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Research Article

Correlation and Path Coefficient Analysis of Malt Barley (*Hordeum distichon* L.) Genotypes

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ABSTRACT

The correlations and path coefficient were studied in 20 diverse genotypes of malt barley in order to understand the relationship and contribution of agronomic characters towards the grain yield. This field experiment was conducted in RCBD design with four replications at Bekoji and Kofele sub-stations of Kulumsa Agricultural Research Center, Southeastern Ethiopia. There was very strong, positive and significant correlation among quality related traits at genotypic level. Malt moisture content (0.821) and Sieve test (0.676) had strong positive correlations with malt extract. Grain yield was positively and significantly correlated with biomass yield and number of kernels per spike. Biomass yield (1.607), harvest index (1.103) and number of total tillers per plant (0.574) had strong and positive direct effect on grain yield at phenotypic level. Malt moisture content (0.725), sieve test (312), wort color (0.234) and malt protein content (0.158) had positive direct effect on malt extract. Therefore, tillers per plant, biomass yield, number of kernels per spike and sieve test can be used as selection criteria to improve grain yield and malt quality together, but cautiously taking grain protein during selection.

Key words: Correlation, Path coefficient, Malt barley, Yield, Yield components

INTRODUCTION

Barley (Hordeum vulgare L.) is an annual cereal crop most widely grown over broad environmental conditions. It has persisted as a major cereal crop through many centuries and it is the world's fourth most important cereal crop after wheat, rice and maize (FAO, 2005). In Ethiopia, barley ranks fifth after teff, wheat, maize and sorghum (CSA, 2014). Barley has a long history of cultivation in Ethiopia and its production is reported to have coincided with the beginning of the plow culture (Zemede, 2000). It is one of the most important crops in Ethiopia with total area coverage of 1,019,478 hectares and total annual production of about 1.9 million tons in the main season (CSA, 2014). Barley is the most dependable cereal and is cultivated on highly degraded mountain slopes giving better yield than other cereal crops in the highland of Ethiopia under extreme marginal conditions of frost and poor soil fertility (Ceccarelli et al., 1999). In Ethiopia, barley types are predominantly categorized as food and malting barley based on their uses while the share of malting barley is on increasing trend nowadays. Besides its grain value, barley straw is also an indispensible component for feed especially during the dry season in the highlands where feed shortage is prevalent (Girma et al., 1996). Barley straw is also used for roof thatching of traditional huts and as a mud plaster of the traditional huts and grain stores, as well as for use as bedding in the rural area (Zemede, 2000). 2 Barley is being produced on about 1 million hectares of land, but the share of malt barley is too small. Suitable malt barley growing regions in Ethiopia are the highlands ranging from 2300 to 3000 m.a.s.l. Malt barley is one of the important crops used as raw material for agro-industries (maltery and breweries). The annual malt barley demand by the existing breweries in the year 2011/12 is projected to be over 67,509.6 tons with an increasing trend. However, only about 45 % has been supplied currently by the Assela Malt Factory to the existing breweries and the remaining balance has been fulfilled through import (Getachew et al., 2007). Barley genotypes are different in grain yield potential as well as different yield related agronomic traits. Mariey et al., (2013) reported significant yield difference among the barley genotypes evaluated. Barley genotypes vary not only in grain yield potential, but also in other yield related parameters. Ahmed et al., (2001) found that barley genotypes significantly differed in plant height, biological yield and grain yield.

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The objective of this study was to establish the interrelationship and direct and indirect effects of some yield components among themselves and with grain yield and those of quality parameters with malt extract in malt barley genotypes.

MATERIALS AND METHODS

The experiments were conducted at Bekoji and Kofele sub-stations of Kulumsa Agricultural Research Center.

A total of twenty genotypes were evaluated in randomized complete block design (RCBD) with four replications in 2015 main cropping season, which lapses from July to December.

