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Character association and path coefficient analysis in Onion (*Allium cepa* L.)

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Abstract
The present investigation was carried out to character association and path coefficient analysis among thirty genotypes of onion for fourteen characters comprised of bulb yield and its contributing characters. These genotypes were planted in Randomized Block Design with three replications during *Rabi*-2016-17, SKN College of Agriculture, Jobner. The result from character association indicated that bulb yield showed significant and positive correlation with number of scales, equatorial diameter, bulb volume, polar diameter, plant height, neck thickness, days to harvest after transplanting, number of leaves, pungency, sulphur content in bulb, dry matter content and TSS. Path coefficient analysis revealed that characters *viz.* equatorial diameter, plant height at harvest, pungency, neck thickness, dry matter content had positive direct effect on bulb yield. Hence, these characters may be simultaneously selected for developing better quality high yielding varieties of onion.

Keywords: Onion, Correlation, pod yield, Path analysis

Introduction
Onion (*Allium cepa* L.) is one of the important bulb crop of the family Amaryllidaceae and grown widely all over the world and consumed in various forms. Onion is characterized by its distinctive flavour and pungency which is the due to sulphur containing compounds (Allyl propyl disulphide) found in the scales of bulb. Onion consumption lowers the blood sugar (Augusti, 1990) [2]. India ranks first in area covering 1196 thousand hectare (Anonymous, 2017-18) [1] & second in production in the world next to China with production of 214.02 lakh tonnes (Anonymous, 2017-18) [1]. In India, onion is produced during two seasons' *i.e kharif* and *rabi*. The *rabi* crop of onion is grown at a very large scale in comparison to *kharif* crop in the state because of adverse climatic conditions like high temperature at the time of *kharif* seedling raising. Onion accounts for 70 percent of our total foreign exchange earnings from the export of fresh vegetables. Government of India has declared onion as an essential commodity. Correlation estimates between yield and its components are useful in developing suitable selection criteria for selecting desired plant types or developing high yielding cultivars. Path analysis is helpful in choosing the characters that have direct and indirect effects on yield. Such a study may be useful in effective selection and simultaneous improvement of the component characters which contribute towards yield.

Materials and Methods
The present investigation was carried out at Horticulutre Farm, S.K.N College of Agriculture, Sri Karan Narendra Agriculute University, Jobner, Rajasthan during the *rabi* season of the year 2016-17. The experimental material for the present study consisted of thirty promising genotypes of Onion collected from Rajasthan Agriculture Research Institute (RARI), Jaipur, Rajasthan and other genotypes from Directorate of Onion and Garlic, Pune, Maharashtra and CCS Haryana Agriculture University, Hisar, Haryana. The experiment was laid out in a completely Randomized Block Design with three replications of each genotype. Ten rows of each genotype were sown at spacing of 15 x 10 cm in a plot of size of 1.0 x 1.5 m^2. The standard cultural practices as mentioned in Package of Practices for Vegetable Crops by Thamburaj and Singh [13] were followed to raise the healthy crop stand

Correlation coefficient analysis
Simple correlation coefficients between yield and yield components and intercorrelation among the various components were calculated using the formula suggested by Panse and Sukhatme (1967) [8].

$$r = \frac{\sum xy - \frac{\sum xy}{n}}{\sqrt{\left(\sum x^2 - \frac{(\sum x)^2}{2}\right)\left(\sum y^2 - \frac{(\sum y)^2}{n}\right)}}$$

Where,
r = Correlation coefficient
n = Number of treatments
X and Y = Characters under study

Path coefficient analysis

Path coefficient analysis was carried out as suggested by Dewey and Lu (1959) [4] by partitioning the simple correlation coefficients into direct and indirect effects. The direct and indirect effects were ranked based on the scales of Lenka and Misra (1973) [6] as given below

Negligible: 0.00 to 0.09
Low: 0.10 to 0.19
Moderate: 0.20 to 0.29
High: 0.30 to 0.99
Very high: > 1.00

Result and Discuss

Correlation coefficient

Phenotypic and genotypic correlation coefficients among fourteen quantitative and qualitative characters are presented in Table 1.1. For most of the characters, genotypic correlation coefficient was found to be higher in magnitude than phenotypic correlation coefficient, indicating a strong inherent association among various characters.

