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Character Association and Path Analysis in Onion(Allium cepa L.) for Yield and Its Attributes

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Abstract
Information on the extent and nature of association among characters helps in formulating efficient scheme of multiple trait selection, as it provides a means of direct and indirect selection of component characters. Therefore, the objective of this study was to assess the nature of association of yield contributing characters among themselves and also the direct and indirect effects of yield contributing characters on yield through path analysis. Two onion cultivars and six plant spacing were used in randomized complete block design in factorial arrangementwith three replications in 2014 cropping season. Correlation analysis revealed that the values of genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients for most of the traits. This suggests that the apparent associations might be largely due to genetic associations among the traits. Total bulb yield showed significant high positive phenotypic correlations with the number of marketable bulbs (r = 0.867**) and weight of marketable bulbs (r = 0.997**). The strongest positive and highly genotypic association was observed between weight of marketable bulbs and total bulb yield (r=0.999**). Weight of marketable bulb which showed maximum direct effect also exerted considerable positive indirect effect via biological fresh matter yield and negative indirect effect through plant height at maturity, indicating the need for attention while selecting these characters.
Keywords: Character association, Onion, Path analysis

1. INTRODUCTION

Onion (*Allium cepa* L.) 2n=16 is an important bulb crop, belongs to the family Alliaceae. The origin of the onion is still somewhat a mystery and Baloch (1994) reported that onion originated from Afghanistan, Tajikistan and Uzbekistan, Western Tien Shan, and India. It is cultivated for food, medicines, religious purpose, spices and condiments since early times ((Randle and Ketter, 1998).

Onion is considered as one of the most important vegetable crops produced on large scale in Ethiopia. It also occupies an economically important place among vegetables in the country. The area under onion is increasing from time to time mainly due to its high profitability per unit area and ease ofproduction, and the increases in small scale irrigation areas. Despite areas increase, the productivity of onion is very low as compared to that of other countries (FAO,2015). In any breeding program of complex characters such as yield for which direct selection is not effective, it becomes essential to measure the contribution of each of the component variables to the observed correlation and to partition the correlation into components of direct and indirect effect (Singh, 2006).

Information on the extent and nature of interrelationship among characters helps in formulating efficient scheme of multiple trait selection, as it provides a means of direct and indirect selection of component characters. Therefore, the objective of this study was to assess the nature of association of yield contributing characters among themselves and also the direct and indirect effects of yield contributing characters on yield through path analysis.

2. MATERIALS AND METHODS

Experimental Site

The experiment was conducted at *Lai Bir*, West Gojam zone of Amhara Regional State, Ethiopia during 2014.The site is situated at an altitude of 1670 meters above sea level, at 10 ^{0}N latitude and 37 ^{0}E longitudes. The mean annual rainfall is 1031 mm, and the mean minimum and maximum temperatures of the area are 10.7 and 28.7^{0}C, respectively. The soil is nitosol with a pH ranging from 5.3-6.5.

Experimental Materials

Onion *(Allium cepa L.)* cultivars used for the experiment were “Adama Red” and “Bombay Red” obtained from Melkassa Agricultural Research Centre. Both cultivars were released in 1980, and adapted within altitude of 700-2000 m and having flat globe bulb shape. “Adama Red” has characteristics of erect leaf arrangement, dark red bulb skin colour and 110-130 maturity days. “Bombay Red” has medium leaf arrangement, light red bulb skin colour and 110-120 maturity days.

Treatments and Experimental Design

The experiment was laid out in randomized complete block design in factorial arrangement with three replications. The treatments consisted of two onion cultivars and six plant spacing (40 cm x 10 cm, 30 cm x 10 cm, 20 cm x 10 cm, 30 cm x 5 cm, 20 cm x 5cm, and 10 cm x 5 cm).