RESULTS AND DISCUSSION

Correlations among Agronomic Traits

The understanding of inter-relationship among various characters is essential for formulating selection criteria. Many interesting associations were observed among yield related traits (Table 1). Generally, both positive and negative genotypic correlations were observed between most of the characters in this study. Yield was positively and significantly correlated with biomass weight (1.00) and number of kernels per spike (1.00). Toffiq et al., (2015) found positive and significant correlation of biological yield (0.580) and number of grains per plant (0.208). Habgood, (1983) and Larika, (1987) also found significant correlation coefficient between grain yield and number of kernels per spike. Grain yield had negative correlation with harvest index, productive tillers per plant, total number of tillers per plant, spike length and awn length. But this result doesn't agree with the result obtained by Solanki and Bakshi, (1973) in which yield was associated positively with number of tillers, number of grains and 1000-grain weight. The negative correlation of thousand kernel weight and number of tillers per plant is in agreement with the finding of Fekadu, (1982). Phenotypic correlation of yield showed positive association with plant height (0.706) and this result agreed with Scherchand and Yoshida, (1996). Grain yield had negative correlation with days to heading, days to maturity, thousand kernel weight and hectoliter weight at phenotypic level. Ifran-ul, (1997) reported negative correlation between grain yield and days to heading, but positive association with thousand grain weight and number of spikelets per spike in contrast to the result found in this study.

Harvest index had negative correlation with yield, biomass weight, hectoliter weight, thousand kernel weight, plant height and days to maturity, but positively associated with days to heading at phenotypic level (Table 9). But positive and significant phenotypic and genotypic correlation between grain yield and harvest index, grains per spike and thousand grain weight was reported by Hennway, (1997). The negative correlation between harvest index and yield could be because of high proportion of biological yield. There was positive correlation between spike length and thousand kernel weight both at phenotypic and genotypic level and this result is in disagreement with the result reported by Fekadu, (1982). The negative correlation of kernel number per spike and thousand kernel weight agreed with the finding of Tofiq et al., (2015), but Carpici and Celik, (2012) found positive correlation between number of kernels per spike and thousand kernel weight.

Correlations of malt extract and quality related parameters

Malt extract content and malting quality characters are the mainstay of malt barley varieties with good malting qualities. The extract provides the source of fermentable sugars, the enzymes necessary for starch conversion, and proteins needed for yeast nutrition (BMBRI, 2006). Very strong and significant genotypic correlation (1.00) between grain protein content and malt protein content was observed in this study. Malt Extract content was found to be correlated strongly and positively with malt moisture content (0.821) followed by sieve test (0.676), malt protein content (0.453) and germination energy (0.239) at genotypic level (Table 2). The phenotypic associations between malt extract with malt moisture content (0.453) and sieve test (0.449) were found to be significant. There was a very weak positive correlation of malt extract with germination energy (0.076) and malt protein content (0.053). Malt moisture content and sieve test were significantly and positively correlated with malt extract content both at genotypic and at phenotypic levels. These traits could be the traits of selection for malt quality characteristics. On the other hand, wort color (-0.414) and (-0.591), and grain protein content (- 0.209) and (-0.256) were negatively correlated both at genotypic and phenotypic levels, respectively.

Genotypic Path Coefficient Analysis of Grain Yield

Yield is the byproduct of different causal factors that contribute directly or indirectly. These independent factors exert specific forces to result in grain yield. The path coefficient analysis of grain yield at genotypic level is presented in (Table 3).

At genotypic level fertile tillers per plant exerted the highest and positive direct effect followed by thousand kernel weight, number of kernels per spike and days to maturity. This result agreed with the findings of Solanki and Bakshi, (1973) and Sajeda et al., (1997). Fertile tillers per plant, thousand kernel weight and number of kernels per spike contributed highly and directly to grain yield at genotypic level. Total tillers per plant, days to heading, hectoliter weight, plant height, harvest index, biomass weight and spike length exerted high but negative force upon yield accumulation. Tofiq et al., (2015) also found that the direct effect of spike length and harvest index on grain yield was negative. However, plant height, biomass weight and number of kernels had better association with yield (Singh, 1998). Thousand kernel weight was among negatively associated traits with yield and this result is in agreement with the report of Carpici and Celik, (2012).

