

Original Research Article

<https://doi.org/10.20546/ijcmas.2017.608.218>

Correlation and Path Analysis Studies in Barley (*Hordeum vulgare* L.) Genotypes under Normal and Limited Moisture Conditions

Jaya Shrimali¹, A.S. Shekhawat¹ and Sunita Kumari^{2*}

¹Department of Plant Breeding and Genetics, College of Agriculture, Bikaner-334006, India

²Department of Genetics and Plant Breeding, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-22105, India

*Corresponding author

ABSTRACT

Keywords

Barley,
Correlation and
Path analysis,
Randomize block
design.

Article Info

Accepted:
19 June 2017
Available Online:
10 August 2017

This research was carried out the correlation among the yield and yield attributing characters and their path analysis for 30 genotypes of Barley in a Randomize Block Design (RBD) with three replications in two environments. The seed yield per plant was found to be positively and significantly associated with plant height, biological yield per plant, test weight, number of spikelets per spike and spike length in both the environments. Path coefficient analysis indicated that biological yield per plant and harvest index in both the environments, were the important characters for selection of high yielding genotype as this exerted high positive direct effect as well as showed high and positive correlation with seed yield.

Introduction

Barley (*Hordeum vulgare* L.) is the world's fourth most important cereal crop after wheat, maize and rice. Barley belongs to the family *poaceae* with chromosome number $2n=2x=14$. Barley is considered as most cosmopolitan of the crops, grown over the wide environmental range as well as it has been considered, as poor man's crop because of its low input requirement and better adaptability to harsh environments, like drought, salinity and alkalinity and marginal lands. Owing to its hardiness, in many countries around the world, it is often considered the only possible rainfed cereal crop under low input and stressful environments.

In any breeding programmed aiming at improving yield, it is essential to know, the degree of association between yield and other metric traits. Yield is complex character, which is contributed by many independent characters and improvement in yield depends upon improvement in its component characters. Correlation coefficient ensures the degree of association, genetic or non genetic relationship between two or more characters which forms the basis for selection. When change in one variable causes the change in another variable, the variables are said to be correlated. This association between the attributes is measured as "correlation

coefficient". If the change is in same direction, the correlation is positive and if it is in opposite direction, the correlation is negative. The value is zero when two variables are not related. In plant breeding, study of correlation is essential because most of the traits such as yield are the end products of interaction of several genetic factors among themselves and their individual and combined interaction with environmental factors. Path analysis simply splits the correlation coefficient into the measures of direct and indirect effect of a set of independent variables on the dependent variables.

Materials and Methods

The germplasm of 30 genotypes was studied at Research Farm of College of Agriculture, Beechwal, Bikaner during *rabi* season 2012-13. Genotypes were obtained from Agriculture Research Station Durgapura, Jaipur, which were differing in growth and morphological characters. The experiment was laid out in Randomized Block Design with three replications. Each genotype was sown in double row with spaced apart at 23 x 10 cm in a plot of 4x3 m size. The genotypes were evaluated in two environments i.e. (i) normal moisture condition and (ii) limited moisture condition.

Normal moisture condition

All the standard agricultural practices were followed to raise the good and healthy crop in normal environment.

Limited moisture condition

first irrigation was given at the time of sowing and second life saving irrigations was given after 30 days of sowing and after 80 of sowing. After that no irrigation was given. The sample size consisted of five plants, selected randomly from each plot in both environments. The observations on different

characters plant height, number of effective tillers per plant, spike length, number of spikelet's per spike, test weight, seed yield per plant, biological yield per plant, harvest index, Membrane stability index, Relative water content and chlorophyll content except days to 50% flowering, days to maturity were recorded on the basis of five selected plants and averaged to obtain the mean.

Genotypic and phenotypic correlation coefficients of yield with the contributing characters and among themselves were calculated by using the genotypic and phenotypic variances and co-variances as described by Singh *et al.*, (1985) and Searle (1961). The direct and indirect effects were estimated through path coefficient analysis as suggested by Wright (1921) and elaborated by Dewey *et al.*, (1959).

Results and Discussion

Character association analysis

The correlations between all possible combinations among the characters were calculated under normal and limited moisture condition at phenotypic and genotypic level and are presented in tables 1 and 2 respectively. Perusal of the table indicates that the magnitude of genotypic correlation coefficient was higher for most of the character pairs than their respective values of phenotypic correlation coefficient, which may be ascribed to the low effect of environment on the character expression.

