DOI : 10.5958/0974-0112.2018.00040.3

Indian J. Hort. 75(2), June 2018: 226-236

Characterization and association of phenotypic and biochemical traits in onion under short day tropical conditions

Ravindra Dangi, Anil Khar*, Sabina Islam and Amrender Kumar**

Division of Vegetable Science, ICAR-Indian Agricultural Research Institute, New Delhi 110 012

ABSTRACT

The aim of the present study was to characterize 58 onion genotypes based on morphological and biochemical traits. Genotypes comprised of landraces, open-pollinated varieties, hybrids and breeding materials. Thirteen quantitative, nine qualitative and four biochemical traits were analyzed. Significant variability was observed in the evaluated morphological and biochemical traits. Pusa White Flat (PWF) was highest yielder and maximum TSS was recorded in 106BS2 (15.30 ± 3.03°B). Arka Kalyan had highest dry matter (15.70 ± 0.57%), Red Creole3 had highest pyruvic acid (6.32 ± 0.17 µmol/ ml) and total phenolic content was recorded highest (36.96 ± 2.00 mg/g FW) in Juni. Genotypes with waxy leaves and firm skin were also identified. Significant correlations between marketable yield and morphological traits were observed. Highly significant correlation between TSS and dry matter (*r* = 0.45), pyruvic acid and dry matter (*r* = 0.35) and significant and negative correlation between TSS and TPC (total phenolic content) (*r* = -0.32) was observed. The finding of this study were important to assess the genetic diversity of indigenous and exotic material and also to know about the correlation of desired traits which will be helpful in devising efficient strategies for trait introgression, breeding new germplasm resources and selecting diverse parents for heterosis breeding programme in short day tropical onion.

Key words : *Allium cepa*, onion diversity, correlation, pyruvic acid, total phenols.

INTRODUCTION

Bulb onion (*Aliium cepa* L.) is an economically important vegetable crop having world annual production of 88.54 million tonnes. China, India, USA, Russia, Turkey and Iran are the top five onion producing countries in the world. Per capita consumption of onion varies greatly among countries and the trend towards increase in consumption is increasing globally. Besides, onion consumption has been associated with reduced incidence of cardiovascular diseases and some cancer types which is attributed to its demonstrated biological properties such as antiplatelet, antioxidant, anti-inflammatory, anti-tumor and hypolipidemic activities.

Evaluating the genetic diversity is a pre-requisite for parental selection for an effective breeding programme. However, the genetic diversity in local bulb onion is persistently eroding due to intensive agriculture and cultivar uniformity. Genetic variability in onion is continuously created due to its allogamous reproductive behaviour. Modern varieties of international seed companies particularly F_1 hybrids having narrow genetic base are replacing existing cultivated onion varieties. Consequently, existing cultivated varieties having prospectively important adaptive genes are in peril to vanish. Therefore, it is important to evaluate and characterize the existing old varieties and landraces. Research on Indian onion diversity has been reported by various authors (Solanki *et al*., 15) but most of the studies are focused on local commercial varieties or germplasm. Besides, the number of genotypes used for diversity analysis are very low and can be as low as 10-12. Use of less number of genotypes are not ideal for diversity assessment which leads to the unavailability of diverse potential genotypes for hybridization and leads to research gap in onion improvement.

Breeding of short day onion varieties with high yield potential, good storage quality and resistance to various biotic and abiotic stress is of prime importance under Indian conditions. Hence, the main aim of our study was to characterize the genotypes based on morphological and biochemical traits, study the correlation of traits within themselves and estimate the extent of genetic diversity of onion genotypes. Identification of traits associated with characterizing genotypes would be useful for diversified onion breeding program. Besides, identification of diverse parents with desirable traits would form the basis for onion heterosis breeding programme. In our studies, we have used for the first time, hybrids and exotic lines from USA and Japan, which are sold in the local market and are grown by the local farmers.