Data to be Collected

All agronomic data were collected on plot and plant bases. Days to maturity, bolting percentage and yield data were recorded from all plants in the middle rows leaving aside plants from the border rows. The following data were recorded on plant basis by randomly selecting 15 plants from central rows. Plant height (cm), Leaf number per plant at maturity, Leaf length (cm), Shoot fresh weight (kg), Shoot dry weight (kg), Total bulb yield (Kg), Number of marketable bulb, Weight of marketable bulb (Kg), Number of unmarketable bulb, Weight of unmarketable bulb (Kg),Biological fresh matter yield (kg), Biological dry matter yield (kg).

Data Analysis

Phenotypic (rp) and genotypic (rg) correlation coefficient

The correlation was estimated using the formula suggested by Miller *et al.* (1958):

$rp = Covxyp / (Varxp \times Varyp)^{1/2}$

Where, rp= phenotypic correlation, Covxyp =phenotypic covariance between the traits x and y, Varxp and Varyp = phenotypic variance of the traits x and y respectively.

$rg = Covxyg / (Varxg \times Varyg)^{1/2}$

Where, rg = genotypic correlation, Covxyg =genotypic covariance between the traits x and y, Varxg and Varyg = genotypic variance of the traits x and y respectively.

Path coefficient analysis

The path coefficient analysis described by Dewey and Lu (1959)allows partitioning of correlation coefficient into direct and indirect contributions (effects) of various traits towards dependent variable and thus helps in assessing the cause-effect relationship as well as effective selection. Genetic correlations were further partitioned into direct and indirect effects using the path coefficient analyses following the method of Dewey and Lu (1959).

$r_{ij} = p_{ij} + \sum r_{ik} P_{jk}$

Where: r_{ij} is association between independent variables (i) and dependent variable j as measured by phenotypic and genotypic correlation coefficients, Pij is component of direct effect of independent variable (j) as measured by the phenotypic and genotypic path coefficients and $\sum r_{ik} p_{jk}$ is the summation of components of indirect effect of a given independent variable (i) on a given dependent variable (j) through all other independent variables.

3. RESULTS AND DISCUSSION

Correlation Coefficient

Correlation co-efficient measure the relationship between two or more variables, which is helpful in determining components of a complex character. Yield is a complex character resulting from the interaction of a number of factors and the environmental conditions. In order to develop a high yielding genotype, selection based on the performance of the yield is usually not very efficient but when it is based on the component characters it may give more efficient results. Phenotypic and genotypic correlation analysis between total bulb yield and yield related traits are presented in Table 1.

Phenotypic correlation

Total bulb yield showed significant high positive phenotypic correlations with the number of marketable bulbs (r = 0.867**), weight of marketable bulbs (r = 0.997**), number of unmarketable bulbs (r = 0.790**), weight of unmarketable bulbs (r = 0.685**), shoot fresh weight (r = 0.762**), shoot dry weight (r = 0.820**), biological fresh matter yield (r = 0.872**) and biological dry matter yield (r = 0.862**).The results signify that these characters are the most important attributes of total bulb yield. Kassahun(2006) andAbayneh (2001) reported significant and positive correlation of bulb yield withfresh weight above ground, dry weight above ground and biological yield per plant.On the other hand, total bulb yieldshowed significant negative phenotypic associations with with plant height at maturity (r = -0.579**), leaf number per plant at maturity (r = -0.658**), and percent dry matter (r = -0.534**).These results could suggest that plant height of onion at maturity negatively affects total bulb yield. The present findings are in agreement with those of Hosamani*et al*. (2010), SamaptikaKar*et al.*(2014), Kadam*et al.* (2016), Prajapati*et al.* (2016), who reportednegative correlation existed between yield and plant height of garlic.

Generally, total bulb yield showed positive phenotypic associations with weight of marketable bulbs, weight of unmarketable bulbs, biological fresh matter yield, number of unmarketable bulb, number of marketable bulb, shoot fresh weight and biological dry matter yield percent dry matter and negative association with all the rest traits across locations. Therefore, the positive association of total bulb yield with these traits suggested that the possibility of simultaneous improvement of grain yield through indirect selection of these positively correlated traits.

