thousand grain weight (g)**	**Number of fertile spikes**
Fallow	4969.4^{b}	40 ^{ab}	33.54 ^{a}	613.4 ^{b}
perko	7020.6^{a}	39 ^{ab}	35.74 ^{a}	833.4 ^{a}
Buko	6863.8^{a}	41 ^{a}	35.87 ^{a}	669.7 ^{ab}
Clover	5584.4^{ab}	37 ^{ab}	35.23 ^{a}	669.8 ^{ab}
Ramtil,Phacilia,Clover	5571.9^{ab}	37 ^{ab}	34.96 ^{a}	688.4 ^{ab}
Oilseed radish	5837.5 ^{ab}	35 ^{b}	34.91 ^{a}	692.4 ^{ab}
N rate				
Control (no fertilizer)	5287.2^{b}	39 ^{ab}	36.56 ^{a}	639.7 ^{b}
50% lower than recommended rate	6488.8^{a}	41 ^{a}	35.43 ^{ab}	673.6 ^{a}
Recommended rate	5987.9^{a}	38 ^{ab}	34.83 ^{bc}	685.2 ^{a}
50% more than recommended rate	6134.6^{a}	36 ^{b}	33.45 ^{c}	689.7 ^{a}

Table 4: Correlation coefficients between 12 traits in wheat *(Triticum astivum L.)*

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Grain yield	1											
Biomass	0.89**	1										
Harvest index	0.404**	-0.035^{ns}	1									
Height plant	0.603**	0.686**	-0.052^{ns}	1								
Thousand grain weight	0.644**	0.562**	0.285**	0.343**	1							
Number of grains per spike	0.691**	0.651**	0.201*	0.484**	0.237*	1						
Number of spikelets per spike	0.355**	0.400**	-0.013^{ns}	0.288**	0.007^{ns}	0.587**	1					
Number of grains per spikelet	0.434**	0.349**	0.229*	0.275**	0.271**	0.573**	-0.318**	1				
Grain weight per spike	0.857**	0.780**	0.302**	0.538**	0.715**	0.845**	0.423**	0.558**	1			
Peduncle length	0.276**	0.339**	-0.071^{ns}	0.319**	-0.005^{ns}	0.457**	0.624**	-0.085^{ns}	0.322**	1		
Diameter of stem	0.468**	0.513**	-0.003^{ns}	0.552**	0.196^{ns}	0.559**	0.554**	0.119^{ns}	0.509**	0.523**	1	
Number of fertile spikes	0.779**	0.703**	0.324**	0.476**	0.419**	0.434**	0.173^{ns}	0.319**	0.547**	-0.005^{ns}	0.237*	1

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With regard to the proportion of nitrogen increased grain yield, straw also significantly increases natural, therefore, seem to encounter nitrogen consumption by reducing the harvest index.

Simple Correlation Analysis

Correlations coefficients between traits are presented in Table 4. Grain yield showed positive and significant correlation with above ground biomass ($r = 0.87^{**}$), Grain weight per spike ($r = 0.85^{**}$), number of fertile spikes ($r = 0.77^{**}$) and number of grains per spike ($r = 0.69^{**}$). Our findings were in agreement with the results of Ali and Shakour (2012) and Khan *et al.,* (1999), who reported significant and positive correlations between grain yield, biomass yield and grain weight per spike…Others authors reported similar results between grain yield, spikes number and number of grains per spike (Sharma and Rao, 1989; Singh and Sharma, 1994; Subhani and Khaliq, 1994; Khan *et al.,* 1999; Mohammad *et al.,* 2002; Aycicek and Yildirim, 2006). Furthermore, a positive and significant correlation was found between grain yield and the number of grains per spike ($r = 0.69^{**}$). Harvest index (HI) also showed a significant positive correlation (0.76^{**}) with grain yield. Mollasadeghi and Shahryari (2011) reported a negative correlation between harvest index and plant height.