Indirectly, harvest index exerted high and positive effect on grain yield via biomass weight followed by fertile tillers per plant, total tillers per plant and spike length. Toffiq et al., (2015) also reported high indirect effect of thousand kernel weight and number of kernels per spike on yield. Hence, selecting plants with high number of tillers, thousand kernel weight and number of kernels per spike would be appropriate for indirect selection of high yielding plants. Baboo 44 and Chauhan, (1992) indicated that days

Table 1: Genotypic (above diagonal) and phenotypic (below diagonal) correlations of 13 traits of twenty barley genotypes studied at Bekoji and Kofele, 2015.

	DH	DM	PlH	TKW	HLW	YLD	BWt	HI	FTP	TTP	SL	AL	NKS
DH		0.676**	-0.119	-0.588**	-0.436*	0.107	-0.023	0.066	0.171	0.018	-0.195	-0.173	0.371*
DM	0.608**		-0.388*	-0.142	0.041	-0.896**	-0.159	-0.080	0.371*	0.358*	-0.022	0.088	0.073
PlH	-0.128	-0.370*		0.148	0.103	1.00***	0.996***	-0.830**	-0.690**	-0.675**	-0.308*	0.066	0.367*
TKW	-0.549**	-0.151	0.150		0.902***	-0.445*	0.227	-0.419*	0.286	0.246	0.169	0.616**	-0.734**
HLW	-0.410*	0.042	0.098	0.869**		-1.00***	0.141	-0.497*	0.326*	0.286	0.170	0.541**	-0.677**
YLD	-0.070	-0.309*	0.706**	-0.120	-0.310*		1.00***	-1.00***	-1.00***	-1.00***	-0.792**	-0.451*	1.00***
BWt	-0.037	-0.120	0.894**	0.231	0.160	0.720**		-0.99***	-0.641**	-0.625**	-0.389*	0.135	0.247
HI	0.006	-0.087	-0.739**	-0.392*	-0.433*	-0.289	-0.863**		0.161	0.330*	0.322*	-0.374*	0.050
FTP	0.181	0.308*	-0.455*	0.188	0.248	-0.417*	-0.288	0.128		0.983***	0.332*	0.244	-0.832**
TTP	0.102	0.284*	-0.498*	0.195	0.236	-0.339*	-0.331*	0.230	0.963***		0.279	0.186	-0.730**
SL	-0.141	-0.011	-0.297	0.162	0.175	-0.310*	-0.281	0.216	0.173	0.187		-0.391*	-0.263
AL	-0.139	0.131	0.059	0.589**	0.497*	-0.191	0.113	-0.358*	0.155	0.121	-0.357*		-0.474*
NKS	0.343*	0.072	0.363*	-0.718**	-0.652**	0.520**	0.234	0.031	-0.566**	-0.553**	-0.229	-0.453*	

**, *= significant at p<0.01 & 0.05, ns = non-significant DH= days to heading, DM= days to maturity, PlH= plant height, TKW= thousand kernel weight, HLW= hectoliter weight, YLD= grain yield, BWt= biomass weight, HI= harvest index, FTP= fertile tillers per plant, TTP= total number of tillers per plant, SL= spike length,AL=awnlength,NKS=numberofkernelsperspike

Table 2: Genotypic (above the diagonal) and phenotypic (below the diagonal) correlations of malt quality parameters of twenty barley genotypes studied at Bekoji and Kofele, 2015

	GPC	MPC	GE	ST	MMC	Ex	WC
GPC		1.000***	-0.597**	-0.159	-0.111	-0.209	0.457*
MPC	0.723**		-0.192	0.245	0.261	0.453*	0.150
GE	-0.307*	-0.202		-0.395*	0.077	0.239	-0.103
ST	-0.024	0.167	0.065		0.608**	0.676**	-0.215
MMC	0.144	0.153	-0.093	0.275		0.821**	-0.989***
Ex	-0.256	0.053	0.076	0.449*	0.453*		-0.591**
WC	0.234	0.118	-0.120	-0.194	-0.650**	-0.414*	

****, **, *= significant at p<0.001, 0.01 & 0.05, ns = non-significant: GPC = grain protein content, MPC= malt protein content, GE= germination energy, ST= sieve test, MMC= malt moisture content, Ex= extract and WC= wort color.