Under normal condition seed yield per plant had significant positive correlation with plant height ($r_g=0.917^{**}$, $r_p=0.798^{**}$), biological yield per plant ($r_g=0.865^{**}$, $r_p=0.782^{**}$), test weight ($r_g=0.846^{**}$, $r_p=0.679^{**}$), number of spikelet per spike ($r_g=0.679^{**}$, $r_p=0.574^{**}$), spike length ($r_g=0.524^{**}$, $r_p=0.473^{**}$) at both phenotypic and genotypic level respectively.

Table.1 Phenotypic and genotypic correlation coefficients between different characters in barley under normal moisture condition

Characters		Days to 50% flowering	Days to maturity	Plant height (cm)	No. of effective tillers per plant	Spike length (cm)	Number of spikelets per spike	Test weight (g)	Biological yield per plant (g)	Harvest index (%)	Relative water content (%)	Membrane stability index	Chlorophyll content (mg/g)	Seed yield per plant (g)
Days to 50% flowering	r _p	1.000	0.551**	0.038	-0.102	-0.044	0.051	0.185	0.041	0.275	0.080	-0.035	0.092	0.183
	r _g	1.000	0.543**	0.095	-0.112	-0.031	0.074	0.220	0.059	0.308	0.017	-0.053	0.142	0.187
Days to maturity	r _p		1.000	-0.046	-0.075	-0.168	0.084	-0.040	-0.038	0.258	0.002	-0.048	0.108	0.107
	r _g		1.000	-0.019	-0.080	-0.168	0.053	-0.034	-0.027	0.303	-0.001	-0.076	0.126	0.109
Plant height (cm)	r _p			1.000	0.310	0.419*	0.698**	0.708**	0.806**	-0.045	-0.211	0.302	0.253	0.798**
	r _g			1.000	0.337	0.441*	0.803**	0.916**	0.896**	-0.049	-0.233	0.357	0.320	0.917**
No. of effective tillers per plant	r _p				1.000	0.445*	-0.026	0.044	0.216	0.043	-0.128	0.444*	0.205	0.286
	r _g				1.000	0.498**	-0.033	0.076	0.241	0.063	-0.142	0.503**	0.151	0.330
Spike length	r _p					1.000	0.279**	0.303	0.329	0.164	0.035	0.270	0.272	0.473**
	r _g					1.000	0.339**	0.380*	0.362*	0.207	0.016	0.289	0.403*	0.524**
Number of spikelets per spike	r _p						1.000	0.579**	0.596**	-0.069	-0.155	0.141	0.235	0.574**
	r _g						1.000	0.743**	0.686**	-0.090	-0.126	0.164	0.345	0.679**
Test weight	r _p							1.000	0.696**	-0.039	-0.088	0.327	0.099	0.679**
	r _g							1.000	0.797**	0.000	-0.120	0.381*	0.182	0.846**
Biological yield per plant	r _p								1.000	-0.353	-0.100	0.229	0.091	0.782**
	r _g								1.000	-0.357	-0.125	0.286	0.088	0.865**
Harvest index (%)	r _p									1.000	-0.090	0.149	0.224	0.286
	r _g									1.000	-0.144	0.154	0.426*	0.148
Relative water content (%)	r _p										1.000	-0.178	0.086	-0.166
	r _g										1.000	-0.189	0.121	-0.214
Membrane stability index	r _p											1.000	0.225	0.334
	r _g											1.000	0.338	0.386*
Chlorophyll content (mg/g)	r _p												1.000	0.248
	r _g												1.000	0.344
Seed yield per plant (g)	r _p													1.000
	r _g													1.000

*, ** Significant at 5 % and 1 % level of significance, respectively

Table.2 Phenotypic and genotypic correlation coefficients between different characters in barley under limited moisture condition

