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Quality assessment in association with yield attributes contributing improved yield in onion (*Allium cepa* L.)

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ABSTRACT

Twenty-three genotypes/ hybrids of onion were evaluated at 'C' block farm of Bidhan Chandra Krishi Viswavidyalaya (Agricultural University), West Bengal, India during the Rabi (winter) seasons of 2017-18 and 2018-19 with an objective of determining the relative contribution of fourteen different characters on bulb yield. The results of this experiment revealed that total bulb yield was found to be positive and significantly correlated with polar diameter, days to maturity, total sugar and phenol both at genotypic and phenotypic level. While, negative association was observed with plant height at 60 DAT (Days after transplanting), pyruvic acid, severity of purple blotch disease both at genotypic and phenotypic level. Path coefficient analysis revealed that maximum positive direct effect on yield per plot was exhibited by average weight of ten bulbs followed by number of scales per bulb, number of leaves at 60 DAT, total sugar percentage, dry matter percentage, and polar diameter. The maximum negative direct effect was exhibited by equatorial diameter followed by plant height at 60 DAT, vitamin C, severity of purple blotch disease, phenol, pyruvic acid, total soluble solids. So a breeder while conducting improvement in onion should undergo selection based on longer polar diameter, more number of days to maturity, higher total sugar percentage and phenol, high average weight of ten bulbs, more number of scales per bulb, more number of leaves at 60 DAT, high polar diameter, high total sugar and dry matter percentage.

Keywords : *Allium cepa*, bulb yield, character association, improvement, path analysis, traits

Onion (*Allium cepa* L.) belonging to the family Alliaceae is one of the most important vegetables grown under outdoor conditions throughout the world. It stands second next to tomato in terms of importance (Sahoo *et al.*, 2017). The crop has originated in the old world and was domesticated in Central Asia, where the related-wild species are still found (Jain, 2012). The crop is valued for its unique pungency and hence has become an essential ingredient for preparing cuisines and seasoning in wide variety of dishes. Onion is popularly known as 'Pyaz', of which the bulbs are used as salad, cooked as vegetable. It is also used in preparation of pickles, flakes, paste etc. It is a rich source of minerals (Ca, P, and Fe), carbohydrates, protein, dietary fibre and vitamins (B and C) while low in calorie. In addition, antioxidant compounds such as quercetin have been reported to be present in onion (Baghizadeh *et al.*, 2009, Bal *et al.*, 2019). The quality of onion is directly proportional to its shape, size, colour and pungency of bulbs. Red coloured onions are generally highly pungent and are preferred in India, whereas, yellow or white coloured ones are less pungent, are preferred in European and Japanese market. Onion is often subjected to deterioration during transit and storage as it is semi-perishable in nature (Haydar *et al.*, 2007) and thus one cannot guarantee that the whole bulk of total production is consumed by people. This is due to lack of systematic crop improvement and low yield potential. These days special emphasis is given to those varieties/ hybrids which exhibits high yield, tolerance to diseases/ pests, good crop stand and keeping qualities (Singh *et al.*, 2013). So to improve yield especially through selection, knowledge of yield as well as the inter-relationship among its contributing characters is an important factor. Thus correlation studies helps in understanding the contribution of yield towards each character by using variance and covariance matrix (Pal *et al.*, 2017). But through correlation studies one cannot draw the conclusion about the nature and extent of contributions by each of the independent characters. So, path coefficient analysis serves the best option by allocating weights to different attributes while undergoing crop improvement programme. Hence, the present investigation was undertaken with an objective to estimate nature and magnitude of yield and its contributing characters to facilitate selection of desired traits towards crop improvement.

MATERIALS AND METHODS

Experimental site and environment

The investigation was carried out at 'C' Block Farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal during the *Rabi* (winter) seasons of 2017-18 and 2018-2019 situating at 23.50 North latitude

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and 89 East longitude and between 23° 23' North latitude and 87° 07' East longitude at MSL of 9.75m. The soil of the experimental farm was fine sandy-loam in texture, neutral in reaction with good water holding capacity. The meteorological observations taken during the experimental period of 2017-18 and 2018-19 are given in tables 1 and 2.