Table 3: Genotypic direct (bold and diagonal) and indirect (non-diagonal) effects of twelve traits on grain yield (ton ha-1) of twenty genotypes studied at Bekoji and Kofele, 2015

	DH	DM	PlH	TKW	HLW	BWt	HI	FTP	TTP	SL	AL	NKS
DH	-5.503	1.545	0.559	-3.920	2.272	0.029	-0.222	1.733	-0.162	0.160	0.342	1.594 r=0.11
DM	-3.717	2.287	1.824	-0.947	-0.214	0.205	0.270	3.751	-3.207	0.018	-0.174	0.315 r=-0.89
PlH	0.655	-0.888	-4.695	0.986	-0.537	-1.287	2.812	-6.983	6.038	0.252	-0.131	1.578 r=1.00
TKW	3.235	-0.325	-0.694	6.667	-4.697	-0.293	1.419	2.899	-2.199	-0.138	-1.219	-3.152 r=-0.45
HLW	2.401	0.094	-0.485	6.013	-5.208	-0.183	1.685	3.295	-2.531	-0.139	-1.071	-2.907 r=-1.00
BWt	0.124	-0.363	-4.676	1.512	-0.736	-1.292	3.345	-6.485	5.596	0.317	-0.267	1.060 r=1.00
HI	-0.360	-0.182	3.894	-2.792	2.588	1.275	-3.390	1.629	-2.950	-0.263	0.741	0.215 r=-1.00
FTP	-0.942	0.847	3.239	1.910	-1.695	0.828	-0.545	10.123	-8.795	-0.271	-0.484	-3.577 r=-1.00
TTP	-0.100	0.820	3.167	1.638	-1.472	0.808	-1.117	9.946	-8.952	-0.228	-0.369	-3.136 r=-1.00
SL	1.075	-0.049	1.447	1.124	-0.886	0.502	-1.091	3.359	-2.501	-0.817	0.775	-1.130 r=-0.79
AL	0.951	0.201	-0.311	4.104	-2.815	-0.174	1.269	2.474	-1.666	0.320	-1.980	-2.035 r=-0.45
NKS	-2.042	0.167	-1.724	-4.891	3.523	-0.319	-0.170	-8.424	6.533	0.215	0.938	4.298 r=1.00

Residual=0: DH= days to heading, DM= days to maturity, PlH= plant height, TKW= thousand kernel weight, HLW= hectoliter weight, BWt= biomass weight, HI= harvest index, FTP= fertile tillers per plant, TTP= total number of tillers per plant, SL= spike length,AL=awnlength,NKS=numberofkernelsperspikes

to maturity, grains per spike and tillers per plant are the most important factors affecting yield. The highest (9.946) indirect effect was observed for total tillers per plant via fertile tillers per plant.

In this study thousand kernel weight, fertile tillers per plant and number of kernels per spike can be used as selection criteria to improve grain yield since these traits had strong positive direct effect and highly significant correlation with grain yield.

Genotypic Path Coefficient Analysis of Malt Extract Content

Malt extract content is the trait of interest in malting barley and affected by different independent factors. The path coefficient analysis of malt extract content of the experiment under study is shown in (Table 4). Grain protein content had the highest (1.4057) positive direct effect followed by malt moisture content (0.3354) at genotypic level. But the high direct effect of grain protein on malt extract is accompanied with strong negative correlation with it that show a cautious to use this trait as selection criteria.