Bulb yield showed significant and positive correlation with number of scales (r_p = 0.771, r_g = 0.994), equatorial diameter (r_p = 0.908, r_g = 0.974), bulb volume (r_p = 0.824 r_g = 0.940), polar diameter (r_p = 0.716, r_g = 0.738), plant height at harvest (r_p = 0.528, r_g = 0.596), neck thickness (r_p = 0.513, r_g = 0.593), days to harvest after transplanting (r_p = 0.465, r_g = 0.510), number of leaves (r_p = 0.378, r_g = 0.461), Pungency (r_p = 0.299, r_g = 0.301), sulphur content in bulb (r_p = 0.319, r_g = 0.296), dry matter content (r_p = 0.233, r_g = 0.258) and TSS (r_p = 0.260, r_g = 0.255). Plant height showed positive significant correlation with pungency (r_p = 0.624), sulphur content in bulb (r_p = 0.617), number of fleshy scale leaves (r_p = 0.579), polar diameter (r_p = 0.535), equatorial diameter (r_p = 0.493), days to harvest after transplanting (r_p = 0.459), neck thickness (r_p = 0.455), average bulb weight (r_p = 0.431), number of leaves (r_p = 0.306) and dry matter content (r_p = 0.224)

Number of leaves showed positive significant correlation with dry matter content (r_p = 0.544), equatorial diameter (r_p = 0.475), bulb volume (r_p = 0.400), number of fleshy scale leaves (r_p = 0.388), days to harvest after transplanting (r_p = 0.349), TSS (r_p = 0.301), pungency (r_p = 0.265), polar diameter (r_p = 0.263), number of leaves (r_p = 0.257) and sulphur content in bulb (r_p = 0.242). Neck thickness showed positive significant correlation with polar diameter (r_p = 0.626), number of fleshy scale leaves (r_p = 0.554), equatorial diameter (r_p = 0.468), bulb volume (r_p = 0.465), days to harvest after transplanting (r_p = 0.324), dry matter content (r_p = 0.271) and pungency (r_p = 0.224).

Polar diameter showed positive significant correlation with number of scales (r_p = 0.693), bulb volume (r_p = 0.687), days to harvest after transplanting (r_p = 0.438), sulphur content in bulb (r_p = 0.406), pungency (r_p = 0.392), dry matter content (r_p = 0.328) and TSS (r_p = 0.239). Equatorial diameter showed positive significant correlation with bulb volume (r_p = 0.830), number of scales (r_p = 0.765), days to harvest after transplanting (r_p = 0.480), sulphur content in bulb (r_p = 0.355), TSS (r_p = 0.354), pungency (r_p = 0.288) and dry matter content (r_p = 0.254).

Bulb volume showed positive significant correlation with number of scales (r_p = 0.710), days to harvest after transplanting (r_p = 0.450), dry matter content (r_p = 0.270), TSS (r_p = 0.242) and pungency (r_p = 0.216). Number of scales showed positive significant correlation with days to harvest after transplanting (r_p = 0.411), pungency (r_p = 0.268) and sulphur content in bulb (r_p = 0.267).

Days to harvest after transplanting showed positive significant correlation with sulphur content in bulb (r_p = 0.488), pungency (r_p = 0.440), dry matter content (r_p = 0.429). TSS showed positive significant correlation with sulphur content in bulb (r_p = 0.217). Dry matter content showed positive significant correlation with pungency (r_p = 0.490) and sulphur content in bulb (r_p = 0.397). Pungency showed positive significant correlation with sulphur content in bulb (r_p =0.917).

Bulb yield showed significant and positive correlation with number of scales, equatorial diameter, bulb volume, polar diameter, plant height at harvest, neck thickness, days to harvest after transplanting, number of leaves, pungency, sulphur content in bulb, dry matter content and TSS content in bulb. These findings corroborated the earlier findings of Rajalingam and Haripriya (2000) [10], Mohanty (2001) [7], Trivedi *et al*. (2006) [14], Gurjar and Singhania (2006) [5], and Saini and Maurya (2014) [11].