Characters		Days to 50% flowering	Days to maturity	Plant height (cm)	No. of effective tillers per plant	Spike length (cm)	Number of spikelets per spike	Test weight (g)	Biological yield per plant (g)	Harvest index (%)	Relative water content (%)	Membrane stability index	Chlorophyll content (mg/g)	Seed yield per plant (g)
Days to 50% flowering	r _p	1.000	0.649**	-0.080	-0.237	-0.171	-0.086	0.047	-0.202	-0.023	0.079	-0.005	0.120	-0.191
	r _g	1.000	0.715**	-0.096	-0.246	-0.183	-0.087	0.028	-0.216	-0.037	0.063	-0.011	0.141	-0.230
Days to maturity	r _p		1.000	-0.180	-0.403*	-0.349	-0.229	-0.103	-0.429*	0.170	-0.052	0.028	0.135	-0.252
	r _g		1.000	-0.189	-0.444*	-0.391*	-0.290	-0.150	-0.470**	0.204	-0.023	0.018	0.22	-0.287
Plant height (cm)	r _p			1.000	0.039	0.184	0.205	0.756**	0.572**	0.164	-0.075	0.114	0.289	0.643**
	r _g			1.000	0.028	0.199	0.279	0.810**	0.586**	0.207	-0.122	0.144	0.304	0.705**
No. of effective tillers per plant	r _p				1.000	0.331	0.192	-0.131	0.179	-0.178	-0.064	0.253	-0.041	0.026
	r _g				1.000	0.340	0.230	-0.165	0.183	-0.194	-0.063	0.277	-0.121	0.035
Spike length	r _p					1.000	0.757**	0.218	0.279	0.182	0.169	0.149	0.154	0.385*
	r _g					1.000	0.939**	0.234	0.294	0.215	0.252	0.184	0.153	0.425*
Number of spikelets per spike	r _p						1.000	0.280	0.268	0.143	0.130	0.222	0.119	0.335
	r _g						1.000	0.303	0.330	0.191	0.210	0.288	0.196	0.425*
Test weight	r _p							1.000	0.675**	0.148	-0.025	0.229	0.196	0.720**
	r _g							1.000	0.717**	0.177	-0.026	0.277	0.190	0.801**
Biological yield per plant	r _p								1.000	-0.287	-0.073	0.201	0.167	0.644**
	r _g								1.000	-0.294	-0.103	0.228	0.155	0.701**
Harvest index (%)	r _p									1.000	0.068	-0.036	0.079	0.539**
	r _g									1.000	0.122	-0.059	0.151	0.470**
Relative water content (%)	r _p										1.000	-0.085	0.068	-0.026
	r _g										1.000	-0.112	0.046	-0.032
Membrane stability index	r _p											1.000	0.253	0.127
	r _g											1.000	0.362*	0.142
Chlorophyll content (mg/g)	r _p												1.000	0.206
	r _g												1.000	0.255
Seed yield per plant (g)	r _p													1.000
	r _g													1.000

*, ** Significant at 5 % and 1 % level of significance, respectively

Table.3 Phenotypic (P) and genotypic (G) path coefficients of various characters on seed yield per plant under normal moisture condition

