African Journal of Agricultural Research Vol. 7(15), pp. 2363-2371, 19 April, 2012
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.1821
ISSN 1991-637X ©2012 Academic Journals

Full Length Research Paper

Ontogenic approach to wheat yield components in six different rotation types

Hossein Ali Fallahi[1]*, Usmon Mahmadyorov[2], Hossein Sabouri[3], Massoud Ezat Ahmadi[4] and Atefeh Sabouri[5]

[1]Agriculture Research Center of Golestan-Agric. Res. Station of Gonbad, Golestan, Iran.
[2]Tajik Agrarian University, Tajikestan.
[3]Department of Plant Production, Collage of Agriculture Science and Natural Resource, Gonbad High Education Center, Golestan, Iran.
[4]Agricultural Research Center of Khorasan, Iran.
[5]Department of Agronomy and Plant Breeding, Collage of Agricultural Science, University of Guilan, Guilan, Iran.

Accepted 1 March, 2012

Grain yield in wheat, similar to other plants, is a complex trait that is directly and indirectly influenced by other plant's characteristics. One of the main goals in wheat breeding programs is to increase the grain yield. Considering the role of crop rotation in the increase of wheat yield, in order to study variations in direct and indirect effects in different rotations, an experiment was conducted with six rotation types as treatments, in six replications, as randomized complete block design. The six rotation types included: wheat-wheat-wheat (without rotation), wheat-canola-wheat, wheat-chickpea-wheat, wheat-cotton-wheat, wheat-watermelon-wheat and wheat-sunflower-wheat. This study was implemented during 2004 to 2009 in the north of Iran, at the research station of Gonbad in Golestan province of Iran. Also, at the end of trial, wheat was cultivated in all experimental units in 2010. The results showed although in all the rotations, the spike numbers in m^2, kernel number per spike and kernel weight were important traits determining grain yield, crop rotations affected on type and amount of direct and indirect effect of yield components. Furthermore, the selection of different traits depending on the rotation's condition can change in the selection. According to the results in wheat-wheat-wheat (without rotation) and wheat-watermelon-wheat and wheat-sunflower-wheat rotations, kernel weight, grain filling periods and vegetative period are useful for selection breeding strategy, while in wheat-canola-wheat and wheat-chickpea-wheat number kernel per spike, number spike, grain filling periods and vegetative period could be useful.

Key words: Breeding, grain yield, path analysis, selection.

INTRODUCTION

Crop rotation is one of the oldest and most effective cultural control strategies. Researchers paid more attention to crop rotation in the early 20th century and several studies on crop rotation had been performed (Campbell et al., 1983; Ehrenpfordt and Ronsch, 1973). The studies revealed that maintenance of crop residues, reduction of tillage, and crop rotation might help reduce soil erosion and increase crop yield (Freebairn et al., 1993). The selection of crops being used in rotation and their order in rotation should be in a way that in addition to enough flexibility to adapt to environmental conditions, it should meet the economical needs of farmers. Under some condition when the crop is not placed in a suitable

*Corresponding author. E-mail: hafallahi@gmail.com.

Abbreviations: VP, The length of vegetative period; **GEF,** duration of grain filling period; **S,** the number of spikes per square meter; **KS,** the number of kernels per spike; **KW,** mean kernel; **GY,** grain yield.

order, loss of yield might be compensated by N application (Ehrenpfordt and Ronsch, 1973). Crop rotation results in the reduction of weed problem and of chemical usage. It should be noticed that rotation do not eradicate weeds, but controls weed population (Zenter and Cambell, 1988). In other hand, one of the main goals in wheat breeding programs is increase of grain yield. Grain yield in wheat can be analyzed in terms of three main components: number of spikes per square meter, number of kernels per spike and kernel weight. These yield component appear sequentially with later developing components under control of earlier developing ones (Garcia del Moral et al., 1991, 2003; Hamid and Grafius, 1978). Tiller producing is the first developmental processes and it occurs during early growth (Garcia del Moral et al., 1991; Simane et al., 1993). Development of floral primordial takes place during the phase of rapid vegetative and floral organs may occur (Miralles et al., 2000). Later, grain filling is maintained by a high contribution from assimilation before and immediately after anthesis and remobilization of vegetative reverse during kernel growth (Bidinger et al., 1977; Royo et al., 1999). In order to increase grain yield, wheat breeders need to evaluate agronomic performance of breeding lines, need to indentify the cause of variability in grain yield (Gebeyehou et al., 1982), and need to define correlations among important traits and analyses indirect and direct effects of important plant traits on grain yield. This type of information also is useful for breeders to improve selection criteria in genetic manipulation.

