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Correlation between grain yield and yield components in winter barley varieties

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Abstract. *The objective of this study was to determine the correlation between yield and its components and their direct and indirect effects on grain yield in two-row winter barley varieties. The experimental work was conducted during the period of 2012-2014 on the research fields of the Faculty of Agriculture, in two different areas in the Republic of Macedonia, Ovche Pole and Strumica. As far as material is concerned, 21 genotypes were used with Macedonian, Serbian, Croatian and Bulgarian origin. Significant and positive coefficient of correlations were obtained between grain yield and number of spike per m^2, number of productive tillers per plant and grain weight per plant, number of grain per spike and grain weight per spike, grain weight per spike and 1000 grains weight in both localities. The highest direct effect to grain yield was obtained by number of spikes per m^2 in both localities. Therefore, this trait can be used as a criterion in breeding to improve the yield of barley varieties.*

Keywords: correlation, yield, path coefficient analysis, barley

Introduction

Barley is one of the most important crops because it's used as raw material in beer production and animal feed, cultivated successfully in a wide range of climate. Grain yield is a complex quantitative trait controlled by a large number of genes and is highly influenced by environmental, morphological and physiological characters. Grain yield in barley, like other crops, is a function of many traits which have interrelation among themselves and affect the grain yield directly or indirectly.

Correlation coefficient and path coefficient analyses are used widely in many crop species by plant breeders to define the nature of complex interrationships among yield components (Dofing and Knight, 1994; Hosin Babaiy et al., 2011; Al-Tabbal and Al-Fraihat, 2012). Correlation coefficient is very important to determine the traits that directly affect the grain yield. The path coefficient analysis is one of the statistical tools which is used to determine the direct or indirect effects of any yield component on grain yield in relation to the other yield components. Correlation coefficient and path coefficient analysis assist to identify the traits that are useful as selection criteria to improve yield (Singh 1987; Milomirka et al., 2005; Drikvand et al., 2011; Khaiti, 2012).

Some studies reported that grain yield was determined by three yield components, spike number per m^2, number of grain per spike and grain weight per spike (Grafius, 1964; Fathi and Rezaie, 2000). On the other hand, Singh et al. (1987) found that grain yield in barley significantly correlated with plant height and this component had high positive direct effects on yield. Some researchers reported positive and significant correlation between plant height and grain yield (Kisana et al., 1999; Bhutta et al., 2005; Jabbari at al., 2010; Biroland Necmettin, 2011; Niazi-Fard et al., 2012). In many studies, it has been shown that the number of spike in m^2 has a positive direct effect on grain yield (Jabbari at al., 2010; Drikvand et al., 2011). Akdeniz et al. (2004) observed positive and significant correlation between grain yield and number of spike per m^2. Significant positive correlation was determined between grain number per spike and weight of grains per spike (Dyulgerova, 2012).

The aim of this study was to determine the correlation between yield and its components and their direct and indirect effects on grain yield in winter two-row barley genotypes.

Material and methods

The experiment was carried out during the period 2012 – 2014 in the research fields of the Faculty of Agriculture, "Goce Delchev" University in two localities in the Republic of Macedonia. The first one was Ovche Pole with altitude between 200 – 400 m and soil type smolnica and the other one was Strumica with 280 m altitude with alluvial soil type. Compared to Strumica location, Ovche Pole locality is characterized by lower average temperatures and lower amount of rainfall as well. The average monthly values for the temperature and rainfall in the period when this research took place did not differ significantly, compared to the general long-term weather data for both of the regions.

In total 21 two-row winter barley genotypes were used in this study. Five of them are Macedonian (Hit, Izvor, Egej, Line 1 and Line 2), two varieties are Serbian (NS 525 and NS 565), two varieties are Croatian (Zlatko and Rex) and the other 12 varieties are with Bulgarian origin (Obzor, Perun, Emon, Lardeya, Orfej, Imeon, Zagorec, Asparuh, Kuber, Sajra, Devinija andOdisej).