Characters		Days to 50% flowering	Days to maturity	Plant height (cm)	No. of effective tillers per plant	Spike length (cm)	Number of spikelets per spike	Test weight (g)	Biological yield per plant (g)	Harvest index (%)	Relative water content (%)	Membrane stability index	Chlorophyll content (mg/g)	Correlation coefficient with seed yield per plant
Days to 50% flowering	P	-0.034	0.002	0.000	-0.005	-0.001	0.002	0.004	0.040	0.175	0.000	0.001	0.000	0.183
	G	0.008	0.013	0.055	0.016	-0.004	-0.008	-0.060	0.045	0.136	0.001	-0.005	-0.011	0.187
Days to maturity	P	-0.019	0.003	0.001	-0.004	-0.004	0.003	-0.001	-0.037	0.164	0.000	0.001	0.000	0.107
	G	0.004	0.023	-0.011	0.011	-0.020	-0.005	0.009	-0.021	0.134	0.000	-0.007	-0.010	0.109
Plant height (cm)	P	-0.001	0.000	-0.012	0.015	0.009	0.023	0.017	0.780	-0.028	0.001	-0.006	0.001	0.798**
	G	0.001	0.000	0.581	-0.049	0.052	-0.083	-0.250	0.690	-0.022	-0.009	0.030	-0.024	0.917**
No. of effective tillers per plant	P	0.003	0.000	-0.004	0.048	0.009	-0.001	0.001	0.209	0.028	0.001	-0.009	0.001	0.286
	G	-0.001	-0.002	0.196	-0.144	0.059	0.003	-0.021	0.186	0.028	-0.006	0.043	-0.012	0.330
Spike length	P	0.001	0.000	-0.005	0.021	0.021	0.009	0.007	0.319	0.104	0.000	-0.006	0.001	0.473**
	G	0.000	-0.004	0.256	-0.072	0.119	-0.035	-0.104	0.279	0.091	0.001	0.025	-0.031	0.524**
Number of spikelets per spike	P	-0.002	0.000	-0.008	-0.001	0.006	0.033	0.014	0.577	-0.044	0.001	-0.003	0.001	0.574**
	G	0.001	0.001	0.467	0.005	0.040	-0.104	-0.203	0.529	-0.040	-0.005	0.014	-0.026	0.679**
Test weight	P	-0.006	0.000	-0.008	0.002	0.006	0.019	0.024	0.673	-0.025	0.001	-0.007	0.000	0.679**
	G	0.002	-0.001	0.532	-0.011	0.045	-0.077	-0.273	0.615	0.000	-0.005	0.032	-0.014	0.846**
Biological yield per plant	P	-0.001	0.000	-0.009	0.010	0.007	0.019	0.017	0.968	-0.224	0.001	-0.005	0.000	0.782**
	G	0.000	-0.001	0.521	-0.035	0.043	-0.071	-0.218	0.771	-0.158	-0.005	0.024	-0.007	0.865**
Harvest index (%)	P	-0.009	0.001	0.001	0.002	0.003	-0.002	-0.001	-0.342	0.636	0.001	-0.003	0.001	0.286
	G	0.002	0.007	-0.029	-0.009	0.024	0.009	0.000	-0.275	0.442	-0.006	0.013	-0.032	0.148
Relative water content (%)	P	0.000	0.000	0.002	-0.006	0.001	-0.005	-0.002	-0.097	-0.057	-0.006	0.004	0.000	-0.166
	G	0.000	0.000	-0.135	0.020	0.002	0.013	0.033	-0.097	-0.064	0.039	-0.016	-0.009	-0.214
Membrane stability index	P	0.001	0.000	-0.004	0.021	0.006	0.005	0.008	0.222	0.094	0.001	-0.021	0.001	0.334
	G	0.000	-0.002	0.207	-0.073	0.034	-0.017	-0.104	0.221	0.068	-0.007	0.085	-0.026	0.386*
Chlorophyll content (mg/g)	P	-0.003	0.000	-0.003	0.010	0.006	0.008	0.002	0.088	0.142	0.000	-0.005	0.003	0.248
	G	0.001	0.003	0.186	-0.022	0.048	-0.036	-0.050	0.068	0.189	0.005	0.029	-0.076	0.344

Residual effect : Phenotypic = 0.0227 and Genotypic =0.0195

Table.4 Phenotypic (P) and genotypic (G) path coefficients of various characters on seed yield per plant under limited moisture condition