Path coefficient analysis developed originally by Wright (1921) and elaborated by Dewey and Lu (1959) and others, has been used to determine the direct and indirect and to determine the interrelationship between grain yield and morphological characteristics in wheat. Path coefficient is a standardized partial regression coefficient, obtained from equations, where the yield related variables are expressed as deviations from the means in unit of standard deviation (Steel and Torrie, 1982). In theses analysis, seed yield and yield components are regarded as a system of interrelated variables, with yield components considered at the same ontogenetic level. The objective of this paper were: i) to examine means between six rotation type, ii) determination of effect of six rotation type on trait correlation, iii) to perform path coefficient analysis and divide correlation coefficient in direct and indirect effects using ontogenic approach in all rotation types, iv) to discuses interrelationship among wheat traits after six different rotation types.

MATERIALS AND METHODS

This experiment was conducted with six treatments (rotation types) in six replications as randomized complementary block design. Each of the rotation was assigned to one experimental unit and used six rotation types including wheat-wheat-wheat (Draya cultivar, without rotation), wheat-canola (Hayola401 cultivar)-wheat, wheat-chickpea (Arman cultivar)-wheat, wheat-cotton (Sahel cultivar)-wheat, wheat-watermelon (Charleston Grey cultivar)-wheat and wheat-sunflower (Hayson33 cultivar)-wheat. This study was implemented during 2004 to 2009 in north of Iran, at the research station of Gonbad in Golestan province of Iran. Also, at the end of trial wheat was cultivated in all experimental units, in 2010. The plot was 12 m^2 with 12 m long, consisting of 10 rows with 20 cm row spacing. The seeding rate was adjusted for a density of 350 viable seeds per square meter in the field. The sowing date was in at the end of November each year. 200 $kgha^{-1}$ Nitrogen fertilizer was applied at three stages (sowing, tillering and heading) and 200 $kgha^{-1}$ Phosphorous was applied at sowing stage. During the trail, six characteristics were measured consist of: 1) VP (the length of vegetative period) that was calculated as days from sowing to anthesis, 2) GEF (duration of grain filling period) was considered to be the days from anthesis to physiological maturity, 3) S (the number of spikes per square meter) was calculated by counting the spikes contained in 1 m of one of the central rows in each plot, 4) KS (the number of kernels per spike) was determined by counting kernels on every spike from a subsample of 10 plant selected from 1 m of row taken completely at random in each plot before harvest), 5) KW (mean kernel weight) was calculated from the weight of three sets of 300 kernels per plot, 6) GY (grain yield) was determined on the basis of the harvested plot in trail. The harvesting date was at the end of May each year. In order to apply path coefficient analysis, firstly, correlation coefficients were determined among traits for six rotation types, from the mean values over blocks and then the correlation coefficients were divided into direct and indirect effects using path coefficient analysis. Also, a cause-effect system based on the ontogeny of the wheat plant was constructed.

In the mentioned system, the number of spikes per square meter and the length of vegetative period are considered to have a mutual relationship. Furthermore, the two aforementioned traits could have a reciprocal influence at early stage of wheat growth. The causal system assumed as described in Garcia del Moral et al. (1991) was based on the ontogeny of the cereal plant (Figure 1). As shown in this figure, the duration of vegetative period affects the kernel per spike and the duration of grain filling period. In this system, tillers have a direct influence on other traits developed after tiller production. Besides, the duration of GEF could modify kernel per spike by reducing the abortion rate of pollinated florate after anthesis. According to this system, the following four sets of simultaneous equations were solved to determine the path coefficient:

$$r_{26} = P_{26} + r_{24}P_{46} + r_{25}P_{56}$$

$$r_{46} = r_{24}P_{26} + P_{46} + r_{45}P_{56}$$

$$r_{56} = r_{25}P_{26} + r_{45}P_{46} + P_{56}$$

$$r_{25} = P_{25} + r_{23}P_{35} + r_{24}P_{45}$$

$$r_{35} = r_{23}P_{25} + P_{35} + r_{34}P_{45}$$

$$r_{45} = r_{24}P_{25} + r_{34}P_{35} + P_{45}$$

$$r_{14} = P_{14} + r_{12}P_{24} + r_{13}P_{34}$$

$$r_{24} = r_{12}P_{14} + P_{24} + r_{23}P_{34}$$

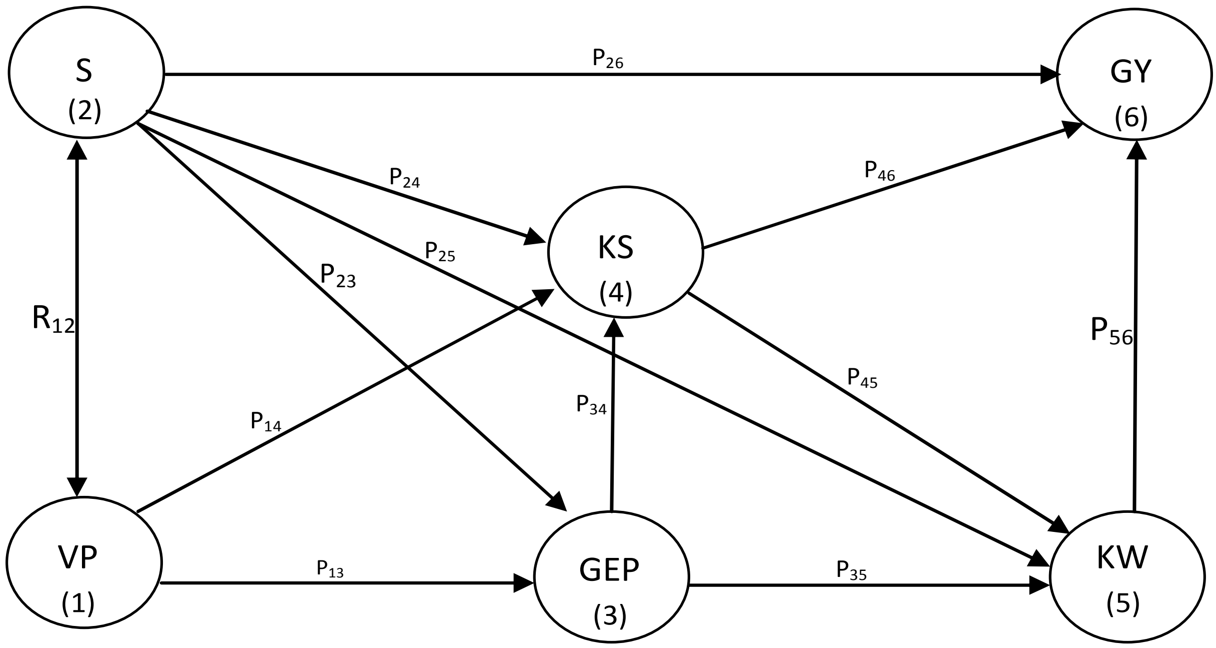

Figure 1. Pathways showing the cause-effect relationships among yield components and their effects on grain yield as described by Garcia del Moral et al. (1991), VP: the length of vegetative period, GEF: duration of grain filling period, S: the number of spikes per square meter, KS: the number of kernels per spike, KW: mean kernel weight, GY: grain yield and P presented as direct effects.

Table 1. Analysis of variance for studied traits.

Source of variation	Degree of freedom	Mean of square					
		Spike (m^{-2})	Kernels spike^{-1}	Kernels weight	Grain yield	Grain filling period	Vegetative period
rep	5	158.961	0.455	0.683*	12584.778	2.044	1.894*
Type of rotation	5	10034.027**	30.336**	7.712**	1987014.911**	3.311**	5.027**
Error	25	74.187	0.383	0.180	10683.11	0.351	0.707
CV		1.990	1.837	1.240	2.169	1.651	0.671

* and ** significant in 5 and 1% probability.

$$r_{34} = r_{13}P_{14} + r_{23}P_{24} + P_{34}$$

$$r_{13} = P_{13} + r_{12}P_{23}$$

$$r_{23} = r_{12}P_{13} + P_{23}$$

The data were analyzed using the PROC GLM procedure of SAS (1992).

RESULTS AND DISCUSSION

Analysis of variance

The analysis of variance revealed significant differences between rotation types for all evaluated traits (Table 1). Then in order to rank the different rotations, compare mean was used.

Compare means

LSD values were calculated at the 5% probability level. The compare mean was revealed, there are three ranks between six rotations so that wheat-chickpea-wheat followed by wheat-cotton-wheat and wheat-watermelon-wheat without significant difference and that had the highest number of spike per m^2. The rotation of wheat-sunflower-wheat owns the lowest spike number in m^2 (Figure 2). There was no significant difference between wheat-cotton-wheat and wheat-watermelon-wheat rotation