Experimental material, layout and observation

Evaluation of twenty-three diverse onion genotypes/ hybrids (Table 3) using Randomized Block Design with three replications during *Rabi* seasons of 2017-2018 and 2018-2019 was done at 'C' Block Farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal, India. Fifty days old seedlings were transplanted in the main field at a plot size of $2\times1m^2$ with a spacing of 15 cm plant to plant and 10 cm row to row. To raise a good crop, recommended package of practices and plant protection measures were taken. Harvesting was undertaken when the tops had fallen and withered. Growth parameters, which include plant height, number of leaves at 60 DAT, number of days to maturity and average weight of ten bulbs were recorded from ten randomly selected plants in each replication of each treatment. Bulb parameters which include polar diameter (mm), equatorial diameter (mm), number of scales per bulb and quality parameters *viz.*, TSS (^{0}Brix) of bulb, dry matter percentage, total sugar percentage using Anthrone method as per Dubois *et al.*, (1956), vitamin C (mg/g) using 2,6 dichloro-phenol indophenols titration method (A.O.A.C., 1975), pyruvic acid (µmole/g) using procedure of Anthon and Barrett (2003) with slight modification of Schwimmer and Weston method (1961), and from ten randomly selected bulbs in each replication of each treatment, total phenol (mg/g) was recorded. Disease severity of purple blotch was recorded on 0-5 scale as given by Bhangale and Joi (1985).

Statistical analysis

As per Al-Jibouri *et al.*(1958), by using analysis of variance and covariance matrix, the genotypic and phenotypic correlations were calculated, where total variability has splitted into replications, genotypes and errors. Furthermore, using genotypic correlation co-efficient, path co-efficient analysis was done to calculate the direct and indirect contribution of different characters with yield, using procedure of Dewey and Lu (1959). These statistical analyses were conducted using OP-STAT Software.

RESULTS AND DISCUSSION

Correlation studies

The phenotypic and genotypic correlation co-efficients are the important components in correlation studies. These two components help us to know the nature of relationship existing between yield and its component characters as well as the association among component characters themselves. Among various characters studied the genotypic correlations were of higher magnitude as compared to the corresponding phenotypic correlation depicting greater contribution of genetic factors towards growth and development of these traits associated (Chattopadhyay *et al.,* 2013).

The degree of association of different characters of onion bulb with bulb yield at both genotypic and phenotypic level were depicted in tables 4 and 5.

Association of different characters with total bulb yield

Total bulb yield was found to be positive and significantly associated with polar diameter (0.286, 0.241), days to maturity (0.495, 0.479), total sugar percentage (0.343, 0.328), phenol (0.465, 0.461) at genotypic and phenotypic levels, whereas, negative associations were observed with plant height at 60 DAT (-0.920, -0.882), pyruvic acid (-0.241, -0.239), severity of purple blotch disease (-0.927, -0.891) at both the level. Negatively non-significant association was noticed with number of leaves at 60 DAT (-0.209, -0.186), number of scales per bulb (-0.078, -0.070), equatorial diameter (-0.110, -0.089), vitamin C (-0.085, -0.056), total soluble solids (-0.058, -0.035) at both genotypic and phenotypic level, whereas, positive and non-significant association were noticed for average weight of 10 bulbs per plot (0.104, 0.109) and dry matter percentage (0.207, 0.201).

Genotypic correlation coefficient

The genotypic coefficient of 23 onion genotypes was worked out and presented in table 4. Among different characters studied, plant height at 60 DAT was found highly significant and positively correlated with number of leaves at 60 DAT (0.246), pyruvic acid (0.238), severity of purple blotch disease (0.952), while, it was highly significant and negatively associated with polar diameter (-0.288), days to maturity (-0.506), total sugar percentage (-0.392), phenol (-0.442) and non-significant correlations were found with number of scales per bulb (0.197), equatorial diameter (0.077), vitamin C (0.075), total soluble solids (0.067). Number of leaves at 60 DAT showed highly significant and positive association with equatorial diameter (0.449), phenol (0.247) and negatively correlated with total sugar percentage (-0.238) and total soluble solids (-0.327). At genotypic level, number of scales per bulb showed highly significant and positive association with equatorial diameter (0.599), average weight of 10 bulbs (0.463), vitamin C (0.557), pyruvic acid (0.496), total sugar percentage (0.292), dry