Characters		Days to 50% flowering	Days to maturity	Plant height (cm)	No. of effective tillers per plant	Spike length (cm)	Number of spikelets per spike	Test weight (g)	Biological yield per plant (g)	Harvest index (%)	Relative water content (%)	Membrane stability index	Chlorophyll content (mg/g)	Correlation coefficient with seed yield per plant
Days to 50% flowering	P	0.013	-0.019	0.000	-0.006	-0.002	0.002	0.003	-0.165	-0.018	-0.002	0.000	0.001	-0.191
	G	-0.070	0.023	0.012	-0.029	0.004	-0.002	0.008	-0.162	-0.025	-0.003	0.001	0.012	-0.230
Days to maturity	P	0.008	-0.029	0.001	-0.010	-0.003	0.005	-0.007	-0.350	0.132	0.001	-0.001	0.001	-0.252
	G	-0.050	0.033	0.024	-0.053	0.009	-0.007	-0.043	-0.353	0.136	0.001	-0.002	0.019	-0.287
Plant height (cm)	P	-0.001	0.005	-0.003	0.001	0.002	-0.004	0.049	0.466	0.127	0.002	-0.003	0.003	0.643**
	G	0.007	-0.006	-0.127	0.003	-0.004	0.006	0.234	0.440	0.138	0.006	-0.018	0.026	0.705**
No. of effective tillers per plant	P	-0.003	0.012	0.000	0.025	0.003	-0.004	-0.008	0.146	-0.138	0.001	-0.007	0.000	0.026
	G	0.017	-0.014	-0.004	0.120	-0.007	0.005	-0.048	0.137	-0.129	0.003	-0.035	-0.010	0.035
Spike length	P	-0.002	0.010	-0.001	0.008	0.009	-0.016	0.014	0.228	0.141	-0.004	-0.004	0.002	0.385*
	G	0.013	-0.013	-0.025	0.041	-0.022	0.022	0.068	0.221	0.143	-0.012	-0.023	0.013	0.425*
Number of spikelets per spike	P	-0.001	0.007	-0.001	0.005	0.007	-0.022	0.018	0.219	0.110	-0.003	-0.006	0.001	0.335
	G	0.006	-0.009	-0.035	0.028	-0.021	0.023	0.088	0.248	0.127	-0.010	-0.036	0.017	0.425*
Test weight	P	0.001	0.003	-0.002	-0.003	0.002	-0.006	0.064	0.551	0.115	0.001	-0.007	0.002	0.720**
	G	-0.002	-0.005	-0.103	-0.020	-0.005	0.007	0.289	0.539	0.118	0.001	-0.035	0.016	0.801**
Biological yield per plant	P	-0.003	0.013	-0.002	0.004	0.003	-0.006	0.044	0.816	-0.222	0.002	-0.006	0.002	0.644**
	G	0.015	-0.015	-0.074	0.022	-0.006	0.008	0.207	0.751	-0.195	0.005	-0.029	0.013	0.701**
Harvest index (%)	P	0.000	-0.005	-0.001	-0.004	0.002	-0.003	0.010	-0.234	0.774	-0.001	0.001	0.001	0.539**
	G	0.003	0.007	-0.026	-0.023	-0.005	0.004	0.051	-0.220	0.665	-0.006	0.007	0.013	0.470**
Relative water content (%)	P	0.001	0.002	0.000	-0.002	0.002	-0.003	-0.002	-0.059	0.052	-0.021	0.002	0.001	-0.026
	G	-0.004	-0.001	0.016	-0.008	-0.006	0.005	-0.008	-0.077	0.081	-0.048	0.014	0.004	-0.032
Membrane stability index	P	0.000	-0.001	0.000	0.006	0.001	-0.005	0.015	0.164	-0.028	0.002	-0.029	0.003	0.127
	G	0.001	0.001	-0.018	0.033	-0.004	0.007	0.080	0.171	-0.039	0.005	-0.125	0.031	0.142
Chlorophyll content (mg/g)	P	0.002	-0.004	-0.001	-0.001	0.001	-0.003	0.013	0.136	0.061	-0.001	-0.007	0.011	0.206
	G	-0.010	0.007	-0.039	-0.014	-0.003	0.005	0.055	0.116	0.100	-0.002	-0.045	0.086	0.255

Residual effect: Phenotypic = 0.0119 and Genotypic = 0.0013

Under limited moisture condition seed yield per plant had positive and significant association with test weight (rg=0.801**, rp=0.720**), plant height (rg=0.705**, rp=0.643**), biological yield per plant (rg=0.701**, rp=0.644**), harvest index (rg=0.470**, rp=0.539**), spike length (rg=0.425*, rp=0.385*) at both genotypic and phenotypic level, respectively. While, number of spikelet per spike (rg=0.425*) had significant and positive association with seed yield per plant at genotypic level.

Path coefficient analysis

The direct and indirect effects of various characters along with their phenotypic correlation coefficients with seed yield per plant are presented in tables 3 and 4 for each of the two environmental conditions. Path coefficient analysis over two environmental conditions indicated the variable contribution of different characters towards seed yield with change of environmental conditions. Change in the diameter and magnitude of direct and indirect effects were noted between environments.

In normal condition the most of the traits which exhibited significant and positive correlation with seed yield per plant had high positive direct effects on seed yield per plant indicating that the major portion of correlation is ascribed to direct effects. Among the traits, biological yield per plant, plant height, harvest index, spike length and membrane stability index. Test weight exhibited high negative direct effect on seed yield per plant at genotypic level. The above findings are in conformity with (Najeeb *et al.*, 2004; Kundalia *et al.*, 2006; Mittal *et al.*, 2009) in barley.

Similar to normal condition, the highest direct effect was exhibited by biological yield per plant, harvest index, test weight and number of effective tillers per plant in limited moisture condition. Such results were earlier reported by

(Vaezi *et al.*, 2010; Ali *et al.*, 2012; Naghahi *et al.*, 2012).

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How to cite this article:

Jaya Shrimali, A.S. Shekhawat and Sunita Kumari. 2017. Correlation and Path Analysis Studies in Barley (*Hordeum vulgare* L.) Genotypes under Normal and Limited Moisture Conditions. *Int.J.Curr.Microbiol.App.Sci*. 6(8): 1850-1856.
doi: <https://doi.org/10.20546/ijcmas.2017.608.218>