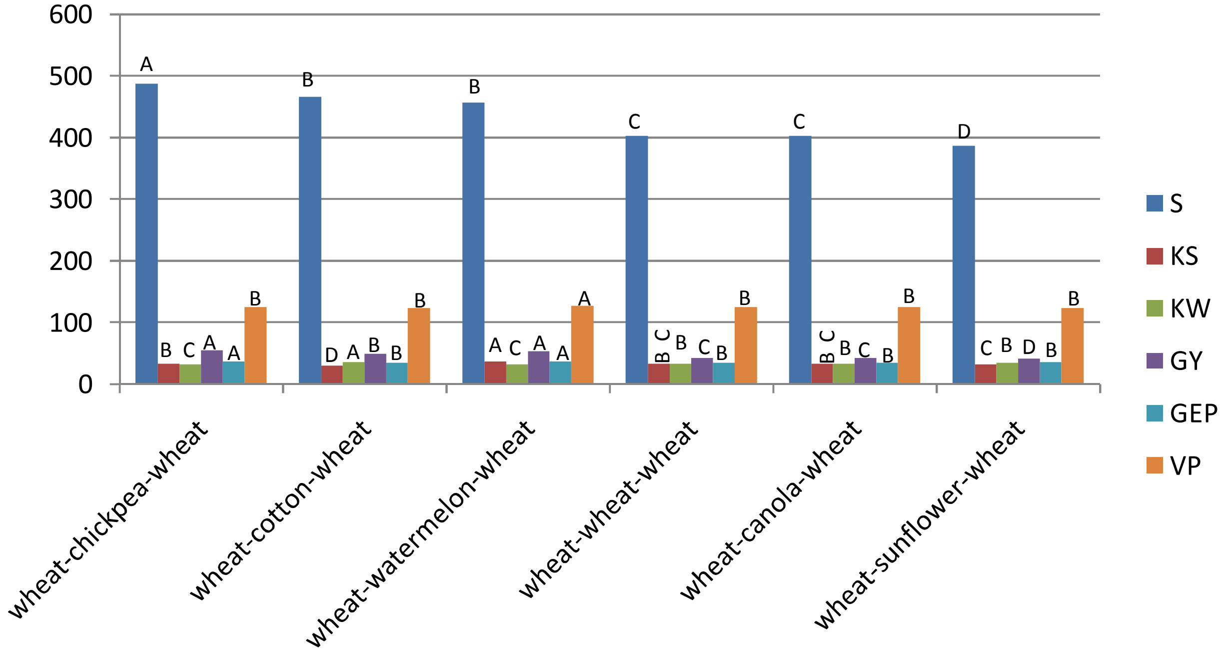

Figure 2. Compared means of six rotation types for studied traits. S: the number of spikes per square meter; KS: the number of kernels per spike; KW: mean kernel weight; GY: grain yield; GEF: duration of grain filling period; VP: the length of vegetative period.

types on spike per square meter and there were also no significant differences between wheat-wheat-wheat and wheat-canola-wheat rotation types on spike m^{-2}. Regarding the number of kernels per spike and kernels weight, there were significant deference between rotation types so that wheat-watermelon-wheat and wheat-cotton-wheat rotations had the first order from the point of view of these traits, respectively. Not only did wheat-chickpea-wheat and wheat-watermelon-wheat significantly produce the highest grain yield that could result from fixation of nitrogen in two years ago, but the mentioned rotations had longest period of grain filling as well. However, there was no significant difference between wheat-wheat-wheat and wheat-canola-wheat in viewpoint all traits.

Overall, it was concluded from the means comparison with the wheat-watermelon-wheat and wheat-chickpea-wheat showed relatively more effective performance than other rotations.

Correlations

Pearson correlation was calculated between different traits for all rotation types (Table 2). This analysis showed correlation coefficients of grain yield with grain filling period and vegetative period are positive, strong and significant in all rotation types. Obviously, grain filling period could increase kernel weight which subsequently would result in increasing of grain yield, which seemed to cause positive correlations between them in all rotation types. Also, a longer vegetative period producing stronger plant which certainly would has a positive effect on the reproductive stage. In other words, these traits could increase photosynthetic time and assimilation time in ripening stage which subsequently would result in grain yield increase which seems to cause positive correlation between them confirming previous reports (Garcia del Moral et al., 2003, 2005; Hafiz and Nayeem, 2010; Khan et al., 2010).

Path analysis

Path coefficient analysis provides information on internal relation among evaluated traits as well as their effects on certain traits. Path coefficient analysis is also applied as an effort to assess the contribution magnitude of various agro morphological characters to grain yield in the form of causes and effect. In addition from the path analysis, it was possible to rank plant characteristics according to their effect on grain yield. The path analysis showed kernel weight, grain filling period, grain filling period and vegetative period as the main contributors to grain yield, kernel weight, kernel per spike and grain filling period, in pathway 1 to 4 respectively (Tables 3 to 6). Result of path analysis on different rotation types are as follows:

Wheat-wheat-wheat rotation

In this rotation spikes per square meter and kernel weight

Table 2. Pearson correlation coefficient for traits in six rotation types.