Table 1: Monthly meteorological observations during the experimental period of 2017-18

Month	Max. temp. (^{0}C)	Min. temp. (^{0}C)	Rainfall (cm)	Max. RH (%)	Min. RH (%)
October, 2017	32.05	24.41	23.1	94.38	72.96
November,2017	27.42	17.04	3.69	93.1	54.6
December.2017	25.94	14.27	1.47	93.54	61.52
January, 2018	24.35	9.4	0.0	89.38	44.64
February,2018	30.78	17	0.0	90.03	44.07
March, 2018	33.94	20.04	0.12	89.45	39.32
April, 2018	34.19	23.51	5.16	89.5	54

Table 2: Monthly meteorological observations during the experimental period of 2018-19

Month	Max. temp (^{0}C)	Min. Temp. (^{0}C)	Rainfall (cm)	Max. RH (%)	Min. RH (%)
September, 2018	33.44	25.41	15.78	87.33	70.133
October, 2018	32.35	22.48	1.65	92.93	52.35
November, 2018	30.81	17.49	0.42	94.43	46.27
December, 2018	24.51	12.05	2.07	92.54	48.03
January, 2019	25.26	9.8	0.0	83.93	43
February, 2019	27.10	14.03	8.25	90.92	44.46
March, 2019	32.09	20.19	2.73	91.58	46.16

Table 3: **Genotypes used in the study along with their sources**

Sl.No.	Name of the genotype	Sources
1	Arka Bheem	ICAR-IIHR, Bangalore
2	Arka Kirtiman	ICAR-IIHR, Bangalore
3	Arka Lalima	ICAR-IIHR, Bangalore
4	Arka Niketan	ICAR-IIHR, Bangalore
5	Akola Safed	PDKV, Akola, Maharashtra
6	Agrifound Light Red	NHRDF, Nasik, Maharashtra
7	Bhima Dark Red	DOGR, Rajgurunagar,Pune
8	Bhima Kiran	DOGR, Rajgurunagar,Pune
9	Bhima Raj	DOGR, Rajgurunagar,Pune
10	Bhima Red	DOGR, Rajgurunagar,Pune
11	Bhima Safed	DOGR, Rajgurunagar,Pune
12	Bhima Shakti	DOGR, Rajgurunagar,Pune
13	BhimaSubhra	DOGR, Rajgurunagar,Pune
14	Bhima Super	DOGR, Rajgurunagar,Pune
15	BhimaSweta	DOGR, Rajgurunagar,Pune
16	Hisar-2	HAU, Hisar
17	Hisar-4	HAU, Hisar
18	Kalyanpur Red Round	CSAUAT, Kanpur
19	L-28	NHRDF, Nasik, Maharashtra
20	Onion HO-3	HAU, Hisar
21	PRO-6	PAU,Ludhiana, Punjab
22	Punjab Naroya	PAU,Ludhiana, Punjab
23	Sukhsagar	Local market

matter percentage (0.279), total soluble solids (0.518), severity of purple blotch disease (0.293). Polar diameter showed highly significant and positive correlation with total soluble solids (0.239) and negatively associated with dry matter percentage (-0.274) and severity of purple blotch disease (-0.277), whereas, equatorial diameter showed highly significant and positive correlation with average weight of ten bulbs (0.797), vitamin C (0.585), total sugar percentage (0.335). Positive and significant correlation of average weight of ten bulbs with vitamin C (0.598), total sugar percentage (0.273), dry matter percentage (0.350), total soluble solids (0.299) were observed. Positive and significant association of number of days to maturity was seen with vitamin C (0.316), total sugar percentage (0.689), dry matter percentage (0.402), phenol (0.507) and negative correlation with severity of purple blotch disease (-0.384).