The experiment was conducted in a randomized block design with three replications. Each replication plot had 1 m^2, consisted of 10 rows and the amount of cultivated seed was evaluated at 500 seeds per m^2. The seeds were hand sown 3 to 5 cm deep on the same day in both localities. The method of setting up the experiment was the same in both localities. The standard growing measures were applied during the vegetation. During the study period phonological phase, degree of lodging and diseases were recorded. Then plant samples were randomly chosen from the middle part of each replication plot from both localities. Plants were evaluated for traits including: number of spikes m^2, plant height (cm), total tillers

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number per plant, number of productive tillers per plant, spike length (cm), number of grain per spike, number of sterile spikelets per spike, grain weight per spike (g), grain weight per plant (g) and 1000 grains weight (g).

Correlation between yield and components of yield, coefficient of variation and path coefficient analysis were performed using SSPS.

Table 1. Average, minimum, maximum and coefficient of variation for examined traits of barley varieties in both localities

Locality		Number of spikes, m^2	Plant height, cm	Total tiller number per plant	Number of productive tillers per plant	Spike length, cm	Number of grains per spike	Number of sterile spikelets per spike	Grain weight per spike, g	Grain weight per plant, g	1000 grains weight, g	Yield, kg/ha
Ovche Pole	Average	673	104	18	8	8.5	27	2	1.28	9.53	47.30	4282
	Min.	567	99	14	7	7.2	26	1	1.23	7.54	45.93	3120
	Max.	776	110	20	9	9.5	29	3	1.38	10.65	49.63	5277
	CV, %	8.56	3.19	7.12	8.78	7.77	2.57	23.32	3.15	8.64	1.82	13.51
Strumica	Average	711	102	18	9	8.6	27	1	1.27	9.93	46.37	4863
	Min.	590	98	16	8	7.3	26	1	1.20	8.43	42.86	3423
	Max.	811	109	20	10	10.0	29	3	1.39	11.26	48.57	5821
	CV, %	9.57	3.18	7.11	7.29	8.60	2.55	49.46	4.36	6.93	3.18	14.11

Table 2. Correlation coefficient between yield and components of yield of barley varieties from locality Ovche Pole

Components of yield	NS m^2	PH	TTNP	NPTP	SL	NGS	NSSS	GWS	GWP	1000 GW	Y
Number ofspikes, m^2 (NS m^2)	1	0.437*	-0.020	0.112	0.127	-0.473	-0.129	-0.480*	0.166	-0.155	0.936**
Plant height (PH)		1	0.415	0.337	-0.222	-0.126	0.087	-0.109	0.303	-0.007	0.452*
Total tiller number per plant (TTNP)			1	0.500*	-0.146	-0.111	-0.026	0.152	0.363	0.436*	0.047
Number of productive tillers per plant (NPTP)				1	-0.422	-0.070	-0.286	-0.033	0.919**	0.047	0.123
Spike length (SL)					1	-0.034	0.120	-0.085	-0.475	-0.093	0.119
Number of grains per spike (NGS)						1	0.480	0.826**	-0.009	-0.006	-0.207
Number of sterile spikelets per spike (NSSS)							1	0.342	-0.249	-0.102	-0.015
Grain weight per spike (GWS)								1	0.036	0.559**	-0.142
Grain weight per plant (GWP)									1	0.079	0.209
1000 grains weight (1000 GW)										1	0.055
Yield (Y)											1

*, ** Statistical significance at P<0.05 and P<0.01.

Table 3. Correlation coefficient between yield and components of yield of barley varieties from locality Strumica

Components of yield	NS m^2	PH	TTNP	NPTP	SL	NGS	NSSS	GWS	GWP	1000 GW	Y
Number of spikes, m^2 (NS m^2)	1	0.260	0.131	0.107	0.109	-0.339	-0.110	-0.367	0.196	-0.228	0.901**
Plant height (PH)		1	0.464*	-0.122	-0.325	-0.304	0.270	-0.070	0.297	0.147	0.238
Total tiller number per plant (TTNP)			1	0.239	0.017	0.029	0.141	0.140	0.583**	0.168	0.210
Number of productive tillers per plant (NPTP)				1	0.365	0.116	-0.414	-0.028	0.569**	-0.121	0.118
Spike length (SL)					1	0.184	-0.293	0.043	-0.051	-0.082	0.139
Number of grains per spike (NGS)						1	0.183	0.685**	0.043	0.151	-0.059
Number of sterile spikelets per spike (NSSS)							1	0.240	0.064	0.184	-0.021
Grain weight per spike (GWS)								1	0.320	0.823**	0.072
Grain weight per plant (GWP)									1	0.407	0.376
1000 grains weight (1000 GW)										1	0.149
Yield (Y)											1

*, ** Statistical significance at P<0.05 and P<0.01.

