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Analysis of Correlation Coefficients, Stepwise Regression, and path analysis of Grain yield in *Triticum aestivum* Cultivars and Lines

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ABSTRACT: Indirect selection in early generations through traits having heritability higher than yield as well as correlated significantly with seed yield is one of the most important breeding procedures. Production of new cultivars adaptable to different environments also has importance for wheat breeders. Cross among new cultivars and selection of superior genotypes among their progenies based on suitable traits is efficient breeding procedures. Therefore، in order to determination of the most yielding bread wheat genotypes، identification of the traits affective on seed and protein yield as well as parents of the best crosses an experiment was conducted 2011-2012. The randomized complete block design with three replications was used. Bread wheat genotypes comprised; Parsi and Sivand cultivars along with 18 lines entitled M-90-3 to M-90-20. Correlation، step-wise regression and path analysis designated that grain filling rate and no.spike/m^2 are the efficient indirect selection criteria to increase seed yield. Increasingly، peduncle length، no. seed/spike and no. spikelet/spike were recommended to improve spike yield while peduncle diameter، days to flowering، days to maturity and plant height for photosynthetic reservoir.
Keywords: *Triticum* aestivum, seed yield, Analysis of correlation coefficient, step-wise regression, path analysis.

Introduction

Ever since its domestication, wheat has been particularly important and been planted across a large extent of farms. It is a key cereal in many corners of the world, constituting the staple food of man around the globe (Shewry et.al, 2009; Rauf et.al, 2007). The wheat breeders are, thus, interested in attaining genotypes desirable in terms of the grain yield and other agricultural properties. To this aim, they may begin to choose from the first generations or postpone the process until the genotype will reach an advanced generation (Abdmishani and Jafari, 1997; Rosielle and Hamblin, 1981). Donald (1985) examined the relevant selection criteria for wheat by describing its desired types, maintaining that specifying a selection criteria was necessary in a yield enhancement program (Shanahan et.al., 1985). The grain yield in wheat is a function of the number of spikes per unit of area, number of grains in a spike, and the grain weight. The higher grain weight is a function of its filling rate and the longer duration of the process (Sofield et.al., 1997). In the meantime, the grain yield is positively correlated with the plant height, number of leaves, and the chaff weight. Also, the genetic correlation is high between the grain yield and grains in a spike, a thousand grain weight as well as the harvest index, also known as HI (Ibrahim, 1994). While the path analysis of common wheat, as of now *Triticum aestivum,* genotypes in India, grains per spike, a hundred grain weight, and the number of claws in the plant directly affected the grain yield. However, the plant height and duration of treatment were of direct negative effect on the grain yield (Mondal et.al., 1997).

Therefore, with the aim of investigating the genotypic correlation of various properties with the grain yield and specifying the best regression model in order to eliminate the ineffective properties and, consequently, path analysis, the present study aimed at determining the best selection indexes to genetically enhance the properties in question.

Materials and Methods

The experiment was conducted in the research farm of Kabootarabad station, Isfahan province, Iran in the agricultural year 2011-2012. In the course of the experiment 16 lines of *Triticum aestivum* along with two control cultivars, i.e. Parsi and Sivand, were examined. The experiment was conducted in the framework of basic randomized complete block design with three repetitions. The experimental terraces included 6 rows of shrubs with 2 meters length at 20cm line intervals (cultivation rows). The shrub intervals on cultivation rows were 4cm and the interval between experimental terraces was 40cm, and that between the repetitions was around 2m. The tillage operation was carried out in mid-September and pilot cultivation in mid-October after preparing the ground and early fertilization according to the guidelines by Soil and Water research Unit. The amount of grain for each cultivar was determined based on a thousand grain weight and 400 grains per square meter. The preparation involved mid-March plowing followed by disc harrowing, leveling, and terracing while the agricultural operation was done as usual and carefully. Moreover, the early irrigation was conducted during October 22-26, then, necessary care taken throughout the winter; afterwards killing the weed and major pests such as *Eurygaster integriceps* was done during the spring.