		Spike (m^{-2})	Kernels $spike^{-1}$	Kernels weight	grain yield	Grain filling period	Vegetative period
Wheat-wheat-wheat	Spike m^{-2}	1					
Wheat-canola-wheat	Spike m^{-2}	1					
Wheat-chickpea-wheat	Spike m^{-2}	1					
Wheat-cotton-wheat	Spike m^{-2}	1					
Wheat-watermelon-wheat	Spike m^{-2}	1					
Wheat-sunflower-wheat	Spike m^{-2}	1					
Wheat-wheat-wheat	Kernels $spike^{-1}$	-0.608	1				
Wheat-canola-wheat	Kernels $spike^{-1}$	-0.324	1				
Wheat-chickpea-wheat	Kernels $spike^{-1}$	0.581	1				
Wheat-cotton-wheat	Kernels $spike^{-1}$	-0.053	1				
Wheat-watermelon-wheat	Kernels $spike^{-1}$	-0.323	1				
Wheat-sunflower-wheat	Kernels $spike^{-1}$	-0.724	1				
Wheat-wheat-wheat	Kernels weight	-0.438	0.576	1			
Wheat-canola-wheat	Kernels weight	0.382	-0.579	1			
Wheat-chickpea-wheat	Kernels weight	-0.546	-0.722	1			
Wheat-cotton-wheat	Kernels weight	-0.363	0.223	1			
Wheat-watermelon-wheat	Kernels weight	0.278	-0.259	1			
Wheat-sunflower-wheat	Kernels weight	-0.721	0.357	1			
Wheat-wheat-wheat	grain yield	0.147	-0.082	0.712	1		
Wheat-canola-wheat	grain yield	-0.224	0.153	-0.060	1		
Wheat-chickpea-wheat	grain yield	-0.534	0.282	-0.054	1		
Wheat-cotton-wheat	grain yield	-0.416	-0.552	-0.117	1		
Wheat-watermelon-wheat	grain yield	0.485	-0.696	0.637	1		
Wheat-sunflower-wheat	grain yield	0.284	-0.637	0.351	1		
Wheat-wheat-wheat	Grain filling period	0.011	0.229	0.880*	0.896*	1	
Wheat-canola-wheat	Grain filling period	-0.413	0.503	-0.161	0.903*	1	
Wheat-chickpea-wheat	Grain filling period	-0.278	0.553	-0.147	0.935**	1	
Wheat-cotton-wheat	Grain filling period	-0.341	-0.608	0.228	0.887*	1	
Wheat-watermelon-wheat	Grain filling period	0.283	-0.348	0.534	0.858*	1	
Wheat-sunflower-wheat	Grain filling period	0.209	-0.389	0.257	0.844*	1	
Wheat-wheat-wheat	Vegetative period	0.099	-0.121	0.689	0.923**	0.898*	1
Wheat-canola-wheat	Vegetative period	-0.061	0.260	-0.403	0.887*	0.759	1
Wheat-chickpea-wheat	Vegetative period	-0.718	-0.095	0.254	0.894*	0.728	1
Wheat-cotton-wheat	Vegetative period	-0.381	-0.567	-0.069	0.868*	0.707	1
Wheat-watermelon-wheat	Vegetative period	0.313	-0.486	0.349	0.893*	0.891*	1
Wheat-sunflower-wheat	Vegetative period	-0.122	-0.277	0.716	0.890*	0.707	1

* and ** significant at 0.05 and 0.01, respectively.

had positive direct effects on grain yield in wheat-wheat-wheat rotation. Only indirect effect of spike per square meter through kernel weight was negative and it outweighed direct effect. Moreover, correlation analysis showed negative grain filling period influence on kernel weight, whereas path analysis revealed a positive relationship between two traits in accordance with previous studies (Garcia del moral et al., 2003, 2005) and negative correlation were due to indirect effect through spike per square meter and kernel per spike. Grain filling period and kernel per spike had positive direct effects on kernel weight. Obviously, duration of grain filling period modify kernel weight by increasing reproductive stage and photosynthesis in accordance with previous reports (Garcia del moral et al., 2003, 2005; Hafiz and Nayeem, 2010).

Wheat-canola-wheat rotation

Among yield components, path analysis showed that kernel per spike had the highest positive direct effect on

Table 3. Path coefficients for the grain yield of wheat grown after six rotation types' fields.

Pathway 1	A	B	C	D	E	F
Spikes m^{-2} vs. grain yield						
Direct effect, P_{26}	0.318	-0.219	-1.048	-0.510	0.193	0.560
Indirect effect via						
Kernels $spike^{-1}$,$r_{24}P_{46}$	0.344	-0.047	0.533	0.028	0.166	0.416
Kernels weight,$r_{25}P_{56}$	-0.515	0.041	-0.019	0.066	0.125	-0.692
Correlation, r_{26}	0.147	-0.224	-0.534	-0.416	0.485	0.284
Kernels $spike^{-1}$ vs. grain yield						
Direct effect, P_{46}	-0.566	0.144	0.917	-0.539	-0.517	-0.575
Indirect effect via						
Spike m^{-2}, $r_{24}P_{26}$	0.193	0.071	-0.609	0.027	-0.062	0.342
Kernels weight,$r_{45}P_{56}$	0.678	-0.062	-0.025	-0.040	-0.116	-0.405
Correlation, r_{46}	-0.082	0.153	0.282	-0.552	-0.696	-0.637
Kernels weight vs. grain yield						
Direct effect, P_{56}	1.177	0.107	0.035	-0.182	0.450	0.960
Indirect effect via						
Spike m^{-2}, $r_{25}P_{26}$	-0.139	-0.084	0.572	0.185	0.053	-0.404
Kernels $spike^{-1}$,$r_{45}P_{46}$	-0.326	-0.083	-0.662	-0.120	0.133	-0.205
Correlation, r_{56}	0.712	-0.060	-0.054	-0.117	0.637	0.351

A: Wheat-wheat-wheat, B: Wheat-canola-wheat, C: Wheat-chickpea-wheat, D: Wheat-cotton-wheat, E: Wheat-watermelon-wheat and F: Wheat-sunflower-wheat.