Table 4. Path coefficient analysis showing the direct and indirect effect of yield components on grain yield in locality Ovche Pole

Components of yield	Direct effect	Indirect effect										Total indirect effect
		NS m^2	PH	TTNP	NPTP	SL	NGS	NSSS	GWS	GWP	1000 GW	
Number of spikes, m^2 (NS m^2)	1.1188530		0.4889388	-0.0223771	0.1253115	0.1420943	-0.5292175	-0.1443320	-0.5370494	0.1857296	-0.1734222	-0.464324
Plant height (PH)	0.0056470	0.0024677		0.0023435	0.0019030	-0.0012536	-0.0007115	0.0004913	-0.0006155	0.0017110	-0.0000395	0.006296
Total tiller number per plant (TTNP)	-0.0040360	0.0000807	-0.0016749		-0.0020180	0.0005893	0.0004480	0.0001049	-0.0006135	-0.0014651	-0.0017597	-0.006308
Number of productive tillers per plant (NPTP)	0.0197080	0.0022073	0.0066416	0.0098540		-0.0083168	-0.0013796	-0.0056365	-0.0006504	0.0181117	0.0009263	0.021757
Spike length SL	0.0175560	0.0022296	-0.0038974	-0.0025632	-0.0074086		-0.0005969	0.0021067	-0.0014923	-0.0083391	-0.0016327	-0.021593
Number of grains per spike (NGS)	0.3762200	-0.1779521	-0.0474037	-0.0417604	-0.0263354	-0.0127915		0.1805856	0.3107577	-0.0033860	-0.0022573	0.179456
Number of sterile spikelets per spike (NSSS)	0.0000054	-0.0000007	0.0000005	-0.0000001	-0.0000016	0.0000007	0.0000026		0.0000019	-0.0000013	-0.0000006	0.000001
Grain weight per spike (GWS)	-0.0619120	0.0297178	0.0067484	-0.0094106	0.0020431	0.0052625	-0.0511393	-0.0211739		-0.0022288	-0.0346088	-0.074789
Grain weight per plant (GWP)	-0.0028720	-0.0004768	-0.0008702	-0.0010425	-0.0026394	0.0013642	0.0000258	0.0007151	-0.0001034		-0.0002269	-0.003254
1000 grains weight (1000 GW)	0.2680610	-0.0415495	-0.0018764	0.1168746	0.0125989	-0.0249297	-0.0016084	-0.0273422	0.1498461	0.0211768		0.203190

Table 5. Path coefficient analysis showing the direct and indirect effect of yield components on grain yield in locality Strumica

Components of yield	Direct effect	Indirect effect										Total indirect effect
		NS m^2	PH	TTNP	NPTP	SL	NGS	NSSS	GWS	GWP	1000 GW	
Number of spikes, m^2 (NS m^2)	1.06634		0.2772507	0.1396917	0.1140993	0.1162320	-0.3614922	-0.1172984	-0.3913500	0.2090044	-0.2431275	-0.256990
Plant height (PH)	-0.01851	-0.0048137		-0.0085907	0.0022588	0.0060172	0.0056284	-0.0049989	0.0012960	-0.0054988	-0.0027216	-0.011423
Total tiller number per plant (TTNP)	0.00264	0.0003459	0.0012253		0.0006311	0.0000449	0.0000766	0.0003723	0.0003697	0.0015395	0.0004436	0.005049
Number of productive tillers per plant (NPTP)	0.00912	0.0009762	-0.0011130	0.0021804		0.0033299	0.0010583	-0.0037769	-0.0002554	0.0051910	-0.0011039	0.006486
Spike length SL	-0.00127	-0.0001384	0.0004126	-0.0000216	-0.0004634		-0.0002336	0.0003720	-0.0000546	0.0000647	0.0001041	0.000041
Number of grains per spike (NGS)	-0.07556	0.0256147	0.0229701	-0.0021912	-0.0087649	-0.0139030		-0.0138274	-0.0517584	-0.0032491	-0.0114095	-0.056518
Number of sterile spikelets per spike (NSSS)	-0.00539	0.0005932	-0.0014561	-0.0007604	0.0022326	0.0015801	-0.0009869		-0.0012943	-0.0003451	-0.0009923	-0.001429
Grain weight per spike (GWS)	0.55592	-0.2040225	-0.0389144	0.0778287	-0.0155657	0.0239045	0.3808049	0.1334207		0.1778943	0.4575218	0.992872
Grain weight per plant (GWP)	0.01403	0.0027511	0.0041688	0.0081832	0.0079867	-0.0007159	0.0006036	0.0008983	0.0044916		0.0057128	0.034080
1000 grains weight (1000 GW)	-0.05585	0.0127348	-0.0082106	-0.0093835	0.0067584	0.0045801	-0.0084340	-0.0102772	-0.0459681	-0.0227327		-0.080932