Path Coefficient Analysis

Path coefficient analysis was employed to resolve correlation coefficient of different characters towards bulb yield into their direct and indirect effects. The results of various causes influencing bulb yield are presented in Table 1.2. The results of path coefficient analysis indicated that at the genotypic level, the maximum direct positive effect on bulb yield was equatorial diameter (1.468) followed by plant height at harvest (0.377), pungency (0.344), neck thickness (0.107), dry matter content (0.090). The maximum negative direct effect on bulb yield was exerted by sulhpur content in bulb (-0.517) followed by number of scales (-0.496), days to harvest after transplanting (- 0.209), number of leaves (-0.131), TSS (-0.103), bulb yield (-0.016) and polar diameter (0.004).

Plant height at harvest showed positive indirect effect on bulb yield through equatorial diameter (0.784) followed by pungency (0.237), neck thickness (0.054) and dry matter content (0.023). Number of leaves showed positive indirect effect on bulb yield through equatorial diameter (0.768) followed by plant height at harvest (0.118), pungency (0.103), dry matter content (0.058) and neck thickness (0.032). Neck thickness showed positive indirect effect on bulb yield through equatorial diameter (0.779) followed by plant height at harvest (0.193), pungency (0.083), dry matter content (0.083) and TSS (0.003).

Polar diameter showed positive indirect effect on bulb yield through equatorial diameter (1.079) followed by plant height at harvest (0.225), pungency (0.135), neck thickness (0.076) and dry matter content (0.031). Equatorial diameter showed positive indirect effect on plant height at harvest (0.202) followed by pungency (0.097), neck thickness (0.057) and dry matter content (0.023).

Bulb volume showed positive indirect effect on bulb yield through equatorial diameter (1.330) followed by plant height at harvest (0.193), pungency (0.076), neck thickness (0.063) and dry matter content (0.024). Number of fleshy scale leaves showed positive indirect effect on bulb yield through equatorial diameter (1.357) followed by plant height at harvest (0.269), pungency (0.104), neck thickness (0.076) and dry matter content (0.016).

Days to harvest after transplanting showed positive indirect effect on bulb yield through equatorial diameter (0.824) followed by plant height at harvest (0.222), pungency (0.174), dry matter content(0.046) and neck thickness (0.046). TSS showed positive indirect effect on bulb yield through equatorial diameter (0.515) followed by pungency (0.0.34), plant height at harvest (0.027) and dry matter content (0.015). Dry matter content showed positive indirect effect on bulb yield through equatorial diameter (0.381) followed by pungency (0.169), plant height at harvest (0.095) and neck thickness (0.026). Sulphur cotent in bulb showed positive indirect effect on bulb yield through equatorial diameter (0.495) followed by pungency (0.318), plant height at harvest (0.251), dry matter content (0.036) and neck thickness (0.022).

At phenotypic level among the various characters studied equatorial diameter had the highest positive effect followed by pungency (0.161), bulb volume (0.144), number of fleshy leaves (0.077), plant height at harvest (0.067), neck thickness (0.037), polar diameter (0.036), days to harvest after transplanting (0.020) whereas sulphur content in bulb (-0.179), number of leaves (-0.088) and dry matter content (-0.040) had negative direct effect. The residual effect at genotypic level was 0.0128 and at phenotypic level was 0.1368. The results are in propinquity with Mohanty (2001) [7], Dehdari *et al*. (2002) [3], Gurjar and Singhania (2006) [5], Solanki *et al*. (2015) [12] and Raghuwanshi *et al.* (2016) [9].