Table 4. Path coefficients for the Kernel weight of wheat grown after six rotation types' fields.

Pathway 2	A	B	C	D	E	F
Spike m^{-2} vs. Kernel weight						
Direct effect, P_{25}	-0.340	0.294	0.623	-0.175	0.126	-0.914
Indirect effect via						
Grain filling period, $r_{23}P_{35}$	0.009	-0.112	-0.250	-0.161	0.136	0.081
Kernels $spike^{-1}$,$r_{24}P_{45}$	-0.113	0.201	-0.918	-0.026	0.016	0.111
Correlation, r_{25}	-0.438	0.382	-0.546	-0.363	0.278	-0.721
Grain filling period vs. Kernel weight						
Direct effect, P_{35}	0.842	0.273	0.900	0.473	0.481	0.388
Indirect effect via						
Spike m^{-2}, $r_{23}P_{25}$	0.001	-0.121	-0.173	0.059	0.035	-0.191
Kernels $spike^{-1}$,$r_{34}P_{45}$	0.040	-0.312	-0.874	-0.304	0.018	0.060
Correlation, r_{35}	0.880	-0.161	-0.147	0.228	0.534	0.257
Kernels $spike^{-1}$ vs. Kernel weight						
Direct effect, P_{45}	0.176	-0.621	-1.581	0.500	-0.051	-0.154
Indirect effect via						
Spike m^{-2}, $r_{24}P_{25}$	0.206	-0.095	0.362	0.009	-0.041	0.662
Grain filling period, $r_{34}P_{35}$	0.193	0.137	0.498	-0.287	-0.167	-0.151
Correlation, r45	0.576	-0.579	-0.722	0.223	-0.259	0.357

A: Wheat-wheat-wheat, B: Wheat-canola-wheat, C: Wheat-chickpea-wheat, D: Wheat-cotton-wheat, E: Wheat-watermelon-wheat and F: Wheat-sunflower-wheat.

Table 5. Path coefficients for the Kernels spike^{-1}of wheat grown after six rotation types' fields.

Pathway 3	**A**	**B**	**C**	**D**	**E**	**F**
Vegetative period vs. Kernels spike^{-1}						
Direct effect, P_{14}	-1.461	-0.250	-0.473	-0.374	-0.798	-0.433
Indirect effect via						
Spike m^{-2}, $r_{12}P_{24}$	0.047	0.003	-0.382	0.134	-0.060	0.097
Grain filling period, $r_{13}P_{34}$	1.388	0.506	0.761	-0.328	0.371	0.059
Correlation, r_{14}	-0.121	0.260	-0.095	-0.567	-0.486	-0.277
Spike m^{-2} vs. Kernels spike^{-1}						
Direct effect, P_{24}	-0.480	-0.063	0.532	-0.354	-0.192	-0.794
Indirect effect via						
Vegetative period, $r_{12}P_{14}$	-0.145	0.015	0.340	0.142	-0.249	0.053
Grain filling period, $r_{23}P_{34}$	0.017	-0.275	-0.290	0.158	0.118	0.017
Correlation, r_{24}	-0.608	-0.324	0.581	-0.053	-0.323	-0.724
Grain filling period vs. Kernels spike^{-1}						
Direct effect, P_{34}	1.546	0.667	1.045	-0.463	0.417	0.084
Indirect effect via						
Vegetative period, $r_{13}P_{14}$	-1.312	-0.190	-0.344	-0.264	-0.711	-0.306
Spike m^{-2}, $r_{23}P_{24}$	-0.005	-.026	-0.148	0.120	-0.054	-0.166
Correlation, r_{34}	0.229	0.503	0.553	-0.608	-0.348	-0.389

A: Wheat-wheat-wheat, B: Wheat-canola-wheat, C: Wheat-chickpea-wheat, D: Wheat-cotton-wheat, E: Wheat-watermelon-wheat and F: Wheat-sunflower-wheat.

Table 6. Path coefficients for the grain filling period of wheat grown after six rotation types' fields.