Results and discussion

In Table 1 are given the values for average, minimum, maximum and coefficient of variation of all tested traits in both localities. The average values for number of spikes per m^2, number of productive tillers per plant, spike length, grain weight per plant and yield for locality Strumica are higher than locality Ovche Pole. That is probably consequence to the favorable climatic conditions in the locality Strumica. The highest coefficient of variation in both localities has the number of sterile spikelets per spike while the lowest coefficient of variation has 1000 grain weight (1.82%) in locality Ovche Pole and number of grains per spike (2.55%) in locality Strumica.

The correlation between grain yield and yield components for the examined traits in barley varieties for locality Ovche Pole are presented in Table 2. Significant and positive correlation was determined between grain yield and number of spikes per m^2 (r = 0.936). A similar significant positive coefficient was also observed by Ataei (2006), Jabbari at al. (2010), Drikvand et al. (2011). Plant height is an important trait directly linked with the productive potential of the plant and many researchers require correlation between plant height and yield. In our study the correlation between grain yield and plant height was significant and positive (r = 0.452). This means that the varieties tested in the locality Ovche Pole have higher values for this property. According to Kisana et al. (1999), Bhutta et al. (2005), Jabbari at al. (2010), Drikvand et al. (2011) and Niazi-Fard et al. (2012) significant and positive correlation between grain yield and plant height was also observed. Significant and positive correlation was determined between number of productive tillers per plant and grain weight per plant (r = 0.919). Grain number per spike is an important yield component and is usually used as a selection trait in barley breeding programmes. In our study the correlation between number of grains per spike and grain weight per spike was significant and positive (r = 0.826). A similar significant and positive coefficient was also observed by Dyulgerova (2012). Positive and significant correlation was obtained between total tiller number per plant and number of productive tillers per plant (r = 0.500). Number of spikes per m^2 showed significant positive relationship with plant height (r = 0.437). 1000 grains weight is an important yield component and it is influenced by genetic and environmental factors. In our study, 1000 grains weight showed significant and positive correlations with grain weight per spike (r = 5.559) and with total tillers number per plant (r = 0.436). It was also determined that 1000 grains weight and grain yield were non-significantly related. Similar results were reported by Drikvand et al. (2011) and Budakli Carpici and Celik (2012).

In Table 3 are given the coefficient of correlation between grain yield and yield components for the examined traits in barley varieties for locality Strumica. Significant and positive coefficient of correlation between yield and number of spikes per m^2 (r = 0.901) was also obtained in locality Strumica. As in locality Ovche Pole, in locality Strumica, the correlation between number of grains per spike and grain weight per spike was significant and positive (r = 0.685). Grain weight per spike showed significant and positive relationship with 1000 grain weight (r = 0.823). Positive and significant correlation was obtained between grain weight per plant with total tiller number per plant (r = 0.583) and number of productive tillers per plant (r = 0.569). Plant height showed significant and positive relationship with total tiller number per plant (r = 0.464).

Comparing the correlation coefficients in both localities it can be concluded that the obtained significant and positive correlation between total tiller number per plant with grain weight per plant in the locality Strumica was not proved in locality Ovche Pole. On the other side, the significant and positive correlation coefficients that have been proven the properties plant height with number of spikes per m^2, plant height with yield and total tiller number per plant with number of productive tillers per plant for locality Ovche Pole were not observed for locality Strumica. The differences in correlations in both locations are probably due to the different climatic conditions in the two localities.