Genotypic correlation

At genotypic level total bulb yield showed positive and highly significant correlations with weight of marketable bulbs (r=0.999**), biological fresh matter yield (r=0.967**),biological dry matter yield (r=0.954**), number of marketable bulb (r=0.933**), and shoot fresh weight (r=0.910**). Therefore, the positive association of total bulb yield with these traits suggested that the possibility of simultaneous improvement of bulb yield through indirect selection of these positively correlated traits. On the other hand, total bulb yield had negative and significance genotypic association with leaf length at maturity (r= -0.979**), plant height at maturity (r= -0.978**) and leaf number per plant at maturity (r= - 0.968**). The strongest positive and highlygenotypic association was observed between weight of marketable bulbs and total bulb yield (r=0.999**) followed by number of marketable bulband biological dry matter yield (r= 0.998**) and shoot dry weight and number of unmarketable bulbs (r= 0.988**).Similar result was found by Tsega*et al.* (2010), Dubey *et al.* (2010) and Bhatt *et al.*(2017) in garlic. have also reported similar significant positive correlation between total bulb yield withweight of marketable bulbs and biological fresh matter yield andbiological dry matter yield.

Generally, the values of genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients for most of the traits. This suggests that the apparent associations might be largely due to genetic associations among the traits. The existence of strong positive association between total bulb yield and other traits helps in identifying traits that could be used for indirect selection for the improvement of bulb yield. Therefore, to facilitate selection in breeding for high yield and other desirable traits, it is logical to examine various components and give more attention to those having the greatest influence on bulb yield. The positive association allows simultaneous genetic improvement for bulb yield. This is because a positive association between two desirable traits makes the job of plant breeder easy for improving both traits simultaneously. Unlike positive correlation, negative correlation between two desirable traits may impede or makes it impossible to achieve the simultaneous improvement of those traits along with each other.

Table 1: Estimates of correlation coefficients at genotypic (above diagonal) and phenotypic (below diagonal) for bulb yield and yield related traits among fourteen characters in onion

Traits	PHM	LNPPM	LLM	SFW	SDW	NMB	WMB	NUMB	WUMB	BFMY	BDMY	PDM	HI	TBY
PHM		0.964**	0.977**	-0.870*	-0.872*	-0.899*	-0.979**	-0.786	-0.644	-0.956**	-0.925**	-0.555	0.476	-0.978**
LNPPM	0.293		0.986**	-0.963**	-0.970**	-0.978**	-0.960**	-0.920**	-0.823*	-0.999**	-0.987**	-0.357	0.570	-0.968**
LLM	0.392*	0.362*		-0.915*	-0.929**	-0.939**	-0.976**	-0.865*	-0.748	-0.982	-0.955**	-0.367	0.637	-0.979**
SFW	-0.452**	-0.558**	-0.482**		0.993	0.998	0.894	0.980**	0.926**	0.972	0.991**	0.234	-0.535	0.910**
SDW	-0.492**	-0.663**	-0.432**	0.867**		0.994	0.889	0.988**	0.936**	0.975	0.987**	0.177	-0.604	0.905*
NMB	-0.544**	-0.657**	-0.479**	0.932**	0.933**		0.919	0.972**	0.907*	0.985	0.998**	0.266	-0.555	0.933**
WMB	-0.571**	-0.646**	-0.524**	0.734**	0.798**	0.842**		0.816*	0.680	0.959	0.943**	0.500	-0.550	0.999**
NUMB	-0.472**	-0.660**	-0.427**	0.877**	0.868**	0.953**	0.759**		0.978**	0.929	0.956**	0.053	-0.613	0.837*
WUMB	-0.358*	-0.607**	-0.392*	0.810**	0.779**	0.878**	0.646**	0.946**		0.837	0.877*	-0.119	-0.589	0.707
BFMY	-0.625**	-0.562**	-0.569**	0.814**	0.789**	0.865**	0.852**	0.775**	0.719**		0.991**	0.339	-0.575	0.967**
BDMY	-0.535**	-0.629**	-0.423*	0.867**	0.866**	0.918**	0.840**	0.858**	0.793**	0.938**		0.318	-0.549	0.954**
PDM	0.447**	-0.093	0.401*	-0.480**	-0.409*	-0.528**	-0.535**	-0.464**	-0.382*	-0.475**	-0.477**		0.367	0.476
HI	-0.019	0.229	-0.084	-0.225	-0.144	-0.165	-0.147	-0.181	-0.198	-0.028	-0.194	0.272		-0.561
TBY	-0.579**	-0.658**	-0.539**	0.762**	0.820**	0.867**	0.997**	0.790**	0.685**	0.872**	0.862**	-0.534**	-0.157	