It is worth noting that our statistical population comprised of the middle section of the center lines of each plot, with the exclusion of peripheral effects. Analysis of correlation coefficients, stepwise regression, and path analysis by means of Davey and Lieu's (1959) method were among those carried out on the resultant values of the study. Also, all the statistical analyses were conducted via SAS, SPSS, and PATH software. The respective diagrams were drawn by means of Office Excel Software.

Results and Discussion

Analysis of Correlation Coefficients

The results of analysis of correlation coefficients for the properties were given in table 1. There is a negative significant correlation between the grain yield and number of number of number of grains per spike (0.58), and number of spikelets per spike (0.61). On the other hand, there exists a direct significant relationship between grain yield and spikes per square meter (0.66), biological yield (0.79), HI (0.79), and the grain filling rate (0.86) as well as protein yield (0.76).

Moreover, the results of correlation coefficient analysis was indicative of the fact that grain yield bore a direct significant relationship with spikes per square meter, biological yield, the HI, grain filling rate, and protein yield whereas its relationship with properties of number of number of number of grains per spike and number of spikelets per spike was reversely significant. It could be inferred that as the number of spikes rises, the biological yield, HI, and grain filling rate could genetically improve the grain yield in genotypes of *Triticum aestivum.*

Such a conclusion had been pointed out by Khan and Naghavi (2012), too. The findings by Richards (1996), Quarrie et.al. (1999), and Golparvar et.al. (2002) to a large extent did confirm such a conclusion for stress inducing conditions.

Table 1. Analysis of Correlation Coefficients for the Properties Measured in Genotypes of *Triticum aestivum*L (n=18)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
2	0.8																		
3	-.21	-.26																	
4	-.64	-.72	0.33																
5	-.04	-.41	0.19	0.35															
6	-.06	-.14	0.50	0.13	0.35														
7	-.07	-.13	0.51	0.44	0.36	0.98													
8	0.01	-.07	0.12	0.32	0.44	0.16	0.17												
9	0.39	0.36	-.16	-.15	-.05	-.68	-.69	0.07											
10	-.05	-.05	-.03	0.18	0.35	0.17	0.18	0.85	0.15										
11	-.07	0.02	-.28	-.25	-.14	0.03	0.14	-.26	0.16	0.29									
12	-.60	-.32	0.12	0.39	-.18	0.23	0.35	-.18	-.41	-.20	-.06								
13	0.28	0.11	-.23	0.10	-.02	-.58	-.61	-.04	0.66	-.10	-.09	-.23							
14	0.17	-.02	-.39	-.04	-.01	-.40	-.31	-.26	0.46	0.23	0.06	-.17	0.79						
15	-.52	-.67	0.21	0.79	0.55	0.13	0.15	0.54	-.18	0.40	-.23	0.28	0.05	0.07					

16	0.05	0.15	0.29	0.23	-.02	-.10	-.21	0.42	0.13	0.28	-.22	0.08	0.06	-.56	0.01				
17	-.28	0.35	-.10	-.15	-.59	-.12	-.15	-.11	-.03	-.01	0.15	0.41	0.26	0.29	-.25	0.15			
18	0.31	0.14	-.17	0.16	0.29	-.38	-.40	0.02	0.46	-.17	-.12	-.32	0.86	0.76	0.21	0.08	-.69		
19	-.13	0.11	0.06	0.06	0.14	-.10	-.11	0.27	0.16	0.13	-.33	0.28	0.24	0.16	0.16	0.08	0.38	0.01	
20	0.08	0.14	-.12	0.09	0.07	-.45	-.45	0.15	0.51	0.01	-.27	0.04	0.76	0.59	0.13	0.08	0.10	0.52	0.81

The properties tabulated above include: 1. Number of days until flowering; 2. Number of days until treatment; 3. Peduncle length; 4. Peduncle diameter; 5. Spike length; 6. Number of grains per spike; 7. Number of spikelets per spike; 8. Spike weight; 9. Number of spikes per square meter; 10. Spike yield; 11. Spike HI; 12. Grain weight; 13.Grain yield; 14. Biological yield; 15. Plant height; 16. HI; 17. Grain filling duration; 18. Grain filling rate; 19. Protein percentage; 20. Protein yield.