Sieve test (-0.6754), malt protein content (-0.4529), germination energy (-0.2542) and wort color (-0.2232) had negative direct effect on malt extract content even if they had positive genotypic correlation with extract. Malt moisture content (r= 0.8213) and sieve test (r= 0.6762) were highly and positively associated with malt extract content. Wort color (-0.5907) showed negative association with malt extract and exerted negative direct effect on malt extract that show this trait can be used as negative selection criterion to improve malt extract.

Table 4: Genotypic direct (bold and diagonal) and indirect(non-diagonal) effects of six traits on malt extract of twenty genotypes studied at Bekoji and Kofele, 2015

	GPC	MPC	GE	ST	MMC	WC
GPC	1.4057	-0.4529	0.0488	-0.1653	0.0874	-0.0335 r=-0.209
MPC	1.4057	-0.4529	0.0488	-0.1653	0.0874	-0.0335 r=0.4529
GE	-0.2699	0.0870	-0.2542	0.2668	0.0259	0.0229 r=0.2385
ST	0.3441	-0.1109	0.1005	-0.6754	0.2040	0.0479 r=0.6762
MMC	0.3662	-0.1180	-0.0197	-0.4108	0.3354	0.2207 r=0.8213
WC	0.2113	-0.0681	0.0261	0.0261	-0.3317	-0.2232 r=-0.5907

Residual=0 : GPC = grain protein content, MPC= malt protein content, GE= germination energy, ST= sieve test, MMC= malt moisture content and WC= wort color.

Table 5: Phenotypic direct (bold and diagonal) and indirect (non-diagonal) effects of twelve traits on grain yield (ton ha-1) of twenty genotypes studied at Bekoji and Kofele, 2015

	DH	DM	PlH	TKW	HLW	BWt	HI	FTP	TTP	SL	AL	NKS
DH	-0.051	0.041	-0.01	0.009	0.017	-0.059	0.006	-0.102	0.058	0.001	-0.018	0.04 r=-0.0698
DM	-0.031	0.067	-0.03	0.002	-0.002	-0.192	-0.096	-0.174	0.163	0.0001	0.017	0.008 r=-0.3086
PlH	0.007	0.025	0.082	-0.002	-0.004	1.437	-0.816	0.257	-0.286	0.002	0.008	0.042 r=0.7061
TKW	0.028	-0.01	0.012	-0.016	-0.037	0.371	-0.433	-0.106	0.112	-0.001	0.074	-0.083 r=-0.1198
HLW	0.021	0.003	0.008	-0.014	-0.042	0.257	-0.477	-0.14	0.135	-0.001	0.063	-0.076 r=-0.3096
BWt	0.002	-0.008	0.073	-0.004	-0.007	1.607	-0.953	0.163	-0.19	0.002	0.014	0.027 r=0.7196
HI	-0.0003	-0.006	-0.06	0.006	0.018	-1.387	1.103	-0.072	0.132	-0.002	-0.045	0.004 r=-0.2892
FTP	-0.009	0.021	-0.037	-0.003	-0.011	-0.463	0.142	-0.565	0.553	-0.001	0.02	-0.066 r=-0.4167
TTP	-0.005	0.019	-0.041	-0.003	-0.01	-0.532	0.254	-0.544	0.574	-0.001	0.015	-0.064 r=-0.3386
SL	0.007	-0.001	-0.024	-0.003	-0.007	-0.451	0.239	-0.098	0.107	-0.007	-0.045	-0.027 r=-0.3104
AL	0.007	0.009	0.005	-0.01	-0.021	0.181	-0.395	-0.087	0.069	0.003	0.126	-0.053 r=-0.1905
NKS	-0.018	0.005	0.03	0.012	0.028	0.376	0.035	0.32	-0.317	0.002	-0.057	0.116 r=0.5397