Table 1: Phenotypic (P) and genotypic (G) correlation coefficients between different characters in onion

		PH (cm)	**NL**	**NT (cm)**	**PD (cm)**	**ED (cm)**	**BV (cm)**	**NS**	**DHT**	**TSS (%)**	**DMC (%)**	**Pungency (%)**	**S (%)**	**ABW (g)**	**BY ha-1(q)**
PH (cm)	P	1.000	0.306**	0.455**	0.535**	0.493**	0.431**	0.579**	0.459**	0.088NS	0.224*	0.624**	0.617**	0.528**	0.528**
	G	1.000	0.312**	0.511**	0.596**	0.535**	0.513**	0.713**	0.590**	0.072NS	0.252*	0.688**	0.665**	0.596**	0.596**
NL	P		1.000	0.257*	0.263*	0.473**	0.400**	0.388**	0.349**	0.301**	0.544**	0.265*	0.242*	0.378**	0.378**
	G		1.000	0.303**	0.349**	0.524**	0.471**	0.422**	0.506**	0.338**	0.647**	0.299**	0.250*	0.461**	0.461**
NT (cm)	P			1.000	0.626**	0.468**	0.465**	0.554**	0.324**	-0.013NS	0.271**	0.224*	0.197NS	0.513**	0.513**
	G			1.000	0.717**	0.531**	0.592**	0.710**	0.432**	-0.027NS	0.315**	0.241*	0.202NS	0.593**	0.593**
PD (cm)	P				1.000	0.703**	0.687**	0.693**	0.438**	0.239*	0.328**	0.392**	0.406**	0.716**	0.716**
	G				1.000	0.735**	0.757**	0.846**	0.494**	0.227*	0.341**	0.393**	0.387**	0.738**	0.738**
ED (cm)	P					1.000	0.830**	0.765**	0.481**	0.354**	0.254*	0.288**	0.355**	0.908**	0.908**
	G					1.000	0.907**	0.924**	0.562**	0.351**	0.259*	0.283**	0.338**	0.974**	0.974**
BV (cm)	P						1.000	0.710**	0.450**	0.242*	0.270*	0.216*	0.206NS	0.824**	0.824**
	G						1.000	0.842**	0.556**	0.249*	0.265*	0.222*	0.207NS	0.940**	0.940**
NS	P							1.000	0.411**	0.132NS	0.176NS	0.268*	0.267*	0.771**	0.771**
	G							1.000	0.473**	0.133NS	0.177NS	0.303**	0.284**	0.994**	0.994**
DHT	P								1.000	0.096NS	0.429**	0.440**	0.488**	0.465**	0.465**
	G								1.000	0.074NS	0.519**	0.506**	0.533**	0.510**	0.510**
TSS (%)	P									1.000	0.176NS	0.112NS	0.217*	0.260*	0.260*
	G									1.000	0.172NS	0.099NS	0.193NS	0.255*	0.255*
DMC (%)	P										1.000	0.490**	0.397**	0.233*	0.233*
	G										1.000	0.491**	0.400**	0.258*	0.258*
Pungency (%)	P											1.000	0.917**	0.299**	0.299**
	G											1.000	0.924**	0.301**	0.301**
S (%)	P												1.000	0.319**	0.319**
	G												1.000	0.296**	0.296**
ABW (g)	P													1.000	1.000**
	G													1.000	1.000**

*Significant at p=0.05 or at 5 % and **Significant at p=0.01 or at 1%

PH – Plant Height at harvest (cm)
NL- Number of Leaves
NT- Neck Thickness (cm)
PD- Polar Diameter (cm)
BV- Bulb Volume (cc)
NS- Number of Scales
DHT- Days to harvest after transplanting
DMC- Dry Matter Content (%)
ABW- Average Bulb Weight (g)
BY – Bulb Yield ha^{-1} (q)

Table 2: Phenotypic (P) and genotypic (G) path coefficients of various characters on bulb yield of onion