* P≤ 0.05; ** P≤ 0.01, PHM = plant height at maturity, LNPPM = leaf number per plant at maturity, LLM = leaf length at maturity, SFW = shoot fresh weight, SDW = shoot dry weight, NMB = number of marketable bulb, WMB = weight of marketable bulbs, NUMB = number of unmarketable bulb, WUMB = weight of unmarketable bulbs, BFMY = biological fresh matter yield, BDMY = biological dry matter yield, PDM = percent dry matter and HI = harvest index, TBY = total bulb yield.

Path Coefficient Analysis

Path coefficient analysis provides an effective means of finding direct and indirect causes of association (Wright, 1921). In the present investigation, the path coefficient analysis was done with fourteen characters using estimates of direct and indirect effects of fourteen characters on bulb yield based on phenotypic and genotypic correlation coefficients (Table 2 and 3).

Phenotypic path analysis

Partitioning of phenotypic correlations into direct and indirect effects on total bulb yield revealed that all the traits included in the path analysis showed positive and negative direct effects (Table 6). Maximum positive direct effects on total bulb yield was exerted by number of marketable bulb (0.131) followed by weight of marketable bulb (0.930), percent dry matter (0.082), and leaf number per plant at maturity(0.082) and was found to be the most important bulb yield components. High and positive direct effect of number of marketable bulb and weight of marketable bulbon bulb yield have also been reported in garlic by Pervin*et al.,* (2014) and Satesh Kumar *et al.*(2015).

Table 2: Estimates of phenotypic path analysis of the direct (bolded diagonal) and indirect (off-diagonal) effects of different characters on bulb yield of onion

Traits	PHM	LNPPM	LLM	SFW	SDW	NMB	WMB	NUMB	WUMB	BFMY	BDMY	PDM	HI	r_p
PHM	**-0.005**	0.024	-0.017	0.030	0.001	-0.071	-0.531	-0.024	-0.001	-0.022	-0.001	0.037	0.001	-0.579**
LNPPM	-0.001	**0.082**	-0.016	0.037	0.002	-0.086	-0.601	-0.033	-0.002	-0.020	-0.002	-0.008	-0.011	-0.658**
LLM	-0.002	0.030	**-0.043**	0.032	0.001	-0.063	-0.487	-0.022	-0.001	-0.020	-0.001	0.033	0.004	-0.539**
SFW	0.002	-0.046	0.021	**-0.066**	-0.003	0.122	0.683	0.044	0.003	0.029	0.002	-0.040	0.011	0.762**
SDW	0.002	-0.055	0.019	-0.058	**-0.003**	0.123	0.742	0.044	0.003	0.028	0.002	-0.034	0.007	0.820**
NMB	0.002	-0.054	0.021	-0.062	-0.003	**0.131**	0.783	0.048	0.003	0.030	0.002	-0.043	0.008	0.867**
WMB	0.003	-0.053	0.023	-0.049	-0.002	0.111	**0.930**	0.038	0.002	0.030	0.002	-0.044	0.007	0.997**
NUMB	0.002	-0.054	0.018	-0.058	-0.003	0.125	0.706	**0.051**	0.003	0.027	0.002	-0.038	0.009	0.790**
WUMB	0.002	-0.050	0.017	-0.054	-0.002	0.115	0.601	0.048	**0.003**	0.025	0.002	-0.031	0.009	0.685**
BFMY	0.003	-0.046	0.025	-0.054	-0.002	0.114	0.792	0.039	0.002	**0.035**	0.002	-0.039	0.001	0.872**
BDMY	0.002	-0.052	0.018	-0.058	-0.003	0.121	0.781	0.043	0.003	0.033	**0.003**	-0.039	0.009	0.862**
PDM	-0.002	-0.008	-0.017	0.032	0.001	-0.069	-0.497	-0.023	-0.001	-0.017	-0.001	**0.082**	-0.013	-0.534**
HI	0.000	0.019	0.004	0.015	0.000	-0.022	-0.137	-0.009	-0.001	-0.001	0.000	0.022	**-0.048**	-0.157