Vitamin C showed highly significant and positive correlation with pyruvic acid (0.768), total sugar percentage (0.478), dry matter percentage (0.531), total soluble solids (0.837) and non- significant correlation with phenol (0.088) and severity of purple blotch disease (0.189). Positive and significant association of pyruvic acid with total sugar percentage (0.364), total soluble solids (0.680), severity of purple blotch disease (0.320) and non-significant association with dry matter percentage (0.210) were obtained. Total sugar percentage showed significant and positive correlation with dry matter percentage (0.460), total soluble solids (0.440), phenol (0.333) and exhibited negative association with severity of purple blotch disease (-0.272). Dry matter showed positive and significant correlation with total soluble solids (0.562), phenol (0.375) and negative and non-significant correlation with severity of purple blotch disease (-0.172). Total soluble solids showed positive and non-significant association with phenol (0.043) and severity of purple blotch (0.069), whereas, phenol exhibited negative association and significant correlation with severity of purple blotch disease (-0.500).

Phenotypic correlation coefficient

Phenotypic correlation coefficient of 23 onion genotypes for 14 characters with yield were worked out and presented in table 5. Plant height exhibited positive and significant correlation with number of leaves (0.240), severity of purple blotch disease (0.870) and negative association with number of days to maturity (-0.459), total sugar percentage (-0.392), phenol (-0.442). Non-significant correlations were found in number of scales per plot (0.197), vitamin C (0.015), pyruvic acid (0.226), TSS (0.018). Number of leaves at 60 DAT showed positive and significant correlation with

Table 4: Genotypic coefficient of correlation among different important traits in onion

Traits	PH	NOL	NOS	PD	ED	AWB	DTM	VC	PA	TS	DM	TSS	PHE	SPB
NOL	0.246*													
NOS	0.197	-0.026												
PD	-0.288*	-0.051	-0.010											
ED	0.077	0.449**	0.599**	-0.193										
AWB	-0.111	0.192	0.463**	-0.287*	0.797**									
DTM	-0.506**	-0.163	0.106	0.100	-0.005	0.007								
VC	0.075	0.215	0.557**	0.090	0.585**	0.598**	0.316**							
PA	0.238*	0.047	0.496**	0.075	0.143	0.138	0.182	0.768**						
TS	-0.392**	-0.238*	0.292*	0.173	0.335**	0.273*	0.689**	0.478**	0.364**					
DM	-0.228	-0.080	0.279*	-0.274*	0.350**	0.363**	0.402**	0.531**	0.210	0.460**				
TSS	0.067	-0.327**	0.518**	0.239*	0.168	0.299*	0.228	0.837**	0.680**	0.440**	0.562**			
PHE	-0.442**	0.247*	-0.014	0.112	0.119	0.132	0.507**	0.088	0.153	0.333**	0.375**	0.043		
SPB	0.952**	0.180	0.293*	-0.277*	0.154	-0.086	-0.384**	0.189	0.320**	-0.272*	-0.172	0.069	-0.500**	
TY	-0.920**	-0.209	-0.078	0.286*	-0.110	0.104	0.495**	-0.085	-0.241*	0.343**	0.207	-0.058	0.465**	-0.927**

Table 5: Phenotypic coefficients of correlation among different important traits in onion

Traits	PH	NOL	NOS	PD	ED	AWB	DTM	VC	PA	TS	DM	TSS	PHE	SPB
NOL	0.240*													
NOS	0.144	-0.045												
PD	-0.198	-0.006	0.007											
ED	0.042	0.293*	0.271*	-0.129										
AWB	-0.126	0.179	0.375**	-0.225	0.590**									
DTM	-0.459**	-0.151	0.098	0.102	-0.001	0.002								
VC	0.015	0.172	0.231	0.005	0.210	0.370**	0.182							
PA	0.226	0.019	0.363**	0.052	0.129	0.127	0.179	0.443**						
TS	-0.359**	-0.201	0.229	0.118	0.325**	0.242*	0.635**	0.287*	0.343**					
DM	-0.226	-0.080	0.213	-0.201	0.314**	0.340**	0.377**	0.260*	0.204	0.425**				
TSS	0.018	-0.216	0.293*	0.068	0.092	0.219	0.173	0.425**	0.466**	0.292*	0.339**			
PHE	-0.429**	0.229	-0.006	0.106	0.079	0.140	0.488**	0.054	0.147	0.305*	0.364**	0.030		
SPB	0.870**	0.143	0.206	-0.220	0.150	-0.058	-0.350**	0.108	0.305*	-0.253*	-0.162	0.060	-0.477**	
TY	-0.882**	-0.186	-0.070	0.241*	-0.089	0.109	0.479**	-0.056	-0.239*	0.328**	0.201	-0.035	0.461**	-0.891**