Apparently, the properties effective on grain yield could be identified using correlation coefficient analysis and utilized as indirect selection indexes, particularly in the preliminary generations. Of course, it is necessary that the selection indexes be capable of simple and inexpensive measurement and exhibit a high correlation with the yield. Furthermore, their narrow sense heritability must be far greater than the yield(Falconer, 2011; Fehr, 2011).

However, it seems that the grain weight shows a noticeable decrease with the rise in the number of grains per spike. That is, such a rise results in the competition between florets for photosynthetic substances, thus resulting in grain weight loss. Yet, a positive significant correlation was observed between the grain weight and the yield in the majority of the studies conducted so far in that it seems in normal conditions (without tension) the reduction in the number of grains per spike is compensated by the grain weight. So, in order to increase both the grain and protein yield it is necessary for the plant to have enough time to fill the grains besides increasing their number. In normal conditions, this is guaranteed by the number of days until further physiological treatment. Typically, this number has a positive significant correlation with that of grains per spike, constituting a further testimony to the above result. The finding was also referred to and emphasized by an array of researchers (Blum, 2011; Quarrie et.al., 1999; Mollasadeghi, 2011).

Analysis of Stepwise Regression

The analysis of stepwise regression was conducted by taking into account the grain yield as the dependent variable and the rest of properties as independent variables in *Triticum aestivum* genotype. The results of processing various linear regression models, as shown in Table 2, indicated that properties like the grain filling rate, grain filling duration, number of spikes per square meter, and peduncle length pose a significant effect on the model and, on the whole, accounted for 98% of the grain yield variations. The grain filing rate alone accounted for 74.1% of the variations, and then the grain filling duration, number of spikes per square meter, and the peduncle length secured 21.9%, 1%, and 1% of the grain yield variations, respectively as shown in Table 2.

Correlation of the properties just mentioned with the grain yield was equal to 0.861, -0.259, 0.659, and -0.227, respectively. However, only the correlation coefficient of grain filling rate and number of spikes per square meter with the grain yield was significant, still being insignificant for the grain filling duration and the peduncle length. The formula below could be proposed to express the relationship between the grain yield, as the dependent variable, and other properties taken account of in the model.

Grain yield = 30.4 grain filling rate+207.37 grain filling duration+1.42 number of spikes per square meter+ 373.76 peduncle length+ -8062.34

Moreover, the stepwise regression analysis of grain yield, i.e. the dependent variable, in contrast to the other properties taken as independent variables indicated that the grain filling rate, grain filling duration, number of spikes per square meter, and peduncle length accounted for much of the grain yield variations (98%), whereas the remaining properties had no significant effect on the grain yield regression model. Meanwhile, the grain filling rate accounted for 74.1% of the variations, thus, comprising much of the grain yield variations. That is to say, with the change in the amounts of this particular property and the choice for increasing its quantity we may expect the grain yield to be enhanced. It is worth mentioning that grain filling duration had a considerable portion in this case (21.9%). However, this is also verified by the findings by some other researchers (Subhashchandra, et.al, 2009; Gashaw, et.al, 2007). The extension of the duration and sufficient rate for grain filling provided the time needed to transfer to the florets the photosynthetic materials reserved in the peduncle. Consequently, together with the number of spikes and the peduncle length, these properties might better serve to improve the grain yield (Blum, 2011). Furthermore, with respect to the grain performance, the properties that had the greatest effect on the regression model, indeed, i.e. the grain filling rate, grain filling duration, peduncle length, and spike harvest index, also had the majority portion and positive coefficients. Improvement in the grain yield seems to be capable of increasing the protein yield as well (Subhashchandra, et.al., 2009; Gashaw, et.al., 2007; Simmonds, 1995).