Pathway 4	**A**	**B**	**C**	**D**	**E**	**F**
Vegetative period vs. Grain filling period						
Direct effect, P_{13}	0.905	0.737	1.090	0.675	0.890	0.744
Indirect effect via						
Spike m^{-2}, $r_{12}P_{23}$	-0.007	0.022	-0.363	0.032	-0.001	-0.037
Correlation, r_{13}	0.898	0.759	0.728	0.707	0.893	0.707
Spike m^{-2} vs. Grain filling period						
Direct effect, P_{23}	-0.079	-0.368	0.505	-0.084	0.005	0.300
Indirect effect via						
Vegetative period, $r_{12}P_{13}$	0.089	-0.045	-0.782	-0.257	0.278	-0.091
Correlation, r_{23}	0.011	-0.413	-0.278	-0.341	0.283	0.209

A: Wheat-wheat-wheat, B: Wheat-canola-wheat, C: Wheat-chickpea-wheat, D: Wheat-cotton-wheat, E: Wheat-watermelon-wheat and F: Wheat-sunflower-wheat.

grain yield followed by kernel weight. Although, spike per square meter had the highest negative direct effect on grain yield but its indirect effect through kernel weight was positive and also among kernel weight component, spike per square meter had the highest positive direct effect on kernel weight. As well as indirect effects through kernel per spike was positive. Similar to the pervious rotation grain filling period had positive influence on kernel weight and also this fact were repeated in other rotations but in here correlation analysis indicated negative effect of this trait on kernel weight. Among kernel per spike components, grain filling period had the highest positive direct effect on kernel per spike. The positive association of vegetative period with kernel per spike was due to the fact that an increase in vegetative period leads to an increase in grain filling, consequently, increasing the kernel per spike, whereas a negative direct effect was revealed by the path coefficient analysis. Regarding grain filling period components, similar to the all rotations vegetative period had highest positive influence on grain filling period and with respect to the importance of this trait in accordance with previous studies (Garcia del moral et al., 2003, 2005; Hafiz and Nayeem, 2010; Khan et al., 2010); it seems vegetative period is one of the important traits in determining yield.

Wheat-chickpea-wheat rotation

In this rotation in agreement with many previous reports (Garcia del moral et al., 2003, 2005; Hafiz and Nayeem, 2010; Khan et al., 2010; Singh et al., 2010) path analysis revealed the knowledge of correlation alone misleading in some cases including direct effect of grain filling period on kernel weight that path analysis showed a high positive effect as a slight increase in this trait may directly contributes to kernel weight whereas correlation observed was negative and other case regarding to role of spike per square meter on the kernel weight that direct effect was opposite of correlation result so that indirect effect of spike per square through kernel per spike was responsible for its negative association with kernel weight. Also, in addition to direct effect of vegetative period on grain filling period, spike per square meter had a direct positive influence on grain filling period that this fact has not shown by correlation analysis. In other hand spike per square meter and kernel per spike had a high negative influence on grain yield and kernel weight respectively therefore in this rotation selection on the base of spike per meter probably could not be beneficial in increasing of yield.

Wheat-cotton-wheat rotation

This rotation showed obvious differences with other rotations so that path coefficient analysis revealed all grain yield components including spike per square meter, kernel per spike and kernel weight had negative direct effect on grain yield. In addition, the vegetative periods, spike per square meter and grain filling period had negative effects on kernel per spike. Therefore, selection for mentioned traits would not improve grain yield and kernel per spike. However, a considerable portion of variation belonged to residual and it is necessary to conduct trail over years and places to estimate the genotype × environment interaction and estimation of unbiased experimental error (Ehdaie et al., 1999; Ashraf et al., 2001). In other hand, two kernel weights components; grain filling period and kernel per spike provided a positive direct contribution to kernel weight and the same of all other rotations vegetative period had a positive influence on grain filling period.

Wheat-watermelon-wheat rotation

Direct effects obtained in the path analysis showed that spike per square meter and kernel weight had positive direct effect on grain yield unlike kernel per spike therefore it seems in this condition selection based on the kernel per spike could not be beneficial to improve grain yield. In addition, direct contribution of grain filling period was positive on kernel weight therefore could be a promising trait in increasing kernel weight and consequently grain yield in this condition. Importance of grain filling period was reported in previous studies (Garcia del moral et al., 2003, 2005; Hafiz and Nayeem, 2010).

Wheat-sunflower-wheat rotation

Similar to former rotation in the pathway 1, the direct influences of spike per square meter and specially kernel weight were positive and could be considered in selection for grain yield in this condition. In the pathway 2, the direct effect of grain filling period was positive on kernel weight therefore similar to wheat-watermelon-wheat condition, this means that increase in grain filling period may directly contributes to kernel weight and indirectly to grain yield. This probably resulted from increased photo-synthesis when grain filling occurs in accordance with previous studies (Van Oosterom and Acevedo, 1992; Garcia del moral et al., 2003). Obviously, path coefficient analysis results are not only useful to wheat breeders but also noticed to all wheat researchers. Our study demonstrated spike per square meter, kernel weight, grain filling period and vegetative period were the most important factors and had compensatory nature in preceding stable and high yield that agrees with results of previous studies (Garcia del moral et al., 2003, 2005; Hafiz and Nayeem, 2010; Khan et al., 2010; Singh et al., 2010). In addition, it has been indicated grain filling period to be important grain yield determining character under all studied conditions, but environmental effects (rotation types in last years ago) had determining role on these yield components. Therefore, in per situation, different traits would be useful in the selection.