Stepwise Regression

Stepwise regression is a semi-automated process of building a model by successively adding or removing variables based solely on the t-statistics of their estimated coefficients. In order to remove effect of non-effective characteristics in regression model on grain yield, stepwise regression was used. The results of stepwise regression in Table 5, 6. The results showed that the biological yield, harvest index and weight spike per unit with R square of 98.3%, justified the maximum of yield changes. Therefore the following equation can be obtained:

Step1: -5.664 +.388** BIO

Step2: GY= -609.446 +.395** BIO + 15.42** HI

Step3: GY =-614.698 + 0.372** BIO + 14.651** HI + 82.009 **WSU

With GY: Grain Yield, BIO: Above ground Biomass, HI: Harvest Index and, WSU: Spike Weight per Unit

Existence of significant R square in a successful regression equation indicates the effectiveness of the traits to increase grain yield (Leilah and Al-Khateeb, 2005), Ahmadizadeh *et al.,* (2011) reported importance of harvest index and biomass to grain yield. Golabadi *et al.,* (2005) revealed that under full irrigation, biological yield and under stress condition harvest index were entered into the regression model by performing stepwise regression. However, our results were not similar to those of Soleymanifard *et al.,* (2012) who found that 75% of variation in grain yield is explained by spikes/m^2, 1000 grain weight and plant height traits. With respect to the positive and significant regression coefficients of biological yield, harvest index and spike weight per unit, it could be stated that increasing the amount of these traits will cause an increase in the yield. Thus, in this study, three traits, biological yield, harvest index and spike weight per unit had the highest impact on the grain yield in Ilam climate.

Table 5: Stepwise regression for grain yield (dependent variable) and other traits (independent variable)

Added trait to model	**1**	**2**	**3**
Intercept	-5.664	-609.446	-614.698
Biomass	.388	.395	.372
Harvesting Index		15.420	14.651
Spike weight per unit area			82.009
R _Square (**R^2**)	.793	.982	.984

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Table 6: Wheat characteristics identified as crucial in wheat grain yield with each one of the used statistical techniques

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
Biomass	.890[a]	.793	.791	90.74712	.793	359.666	1	94	.000
Harvesting Index	.991[b]	.982	.982	26.63483	.190	998.173	1	93	.000
Spike weight per unit area	.992[c]	.984	.983	25.83688	.001	6.833	1	92	.010

Table 7: Stepwise regression for grain yield (dependent variable) and other traits (independent variable).

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-5.664	33.123		-.171	.865
	Biomass	.388	.020	.890	18.965	.000
2	(Constant)	-609.446	21.441		-28.424	.000
	Biomass	.395	.006	.906	65.695	.000
	Harvest Index	15.420	.488	.436	31.594	.000
3	(Constant)	-614.698	20.896		-29.417	.000
	Biomass	.372	.010	.854	35.566	.000
	Harvest Index	14.651	.558	.414	26.279	.000
	Spike weight per unit area	82.009	31.373	.066	2.614	.010

a. Dependent Variable: grain yield

Path Analysis

A path coefficient is a standardized regression coefficient (beta) showing the direct effect of an independent variable on a dependent variable in the path model. Thus when the model has two or more causal variables, path coefficients are partial regression coefficients which measure the extent of effect of one variable on another in the path model controlling for other prior variables, using standardized data or a correlation matrix as input.

Path coefficient technique was performed to divide the correlation coefficients between grain yield and yield related traits into direct and indirect effects via alternative characters or pathways. If the correlation function of a trait is due to a direct effect of this trait reflect the actual relationship between them. Therefore, these traits can be selected in order to improve the performance. According to Table 8 the results showed that harvest index and biomass had positive direct effect on grain yield (0.552^{**} and 0.57^{**}, respectively), whereas number of fertile spikes had a negative direct effect on grain yield (-0.449^{**}).

The highest indirect effects on grain yield were observed with harvest index (0.507) on biomass, and biomass (0.491) on harvest index. The highest negative indirect effects on grain yield were observed with harvest index (-0.35) on the number of fertile spikes, and number of fertile spikes (-0.136) on Spike weight per unit area.