*Note : **Significant at 1% level, *Significant at 5% level*

PH-Plant height at 60 DAT, NOL-Number of leaves at 60 DAT, NOS- Number of scales/bulb, PD-Polar diameter, ED-Equatorial diameter, AWB-Average weight of 10 bulbs, DTM- Days to maturity, VC- Vitamin C, PA-Pyruvic acid, TS-Total sugar %, DM- Dry matter %, TSS- Total soluble solids, PHE- Phenol, SPB- Severity of purple blotch disease, TY-Total yield.

Table 6: Estimates of direct and indirect effects of effects of different important traits in onion

Traits	PH	NOL	NOS	PD	ED	AWB	DTM	VC	PA	TS	DM	TSS	PHE	SPB
PH	**-0.611**	0.124	0.100	-0.039	-0.066	-0.058	-0.028	-0.029	-0.020	-0.108	-0.051	-0.001	0.074	-0.205
NOL	-0.150	**0.505**	-0.013	-0.007	-0.389	0.101	-0.009	-0.083	-0.004	-0.065	-0.017	0.005	-0.041	-0.038
NOS	-0.120	-0.013	**0.511**	-0.001	-0.519	0.244	0.005	-0.217	-0.042	0.081	0.062	-0.008	0.002	-0.063
PD	0.176	-0.025	-0.005	**0.137**	0.167	-0.151	0.005	-0.035	-0.006	0.048	-0.061	-0.003	-0.018	0.059
ED	-0.047	0.227	0.306	-0.026	**-0.866**	0.421	-0.0002	-0.227	-0.012	0.092	0.078	-0.002	-0.020	-0.033
AWB	0.067	0.097	0.236	-0.039	-0.691	**0.529**	0.0004	-0.233	-0.012	0.075	0.081	-0.004	-0.022	0.018
DTM	0.309	-0.082	0.053	0.013	0.004	0.003	**0.055**	-0.122	-0.015	0.190	0.090	-0.003	-0.085	0.082
VC	-0.045	0.108	0.284	0.012	-0.506	0.316	0.017	**-0.389**	-0.065	0.132	0.119	-0.013	-0.014	-0.040
PA	-0.145	0.024	0.253	0.010	-0.123	0.073	0.010	-0.299	**-0.085**	0.100	0.047	-0.010	-0.025	-0.069
TS	0.239	-0.120	0.149	0.023	-0.290	0.144	0.038	-0.186	-0.031	**0.276**	0.103	-0.006	-0.056	0.058
DTM	0.139	-0.040	0.142	-0.037	-0.303	0.191	0.022	-0.206	-0.017	0.127	**0.224**	-0.008	-0.063	0.037
TSS	-0.041	-0.165	0.265	0.032	-0.146	0.158	0.012	-0.326	-0.058	0.121	0.126	**-0.015**	-0.007	-0.014
PHE	0.270	0.125	-0.007	0.015	-0.103	0.069	0.028	-0.034	-0.013	0.092	0.084	-0.001	**-0.169**	0.107
SPB	-0.581	0.091	0.149	-0.038	-0.133	-0.045	-0.021	-0.073	-0.027	-0.075	-0.038	-0.001	0.084	**-0.215**

Note : Residual : 0.048

***Significant at 1% level, *Significant at 5% level*

PH-Plant height at 60 DAT, NOL-Number of leaves at 60 DAT, NOS- Number of scales/bulb, PD-Polar diameter, ED-Equatorial diameter, AWB-Average weight of 10 bulbs, DTM- Days to maturity, VC- Vitamin C, PA-Pyruvic acid, TS-Total sugar %, DM- Dry matter %, TSS- Total soluble solids, PHE- Phenol, SPB- Severity of purple blotch disease.