The purpose of using the path coefficient analysis in this study was to obtain further information about the interrelationships between the yield and yield components and about the influence of yield components on grain yield. In Table 4 and 5 are presented the direct and indirect effects of yield components on grain yield for both localities. In our study, path coefficient analysis for locality Ovche Pole showed that number of spikes per m^2 has the highest direct positive effect on grain yield, followed by number of grains per spike. For locality Strumica number of spikes per m^2 and grain weight per spike have the highest direct positive effect on yield. Similar direct positive effect on grain yield was observed by Budakli Carpici and Celik (2012). These results indicate that an increase in any of these yield components causes some increase in yield. Indirect effect on yield have the properties total tiller number per plant and weight of grain per plant for locality Ovche Pole and for locality Strumica the properties number of sterile spikelets per spike and plant height.

Conclusion

Through correlation and path coefficient analysis it was observed that in locality Ovche Pole the grain yield depends on the number of spikes per m^2 and the plant height while in locality Strumica the grain yield depends only on the number of spikes per m^2. The number of productive tillers per plant has a crucial role to grain weight per plant. In both localities, the trait 1000 grains weight has strong influence on grain weight per spike.

The highest direct positive effect on grain yield had the number of spikes per m^2 in both localities. In selecting the productive variety in locality Ovche Pole the established indirect effect of total tiller number per plant and in locality Strumica the number of sterile spikelets per spike should be taken into account. In other examinations more importance should be given to the traits which have direct positive effect on yield as criteria in breeding to improve the yield of barley varieties.

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Instruction for authors

Preparation of papers

Papers shall be submitted at the editorial office typed on standard typing pages (A4, 30 lines per page, 62 characters per line). The editors recommend up to 15 pages for full research paper (including abstract references, tables, figures and other appendices)

The manuscript should be structured as follows: Title, Names of authors and affiliation address, Abstract, List of keywords, Introduction, Material and methods,Results, Discussion, Conclusion, Acknowledgements (if any), References, Tables, Figures.

The title needs to be as concise and informative about the nature of research. It should be written with small letter /bold, 14/ without any abbreviations.

Names and affiliation of authors The names of the authors should be presented from the initials of first names followed by the family names. The complete address and name of the institution should be stated next. The affiliation of authors are designated by different signs. For the author who is going to be corresponding by the editorial board and readers, an E-mail address and telephone number should be presented as footnote on the first page. Corresponding author is indicated with *.

Abstract should be not more than 350 words. It should be clearly stated what new findings have been made in the course of research. Abbreviations and references to authors are inadmissible in the summary. It should be understandable without having read the paper and should be in one paragraph.

Keywords: Up to maximum of 5 keywords should be selected not repeating the title but giving the essence of study.

The introduction must answer the following questions: What is known and what is new on the studied issue? What necessitated the research problem, described in the paper? What is your hypothesis and goal ?

Material and methods: The objects of research, organization of experiments, chemical analyses, statistical and other methods and conditions applied for the experiments should be described in detail. A criterion of sufficient information is to be possible for others to repeat the experiment in order to verify results.

Results are presented in understandable tables and figures, accompanied by the statistical parameters needed for the evaluation. Data from tables and figures should not be repeated in the text. **Tables** should be as simple and as few as possible. Each table should have its own explanatory title and to be typed on a separate page. They should be outside the main body of the text and an indication should be given where it should be inserted.

Figures should be sharp with good contrast and rendition. Graphic materials should be preferred. Photographs to be appropriate for printing. Illustrations are supplied in colour as an exception after special agreement with the editorial board and possible payment of extra costs. The figures are to be each in a single file and their location should be given within the text.

Discussion: The objective of this section is to indicate the scientific significance of the study. By comparing the results and conclusions of other scientists the contribution of the study for expanding or modifying existing knowledge is pointed out clearly and convincingly to the reader.

Conclusion: The most important consequences for the science and practice resulting from the conducted research should be summarized in a few sentences. The conclusions shouldn't be numbered and no new paragraphs be used. Contributions are the core of conclusions.

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Todorov N and Mitev J, 1995. Effect of level of feeding during dry period, and body condition score on reproductive performance in dairy cows,IXth International Conference on Production Diseases in Farm Animals, September 11–14, Berlin, Germany.

Thesis:

Hristova D, 2013. Investigation on genetic diversity in local sheep breeds using DNA markers. Thesis for PhD, Trakia University, Stara Zagora, Bulgaria, (Bg).

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Animal welfare

Studies performed on experimental animals should be carried out according to internationally recognized guidelines for animal welfare. That should be clearly described in the respective section “Material and methods”.

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