However, plant height, spikes number per plant, number of grains per spike and thousand-kernel weight showed a non-significant effects on grain yield. Similar results were reported by Singh and Diwivedi, (2002) and Leilah and Al-Khateeb (2005), Ahmadizadeh *et al*., (2011) who revealed that biological yield per plant and harvest index had positive and high direct effect on grain yield. Conversely, Baranwal *et al.*, (2012) reported that sheath length followed by grains per spike, spike length and 1000-grain weight exhibited the maximum positive direct effect.

Table 8: Path coefficient (direct and indirect effects) of the estimated yield attributes on grain yield variation of wheat

Factors	Biomass	Harvesting Index	Weight spike per Unit	Number of fertile spikes	Total
Biomass	0.552	0.507	0.103	0.385	0.778
Harvesting Index	0.491	0.57	-0.009	-0.35	0.703
Weight spike per Unit	0.223	-0.02	0.256	-0.136	0.325
Number of fertile spikes	0.473	0.444	0.077	-0.449	0.546

Statement: Underlined numbers are direct effects.

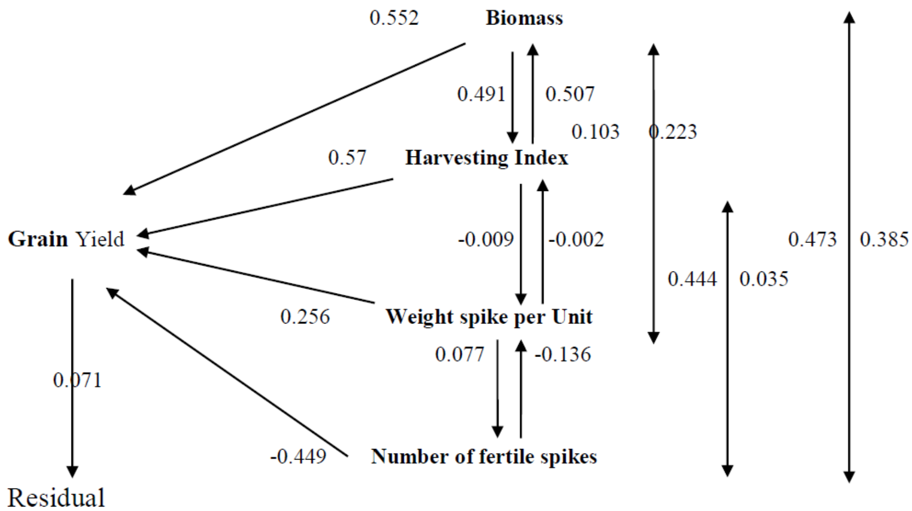

Figure 1: Path coefficient (direct and indirect effects) of the estimated yield attributes on grain yield variation of wheat

Table 9: Wheat characteristics identified as crucial in wheat grain yield with each one of the used statistical techniques

Trait	Simple correlation	Path analysis	Stepwise regression
Biomass	*	*	*
Harvest index	*	*	*
Height plant	*		
Thousand grain weight	*		
Number of grains per spike	*		
Number of spikelets per spike	*		
Number of grains per spikelet	*		
Weight spike per Unit	*	*	*
Peduncle length	*		
Diameter of plant	*		
Number of fertile spikes	*	*	

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Conclusion

The results showed that grain yield had significant positive correlations with traits such as number of fertile spikes, spike weight per unit area, harvest index, biomass, thousand grain weight, number of grains per spike, and plant height. To remove the effects of ineffective impact on yield was used traits in the regression model, stepwise regression. Important traits in grain yield in this study included three traits of biological yield (biomass), harvest index and spike weight per unit. The model has a coefficient of determination of 0.984. Therefore, the multiple statistical procedures which have been used in this study showed that above ground biomass and harvest index and spike weight per unit were the most important variables to be considered under Ilam conditions. This was clear with all statistical procedures used in this study (Table 9). Hence, we concluded that above ground biomass and harvest index and spike weight per unit are good measures of predicting grain yield.

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