So that in wheat-wheat-wheat, wheat-watermelon-wheat and wheat-sunflower-wheat rotation, kernel weight, grain filling periods and vegetative period and in wheat-canola-wheat and wheat-chickpea-wheat kernel per spike, grain filling periods and vegetative period are useful for selection breeding strategy, respectively.

Conclusion

Crop rotation in a suitable order increase crop yield but when the crop is not placed in a suitable order, yield might decrease due to lack or overdose of essential macro and micro elements. Moreover, crop rotation effects on associations among yield with components. The results of this study indicated that crop rotation can change type and amount of direct and indirect effect of yield components and the selection of different traits depending on the rotation's condition can change in the selection. According to result, it could be concluded that selection strategy according to trait depends on the type of planting conditions in the past year.

REFERENCES

Ashraf M, Qureshi AG, Khan NA (2001). Genotype-environment interaction in wheat. J. Biol. Sci., 1: 356-367.

Bidinger FR, Musgrave RB, Fischer RA (1977). Contribution of stored preanthesis assimilates to grain yield in wheat and barley. Nature, 270: 431-433.

Campbell CA, Moulin AP, Curtin D, Lafond GP, Townley-Smith L (1983). Soil aggregation as influenced by cultural practices in Saskatchewan: Black Chernozemic. Soil Sci., 73: 579-595.

Dewey DR, Lu KH (1959). A correlation and path coefficient analysis of components of crested wheat grass and seed production. Agron. J., 51: 515-518.

Ehdaie B, Shakiba MR, Giles Waines J (1999). Path analysis of genotype × environment interactions of wheats to nitrogen. Agronomy. 19: 45-56.

Ehrenpfordt V, Ronsch H (1973). Controlling crop rotation effects by using nitrogen fertilization as a measure of intensification. Archive fur Acker und Pflanzenbau und Bodendunde. 17: 435-440.

Freebairn DM, Loch RJ, Cagle AL (1993). Tillage methods and soil water conservation in Australia. Soil Tillage Res., 27: 303-325.

Garcia-del Moral LF, Ramos JM, Garcia-del Moral MB, Jimenez T (1991). Ontogenetic approach to grain production in spring barley based on path coefficient analysis. Crop Sci., 31: 1179-1185.

Garcia-del Moral LF, Rharrabti Y, Villegas D, Royo C (2003). Evaluation of grain yield and its components in durum wheat under Mediterranean conditions: An ontogenic approach. Agron. J., 95: 266-274.

Garcia-del Moral LF, Rharrabti Y, Martos V, Royo C (2005). Yield Formation in Mediterranean durum wheats under two contrasting water regimes based on path-coefficient analysis. Euphytica, 146: 203-212.

Gebeyehou G, Knott DR, Baker RJ (1982). Relationships among durations of vegetative and grain filling phases, yield components and grain yield in durum wheat cultivars. Crop Sci., 22: 287-290.

Hafiz KM, Nayeem Dar A (2010). Correlation and path coefficient analysis of some quantitative traits in wheat. Afric. Crop Sci. J., 18: 9-14.

Hamid ZA, Grafius JE (1978). Developmental allometry and its amplication to grain yield in barely. Crop Sci. 18: 83-86.

Khan AJ, Azam F, Ali A (2010). Relationship of morphological traits and grain yield in recombinant inbred wheat lines grown under drought conditions. Pak. J. Bot., 42: 259-267.

Miralles DJ, Richards, RA, Slafer GA (2000). Duration of the stem elongation period influences the number of fertile in wheat and barley. Aust. J. Plant Physiol., 27: 931-940.

Royo C, Voltas J, Romagosa I (1999). Remobilization of preanthesis assimilates to the grain for grain only and dual-purpose (forage and grain) triticale. Agron. J., 91: 312-316.

SAS Institute (1992). STAT Guide for personal computers. 704 p. 8th ed. SAS Institute, Cary, North Carolina, USA.

Simane B, Struik PC, Nachit MM, Peacock JM (1993). Ontogenic analysis of field components and yield stability of durum wheat in water-limited environment. Euphytica. 71: 211-219.

Singh BN, Vishwakarma SR, Singh, VK (2010). Character association and path analysis in elite lines of wheat (*Triticum Aestivum* L.). Plant Archives, 10: 845-847.

Steel RG, Torrie JH (1982). Principles and procedures of statistics: A biometrical approach. 2nd End McGraw-Hill Int Book Co, Tokyo, Japan.

Van Oosterom EJ, Acevedo E (1992). Adaptation of barley (*Hordeum vulgare* L.) to harsh Mediterranean environments: III. Plant ideotype and grain yield. Euphytica, 62: 29-38.

Wright S (1921). Correlation and causation. J. Agric. Res., 20: 557-585.

Zenter RP, Campbell CA (1988). First 18 years of a long-term crop rotation study in southwestern Saskatchewan-yields, grain protein and economic performance. Can. J. Plant Sci., 68(1): 1-21.