PHM = plant height at maturity, LNPPM = leaf number per plant at maturity, LLM = leaf length at maturity, SFW = shoot fresh weight, SDW = shoot dry weight, NMB = number of marketable bulb, WMB = weight of marketable bulbs, NUMB = number of unmarketable bulb, WUMB = weight of unmarketable bulbs, BFMY = biological fresh matter yield, BDMY = biological dry matter yield, PDM = percent dry matter and HI = harvest index, TBY = total bulb yield.

Shoot fresh weight exerted negative direct effects on total bulb yield but exhibited positive phenotypic correlation with bulb yield due to their positive indirect effects through number of marketable bulb and weight of marketable bulb. Therefore, the indirect causal factor should be considered simultaneously.

Generally, number of marketable bulb and weight of marketable bulb turned out to be the major components of total bulb yield and direct selection for these traits will be rewarding for bulb yield improvement.

Genotypic path analysis

Genotypic path analysis showed that weight of marketable bulb, leaf number per plant at maturity, number of unmarketable bulb, shoot fresh weight and harvest index showed positive direct effect (Table 3). The highest genotypic direct effect on total bulb yield was exerted by weight of marketable bulb (1.600) followed by leaf number per plant at maturity (1.009). Tsega*et al.* (2010), Singh *et al.,* (2012), Singh *et al.,* (2013) andDhall*et al.*(2013) also reported that weight of marketable bulb had the highest direct effect on total bulb yield. The positive genotypic direct effect of weight of marketable bulb and harvest index are in conformity with the results obtained by Sharma *et al*. (2016) in their study on character association and path analysis in garlic.

Table 3: Estimates of genotypicpath analysis of the direct (bolded diagonal) and indirect (off-diagonal) effects of different characters on bulb yield of onion