*The diagonal values **in bold** represent direct effects*

equatorial diameter (0.293) and non-significant correlation with average weight of ten bulbs (0.192), vitamin C (0.172), pyruvic acid (0.047), phenol (0.229), severity of purple blotch disease (0.143) , whereas, negative and non-significant correlations were observed with number of scales per bulb (-0.045), polar diameter (-0.006), days to maturity (-0.163), total sugar percentage (-0.201), dry matter percentage (-0.080) and TSS (-0.216). Number of scales per bulb showed positive and significant association with equatorial diameter (0.599), average weight of ten bulbs (0.463), pyruvic acid (0.363), TSS (0.518), while, non-significant association was observed in number of days to maturity (0.098), vitamin C (0.106), total sugar percentage (0.2290), dry matter percentage (0.213), severity of purple blotch disease (0.206). Polar diameter showed non-significant correlation with number of days to maturity (0.100), vitamin C (0.090), pyruvic acid (0.075), total sugar percentage (0.118), TSS (0.068), phenol (0.106). Whereas, equatorial diameter showed positive and significant correlation with average weight of 10 bulbs (0.797), total sugar percentage (0.335), dry matter percentage (0.314) and non-significant correlation with vitamin C (0.585), pyruvic acid (0.129), TSS (0.092), phenol (0.079), severity of purple blotch disease (0.150). Average weight of 10 bulbs showed positive and significant association with vitamin C (0.598), total sugar percentage (0.273), dry matter percentage (0.363) and non-significantly correlation with number of days to maturity (0.002), pyruvic acid (0.138), TSS (0.219), phenol (0.140). Positive and significant association of number of days to maturity was observed with total sugar percentage (0.689), dry matter percentage (0.377), phenol (0.507) and negatively associated with severity of purple blotch disease (-0.384) and non-significant association was observed for vitamin C (0.182), pyruvic acid (0.179), TSS (0.173).

Vitamin C showed positive and significant correlation with pyruvic acid (0.443), total sugar percentage (0.287), dry matter percentage (0.260), TSS (0.425) and non-significantly correlated with phenol (0.054), severity of purple blotch disease (0.189). Pyruvic acid showed positive and significant association with total sugar percentage (0.343), TSS (0.292), severity of purple blotch disease (0.305) and non-significant association with dry matter percentage(0.210), phenol (0.153).Total sugar percentage showed positive and significant correlation with dry matter percentage (0.425), TSS (0.440), phenol (0.333) and negative correlation with severity of purple blotch disease (-0.253). Dry matter percentage showed positive and significant association with TSS (0.562), phenol (0.375) and negative and non-significant association with severity of purple blotch disease (-0.172).TSS showed non-significant correlation with phenol (0.030), severity of purple blotch disease (0.060). Phenol content showed negative and significant association with severity of purple blotch disease (-0.477). Mahanthesh *et al*. (2007), Dhotre (2009), Hosamani *et al.* (2010), Bharti *et al.* (2011), Ashok *et al.* (2013), Rajya Laksmi (2015), Sharma *et al*. (2015), Raghuwanshi *et al.* (2016) reported association analysis result on onion.

Path coefficient analysis

Path coefficient analysis was originally proposed by Dewey and Lu (1959). It helps to analyze direct and indirect effects of each trait and permits a critical examination of the relative importance of each trait. In order to understand such effects the estimates of direct and indirect effects were worked out through path coefficient analysis (Table 6).

The analysis revealed maximum positive direct effect on yield per plot by average weight of 10 bulbs (0.529) followed by number of scales per bulb (0.511), number of leaves at 60 DAT (0.505), total sugar percentage (0.276), dry matter percentage (0.224), polar diameter (0.137), whereas, the maximum negative direct effect was exhibited by equatorial diameter (-0.866), plant height at 60 DAT (-0.611), vitamin C (-0.389), severity of purple blotch disease (-0.215), phenol (-0.169), pyruvic acid (-0.085), total soluble solids (-0.015).