Residual=0.1079 : DH= days to heading, DM= days to maturity, PlH= plant height, TKW= thousand kernel weight, HLW= hectoliter weight, BWt= biomass weight, HI= harvest index, FTP= fertile tillers per plant, TTP= total number of tillers per plant, SL= spike length,AL=awnlength,NKS=numberofkernelsperspike

Table 6: Phenotypic direct (bold and diagonal) and indirect(non-diagonal) effects of six traits on malt extract of twenty genotypes studied at Bekoji and Kofele, 2015

	GPC	MPC	GE	ST	MMC	WC
GPC	-0.5174	0.1146	0.2083	-0.0076	0.1040	0.0545 r=-0.2557
MPC	-0.3742	0.1584	0.1370	0.0520	0.1108	0.0276 r=0.0527
GE	0.1590	-0.0320	-0.6780	0.0204	-0.0674	-0.0279 r=0.0762
ST	0.0126	0.0264	-0.0443	0.3122	0.1994	-0.0453 r=0.4486
MMC	-0.0742	0.0242	0.0631	0.0859	0.7249	-0.1517 r=0.4530
WC	-0.1209	0.0187	0.0810	-0.0605	-0.4711	0.2335 r=-0.4144

Residual=0.45547: GPC = grain protein content, MPC= malt protein content, GE= germination energy, ST= sieve test, MMC= malt moisture content and WC= wort colors

Malt protein content, malt moisture content and sieve test had positive indirect effect via grain protein content. Hence, it would be possible to select these parameters indirectly for the selection of genotypes with good malt extract content attributes.

Phenotypic Path Coefficient Analysis of Grain Yield

Biomass weight has exerted the highest positive direct effect for the grain yield accumulation followed by harvest index, total tillers per plant, awn length and number of kernels per spike, at phenotypic level as reported by Baboo and Chauhan, (1992). The phenotypic path coefficient analysis of grain yield is presented in (Table 15). Fertile tillers per plant, days to heading, spike length, hectoliter weight and thousand kernel weight exerted negative direct effect. This is in accordance with Setotaw et al., (2014). According to this study biomass yield, total tillers per plant and harvest index can be used as selection criteria to improve grain yield since these traits have strong positive correlation (Table 5).

Biomass weight (r=0.7196), plant height (r=0.7061) and number of kernels per spike (r=0.5397) have shown better association with grain yield at phenotypic level. Plant height (1.437), number of kernels per spike (0.376), thousand kernel weight (0.371), hectoliter weight (0.257) and awn length (0.181) exerted strong and positive indirect effect on grain yield via biomass weight. Nadziak et al., (1994) and Hennawy (1997) reported that number of kernels per spike and grain weight had strong main effect on yield. On the other hand, Naike et al., (1998) revealed that direct selection for productive tillers per plant and selection against plant height can improve grain yield. Accordingly, it would be possible to select these traits indirectly for the selection of plants with better yield.

Phenotypic Path Coefficient Analysis of Malt Extract Content

At phenotypic level, malt moisture content (0.7249), sieve test (0.3122), wort color (0.2335) and malt protein content (0.1584) exerted positive direct effect on malt extract content. The phenotypic path coefficient analysis of malt extract content is presented in (Table 6). Germination energy (-0.6780) and grain protein content (-0.5174) exerted negative direct effect on malt extract. According to our result it is possible to improve malt extract by selecting genotypes with high sieve test, good wort color and reduced grain protein and malt protein content. The result did also show the trait with positive direct effect have strong positive correlation (Table 16). This experiment showed malt moisture content (r=0.4530) and sieve test (r=0.4486) had strong association with malt extract content.

Grain protein content had positive direct effect on malt extract at genotypic level, but negative direct effect at phenotypic level. In addition, it had negative correlations both at genotypic and phenotypic. This shows cautious selection of malt barley genotypes based on the protein content of the grain.

Conclusion

Tillers per plant, biomass yield, number of kernels per spike and sieve test can be used as selection criteria to improve grain yield and malt quality together, but cautiously taking grain protein during selection.

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