Table 2. Stepwise Regression for Grain Yield (Dependent Variable) Compared to Other Properties (Independent Variables)

Variables Introduced into the Model	Regression Coefficient*	Standard Error	t Statistic	Degree of Probability	model coefficient
Grain Filling Rate	30.40	1.71	17.83	0.000	74.1
Grain Filing Duration	207.37	21.9	9.83	0.000	96.0
Number of Spikes per Square Meter	1.42	0.43	3.33	0.005	97.0
Peduncle Length	373.76	144.27	2.59	0.022	98.0
y-intercept	-8062.34	1168.45	-6.90	0.000	
* Regression coefficient values were t-tested in proportion to zero					

Path analysis

The results as to the grain yield path analysis, as shown in Table 3, indicated that grain filling rate, grain filling duration, number of spikes per square meter, and peduncle length were 1.22, 0.61, 0.17 and 0.12, respectively, having the utmost direct positive effect on the grain yield. Besides, the grain filling rate and number of spikes per square meter had positive significant correlation coefficients proportionate to the grain yield which were of the same symbol as their direct effect on this property (see Table 3).

Although the indirect effect of grain filing rate on the grain yield through the grain filling duration was a negative value (-0.42), in total, due to the sizable direct effect of this property, its correlation with grain yield was highly considerable (see Table 3). So, it is the best index for selection to improve the grain yield.

However, as for the number of spikes per square meter, despite the marginal positive effect it posed on the grain yield, as a consequence of its substantial indirect effect through grain filling rate on the grain performance, on the whole its correlation coefficient with the yield was highly considerable, as shown in table 3. Thus, it could constitute a reliable selection index with respect to enhancement of grain yield. Other properties had indirect negative effect where their effect on the grain yield via those properties was both negative and significant. Therefore, the choice for lower quantities of these properties might lead to enhancement in grain yield.

Moreover, the path analysis of the grain yield based on Davey and Lieu's (1959) method demonstrated that grain filling rate caused the largest direct positive effect on the grain yield while having the highest positive correlation coefficient with it. The considerable negative effect, though, it left on the grain yield particularly via grain filing rate caused its negative correlation coefficient with the grain yield.

Nonetheless, number of spikes per square meter has a direct positive but slight effect, but its indirect effect on the yield through grain filling rate is positive and significant. Peduncle length, besides negative correlation coefficient poses relatively large indirect negative effect on the grain yield, whereas its direct effect is positive. Thus, it appears that grain filling rate serves as the best indirect selection index in order to improve the grain yield in genotypes of *Triticum aestivum*. Besides, number of spikes per square meter is another property of relevance, especially if its indirect effects on the grain yield are taken into consideration parallel to its direct effect.

However, the grain filling duration and peduncle length did not constitute reliable selection indexes in this regard and, thus, were not recommendable. Amid this, similar results were attained by other researchers in this regard (Subhashchandra, et.al., 2009; Gashaw, et.al., 2007; Simmonds, 1995).

path analysis for protein yield as a dependent variable was also indicative of the highest direct positive effect that grain filling rate and grain filling duration had on the grain yield, although only the former's correlation coefficient with protein yield was significant. So, it seemed to be the best selection index to improve grain and protein yield in genotypes of *Triticum aestivum.* Other researchers reported similar results (Perry, 1989).

Nonetheless, using the path analysis, Moghaddam and colleagues (1997) reported a thousand grain weight and number of grains per spike to be the optimum indirect selection indexes for improving the grain yield in *Triticum aestivum.* Also, Ehdaie and Wianes (1989) proposed a thousand grain weight, number of grains per spike, and HI to that effect. Sidwell, et.al. (1976) emphasized the significance of the number of fertilized spikes in improving the grain yield.

Table 3. PathAnalysis of Grain Yield in Genotypes of Triticum aestivum*

Variables	Grain Filling Rate	Grain Filling Duration	Number of Spikes per Square Meter	Peduncle Length	E
Grain Filling Rate	1.22	-0.42	0.08	-0.02	0.861
Grain Filling Duration	-0.85	0.61	-0.01	-0.01	-0.260
Number of Spikes per Square Meter	0.56	-0.02	0.17	-0.05	0.658
Peduncle Length	-0.21	-0.06	-0.08	0.12	-0.227
Remainder	0.132				

* Numbers on the main diameter indicate the direct effect and others the indirect effect.

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