Plant height at 60 DAT showed positive indirect effect on bulb yield via number of leaves at 60 DAT (0.124), number of scales per bulb (0.100), and phenol (0.074) and negative indirect effect via polar diameter (-0.039), equatorial diameter (-0.066), average weight of 10 bulbs (-0.058), days to maturity (-0.028), vitamin C (-0.029), pyruvic acid (-0.020), total sugar percentage (-0.108), dry matter percentage (-0.051), total soluble solids (-0.001), severity of purple blotch disease (-0.020) were observed. Number of leaves at 60 DAT showed positive indirect effect on bulb yield via average weight of 10 bulb (0.101), total soluble solids (0.005) whereas negative indirect effect was observed via plant height at 60 DAT (-0.015), number of scales per bulb (-0.013), polar diameter (-0.007), equatorial diameter (-0.389), days to maturity (-0.009), vitamin C (-0.083), pyruvic acid (-0.004), total sugar percentage (-0.069), dry matter percentage (-0.017), phenol (-0.041), severity of purple blotch disease (-0.038). Number of scales per bulb showed positive indirect effect on bulb yield via average weight of 10 bulbs (0.244), days to maturity (0.005), total sugar percentage (0.080), dry matter percentage (0.062), phenol (0.002) whereas negative indirect effect via plant height at 60 DAT (-0.120), number of leaves at 60 DAT(-0.013), polar diameter (-0.001), equatorial diameter (-0.519), vitamin C (-0.217), pyruvic acid

(-0.042), TSS (-0.051), severity of purple blotch disease (-0.063). Polar diameter showed positive indirect effect on bulb yield via plant height at 60 DAT (0.176), equatorial diameter (0.167), days to maturity (0.005), total sugar percentage (0.048), severity of purple blotch disease (0.059) and negative indirect effect was noted via number of leaves at 60 DAT (-0.025), number of scales per bulb (-0.005), average weight of 10 bulbs (-0.151), vitamin C (-0.035), pyruvic acid (-0.006), dry matter percentage (-0.616), TSS (-0.003), phenol (-0.018). Equatorial diameter showed positive indirect effect on number of leaves at 60 DAT (0.227), number of scales per bulb (0.306), average weight of 10 bulbs (0.421), total sugar percentage (0.092), dry matter percentage (0.078) and negative indirect effect was observed through plant height at 60 DAT (-0.047), polar diameter (-0.026), days to maturity (-0.227), pyruvic acid (-0.012), TSS (-0.002), phenol (-0.020). Average weight of 10 bulbs showed positive indirect effect via plant height at 60 DAT (0.067), number of leaves at 60 DAT (0.097), number of scales per bulb (0.236), days to maturity (0.004), total sugar percentage (0.075), dry matter percentage (0.081), severity of purple blotch disease (0.018) and negative indirect effect was recorded via polar diameter (-0.039), equatorial diameter (-0.691), vitamin C (-0.233), pyruvic acid (-0.011), TSS (-0.004), phenol (-0.022). Days to maturity showed positive indirect effect via plant height at 60 DAT (0.309), number of scales per bulb (0.053), polar diameter (0.013), equatorial diameter (0.004), average weight of 10 bulbs (0.003), total sugar percentage (0.190), dry matter percentage (0.090), severity of purple blotch disease (0.082) and negative indirect effect was noted via number of leaves at 60 DAT (-0.082), vitamin C (-0.012), pyruvic acid (-0.015), TSS(-0.003), phenol (-0.085).