Characters		Plant Height at harvest (cm)	Number of leaves	Neck thickness(cm)	Polar Diameter (Cm)	Equatorial Diameter(cm)	Bulb volume (cc)	Number. of scales	Days to harvest from Transplanting	TSS (%)	Dry Matter Content (%)	Pungency (%)	Sulphur content (%)	r with Average Bulb Weight (g)
Plant Height at harvest (cm)	P	0.067	-0.026	0.017	0.019	0.347	0.062	0.045	0.009	0.000	-0.001	0.100	-0.110	0.528**
	G	0.377	-0.041	0.054	-0.002	0.784	-0.008	-0.354	-0.123	-0.007	0.023	0.237	-0.344	0.596**
Number of leaves	P	0.020	-0.086	0.010	0.009	0.333	0.058	0.030	0.007	-0.001	-0.002	0.043	-0.043	0.378**
	G	0.118	-0.131	0.032	-0.001	0.768	-0.007	-0.209	-0.106	-0.035	0.058	0.103	-0.129	0.461**
Neck thickness(cm)	P	0.030	-0.022	0.037	0.022	0.329	0.067	0.043	0.007	0.000	-0.001	0.036	-0.035	0.513**
	G	0.193	-0.040	0.107	-0.003	0.779	-0.009	-0.353	-0.090	0.003	0.028	0.083	-0.105	0.593**
Polar Diameter (cm)	P	0.036	-0.023	0.023	0.036	0.494	0.099	0.054	0.009	-0.001	-0.001	0.063	-0.073	0.716**
	G	0.225	-0.046	0.076	-0.004	1.079	-0.012	-0.420	-0.103	-0.023	0.031	0.135	-0.200	0.738**
Equatorial Diameter(cm)	P	0.033	-0.041	0.017	0.025	0.704	0.119	0.059	0.010	-0.001	-0.001	0.046	-0.064	0.908**
	G	0.202	-0.069	0.057	-0.003	1.468	-0.014	-0.459	-0.117	-0.036	0.023	0.097	-0.175	0.974**
Bulb volume (cc)	P	0.029	-0.034	0.017	0.025	0.584	0.144	0.055	0.009	-0.001	-0.001	0.035	-0.037	0.824**
	G	0.193	-0.062	0.063	-0.003	1.330	-0.016	-0.418	-0.116	-0.026	0.024	0.076	-0.107	0.940**
Number of Scales	P	0.039	-0.033	0.021	0.025	0.538	0.102	0.077	0.008	0.000	-0.001	0.043	-0.048	0.771**
	G	0.269	-0.055	0.076	-0.003	1.357	-0.013	-0.496	-0.099	-0.014	0.016	0.104	-0.147	0.994**
Days to harvest after Transplanting	P	0.031	-0.030	0.012	0.016	0.338	0.065	0.032	0.020	0.000	-0.002	0.071	-0.087	0.465**
	G	0.222	-0.066	0.046	-0.002	0.824	-0.009	-0.235	-0.209	-0.008	0.047	0.174	-0.276	0.510**
TSS (%)	P	0.006	-0.026	0.000	0.009	0.249	0.035	0.010	0.002	-0.002	-0.001	0.018	-0.039	0.260*
	G	0.027	-0.044	-0.003	-0.001	0.515	-0.004	-0.066	-0.016	-0.103	0.015	0.034	-0.100	0.255*
Dry Matter Content (%)	P	0.015	-0.047	0.010	0.012	0.179	0.039	0.014	0.009	0.000	-0.004	0.079	-0.071	0.233*
	G	0.095	-0.085	0.034	-0.001	0.381	-0.004	-0.088	-0.108	-0.018	0.090	0.169	-0.207	0.258*
Pungency (%)	P	0.042	-0.023	0.008	0.014	0.203	0.031	0.021	0.009	0.000	-0.002	0.161	-0.164	0.299**
	G	0.260	-0.039	0.026	-0.001	0.415	-0.004	-0.150	-0.106	-0.010	0.044	0.344	-0.478	0.301**
Sulphur content in bulb (%)	P	0.041	-0.021	0.007	0.014	0.250	0.030	0.021	0.010	-0.001	-0.002	0.147	-0.179	0.319**
	G	0.251	-0.033	0.022	-0.001	0.495	-0.003	-0.141	-0.111	-0.020	0.036	0.318	-0.517	0.296**

Residual effect: Phenotypic = 0.0128 and Genotypic = 0.13686

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