Traits	PHM	LNPPM	LLM	SFW	SDW	NMB	WMB	NUMB	WUMB	BFMY	BDMY	PDM	HI	r_g
PHM	**-1.412**	0.973	-0.086	-0.409	0.251	0.116	-1.567	-0.710	0.026	0.661	0.721	0.284	0.176	-0.978**
LNPPM	-1.361	**1.009**	-0.087	-0.453	0.279	0.126	-1.537	-0.831	0.033	0.691	0.769	0.183	0.211	-0.968**
LLM	-1.379	0.995	**-0.089**	-0.430	0.267	0.121	-1.561	-0.781	0.030	0.680	0.744	0.188	0.236	-0.979**
SFW	1.229	-0.972	0.081	**0.470**	-0.286	-0.128	1.430	0.885	-0.037	-0.672	-0.773	-0.120	-0.198	0.910**
SDW	1.383	-0.969	0.086	0.421	**-0.288**	-0.128	1.422	0.892	-0.037	-0.675	-0.770	-0.090	-0.224	0.905*
NMB	1.270	-0.987	0.083	0.469	-0.286	**-0.128**	1.471	0.878	-0.036	-0.681	-0.778	-0.136	-0.206	0.933**
WMB	1.383	-0.969	0.086	0.421	-0.255	-0.118	**1.600**	0.737	-0.027	-0.663	-0.735	-0.256	-0.204	0.999**
NUMB	1.110	-0.929	0.077	0.461	-0.284	-0.125	1.305	**0.903**	-0.039	-0.643	-0.745	-0.027	-0.227	0.837*
WUMB	0.910	-0.830	0.066	0.436	-0.269	-0.116	1.089	0.883	**-0.040**	-0.579	-0.684	0.061	-0.218	0.707
BFMY	1.349	-1.008	0.087	0.457	-0.280	-0.126	1.534	0.839	-0.033	**-0.692**	-0.773	-0.173	-0.213	0.967**
BDMY	1.306	-0.996	0.085	0.466	-0.284	-0.128	1.508	0.863	-0.035	-0.686	**-0.780**	-0.162	-0.204	0.954**
PDM	0.784	-0.361	0.033	0.110	-0.051	-0.034	0.800	0.048	0.005	-0.235	-0.248	**-0.511**	0.136	0.476
HI	-0.671	0.576	-0.056	-0.252	0.174	0.071	-0.881	-0.554	0.024	0.398	0.428	-0.187	**0.371**	-0.561

PHM = plant height at maturity, LNPPM = leaf number per plant at maturity, LLM = leaf length at maturity, SFW = shoot fresh weight, SDW = shoot dry weight, NMB = number of marketable bulb, WMB = weight of marketable bulbs, NUMB = number of unmarketable bulb, WUMB = weight of unmarketable bulbs, BFMY = biological fresh matter yield, BDMY = biological dry matter yield, PDM = percent dry matter and HI = harvest index, TBY = total bulb yield.

The direct effect of plant height at maturity and leaf length at maturity on total bulb yield and the overall correlation was high and negative due to maximum negative indirect effect of weight of marketable. Therefore, such considerable indirect effects should be considered for selection. Weight of marketable bulb which showed maximum direct effect also exerted considerable positive indirect effect via biological fresh matter yield and negative indirect effect through plant height at maturity, indicating the need for attention while selecting these characters. Generally, some yield components such as weight of marketable bulb, leaf number per plant at maturity and number of unmarketable bulb had big importance in determining total bulb yield.

4. SUMMARY AND CONCLUSION

In order to develop a high yielding genotype, selection based on the performance of the yield is usually not very efficient but when it is based on the component characters it may give more efficient results. Total bulb yield showed significant high positive phenotypic correlations with the number of marketable bulbs (r = 0.867**), weight of marketable bulbs (r = 0.997**), number of unmarketable bulbs (r = 0.790**), weight of unmarketable bulbs (r = 0.685**), shoot fresh weight (r = 0.762**), shoot dry weight (r = 0.820**), biological fresh matter yield (r = 0.872**) and biological dry matter yield (r = 0.862**). At genotypic level total bulb yield showed positive and highly significant correlations with weight of marketable bulbs (r=0.999**), biological fresh matter yield (r=0.967**), biological dry matter yield (r=0.954**), number of marketable bulb (r=0.933**), and shoot fresh weight (r=0.910**).The values of genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients for most of the traits. This suggests that the apparent associations might be largely due to genetic associations among the traits. Number of marketable bulb and weight of marketable bulb turned out to be the major components of total bulb yield and direct selection for these traits will be rewarding for bulb yield improvement. Though, further evaluation of these and other genotypes of onion at more locations and over years is advisable to confirm the promising results observed in the present study.

In general, it may be concluded that the information from this study could be valuable for researchers and/or academicians who anticipate to know the direct and indirect effects of yield component traits in different varieties of onion.

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