Vitamin C showed positive indirect effect via number of leaves at 60 DAT (0.108), number of scales per bulb (0.284), polar diameter (0.012), average weight of 10 bulbs (0.316), days to maturity (0.017), total sugar percentage (0.132), dry matter percentage (0.119) and negative indirect effect was observed via plant height at 60 DAT (-0.045), equatorial diameter (-0.506), polar diameter (-0.065), TSS (-0.013), phenol (-0.014), severity of purple blotch disease (-0.040). Pyruvic acid showed positive indirect effect on bulb yield per plot via number of leaves at 60 DAT (0.024), number of scales per bulb (0.253), polar diameter (0.010), average weight of 10 bulbs (0.073), days to maturity (0.010), total sugar percentage (0.100), dry matter percentage (0.047) and negative indirect effect was noted via plant height at 60 DAT (-0.145), equatorial diameter (-0.123), vitamin C (-0.299), TSS(-0.010), phenol (-0.025), severity of purple blotch disease (-0.069).Total sugar showed positive indirect effect on bulb yield per plot via plant height at 60 DAT (0.239), number of scales per bulb (0.143), polar diameter (0.023), average weight of 10 bulbs (0.144), days to maturity (0.038), dry matter percentage (0.103), severity of purple blotch disease (0.058) and negative indirect effect was observed via number of leaves at 60 DAT (-0.120), equatorial diameter (-0.290), vitamin C (-0.186), pyruvic acid (-0.031), TSS (-0.006), phenol (-0.056). Dry matter percentage showed positive indirect effect via plant height at 60 DAT (0.139), number of scales per bulb (0.142), average weight of 10 bulbs (0.191), days to maturity (0.022), total sugar (0.127), severity of purple blotch disease (0.037) and negative indirect effect was noted via number of leaves at 60 DAT (-0.040), polar diameter (-0.037), equatorial diameter (-0.303), vitamin C (-0.206), pyruvic acid (-0.017), TSS (-0.008), phenol (-0.063). Total soluble solids showed positive indirect effect on bulb yield per plot via number of scales (0.265), polar diameter (0.032), average weight of 10 bulbs (0.158), days to maturity (0.012), total sugar percentage (0.121), dry matter percentage (0.126) and negative indirect effect was observed via plant height at 60 DAT (-0.041), number of leaves at 60 DAT (-0.185), equatorial diameter (-0.146), vitamin C (-0.326), pyruvic acid (-0.058), phenol (-0.007), severity of purple blotch disease (-0.014).Phenol showed that positive indirect effect via plant height at 60 DAT (0.270), number of leaves at 60 DAT (0.125), polar diameter (0.015), average weight of 10 bulbs (0.069), days to maturity (0.028), total sugar percentage (0.092), dry matter percentage (0.084), severity of purple blotch disease (0.107) and negative indirect effect was noted via number of scales per bulb (-0.007), equatorial diameter (-0.103), vitamin C (-0.034), TSS (-0.001), phenol (-0.169).

Severity of purple blotch disease showed positive indirect effect via number of leaves at 60 DAT (0.091), number of scales per bulb (0.149), phenol (0.084) and negative indirect effect via plant height at 60 DAT (-0.581), polar diameter (-0.038), equatorial diameter (-0.133), average weight of 10 bulbs (-0.045), days to maturity (-0.021), vitamin C (-0.073), pyruvic acid (-0.027), total sugar percentage (-0.075), days to maturity (-0.038), TSS (-0.001).

Monpara *et al.* (2005) showed that the polar had higher positive direct and indirect contribution towards bulb weight through equatorial and polar diameter, days to maturity. Golani *et al.* (2006) explained that while conducting path coefficient analysis emphasis should be given on direct and indirect effects while imposing selection criteria on bulb yield of onion. Consequently, these characters showed high level of positive indirect effect with strong correlation with total yield may help to consider the development of high yielding genotype.

Selection of major contributing traits identified in the analyses *viz.*, polar diameter, days to maturity, total sugar percentage, phenol content and high average weight of ten bulbs would be rewarding in rapid improvement of breeding populations for quality as well as bulb yield of onion. Framing the selection criteria, Sukhsagar, Punjab Naroya, Arka Niketan genotypes and Arka Kirtiman as a hybrid were identified to be of superior quality traits and high yielding, besides, Arka Bheem, Kalyanpur Red Round, Akola Safed, Agrifound Light Red out of twenty-three diverse onion genotypes/ hybrids considered in the experiment. These genotypes/ hybrids are being under evaluation for their identification for release as a variety and are in the germplasm panel for being utilized in further breeding programme.

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