MATERIALS AND METHODS

The experiment was carried out in the Division of Vegetable Science, ICAR-IARI, New Delhi. Delhi is

*Corresponding author's E-mail : anil.khar@gmail.com
**Agricultural Knowledge Management Unit, ICAR-IARI

classified as sub-tropical, semi-arid with cold winter and hot dry summer and falls under 28° 38’ 41.2800’’ N and 77° 13’ 0.1956’’ E with an elevation of 222 m height above mean sea level. A total of 58 genotypes comprising of 35 open pollinated varieties (OPVs), 13 hybrids, 4 landraces (LR) and 6 breeding lines (BL) were planted in randomized block design with three replications. In each replication, 60 plants of each genotype were planted in three rows with a spacing of 10 cm (plant to plant) and 15 cm (row to row). Thirteen quantitative and nine qualitative traits were recorded according to the guidelines of PPVFRA. Recommended cultural practices were followed for raising the crop. Biochemical analysis was carried out for total soluble solids (˚B), dry matter (%), pyruvic acid (µmol/ml) of bulbs and total phenolic content (mg/g FW). Total soluble solids (TSS) of onion were ascertained by using a hand refractometer model-PAL-3 (ATAGO, Japan) and expressed in °B. Dry matter (DM) of the onion bulbs was determined according to Nieuwhof *et al.* (10) with a couple of modifications. Pyruvic acid (PA) was assessed according to Anthon and Barrett (1). Total phenolic content (TPC) of onion leaves was assessed by Folin Ciocalteu Reagent method (Singleton and Rossi, 14) and expressed in ‘mg gallic acid equivalent (GAE)/g of fresh weight’. Data obtained from the experiments was subjected to analysis of variance with the use of Proc GLM procedure. Pearson’s correlation analysis was done by using PROC CORR. In addition, for individual basic statistics PROC UNIVARIATE was used. All the analysis was done using SAS, version 9.3 (SAS Institute, Cary, NC, USA).

RESULTS AND DISCUSSION

Significant variability ($p<0.0001$) was observed among all the genotypes for all the morphological and biochemical traits studied (Table 1). Observation on different morphological traits (Table 2) analyzed suggested that maximum plant height was recorded in Hisar-3 (61.40 ± 0.87 cm) and minimum in Red Creole1 (38.60 ± 1.31 cm). Significant differences for plant height have also been observed by Solanki *et al.* (15). Highest number of leaves were recorded in Early Grano (10.87 ± 0.76) and least in Red Creole1 (5.87 ± 0.23). Largest leaf length was observed in Hisar-3 (48.07 ± 1.30 cm) and the smallest in Red Creole1 (28.60 ± 1.00 cm). Likewise, widest leaf width was observed in N-2-4-1 (1.18 ± 0.06 cm) and narrowest in Superex (0.62 ± 0.02 cm). Pusa Red (15.93 ± 0.50 cm) recorded longest pseudostem and Juni (8.33 ± 0.50 cm) recorded shortest. Similarly, the widest pseudostem was recorded in Bhima Shweta (1.72 ± 0.04 cm) and narrower pseudostem in Superex (0.78 ± 0.01cm). Studies on bulb and yield related traits (Table 3) showed that Sukhsagar1 (4.52

Table 1. General statistics of the variables recorded in onion genotypes.

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum
PH (cm)	58	52.31	5.20	3034.00	38.60	61.40
NOL	58	8.43	0.99	489.19	5.87	10.87
LL (cm)	58	38.63	4.22	2241.00	28.60	48.07
LW (cm)	58	0.91	0.12	52.59	0.62	1.18
PsL (cm)	58	11.65	1.72	675.80	8.33	15.93
PsW (cm)	58	1.27	0.23	73.65	0.78	1.72
P (cm)	58	3.79	0.33	219.97	2.91	4.52
E (cm)	58	4.97	0.33	288.42	4.32	6.00
N (cm)	58	0.78	0.14	45.18	0.48	1.15
TSS (°B)	58	11.52	1.35	668.39	7.03	15.30
ABW (kg)	58	50.26	10.09	2915.00	25.85	75.99
FW (kg)	58	0.55	0.23	31.65	0.22	1.47
MY (t/ ha)	58	20.74	8.15	1203.00	5.71	46.74
GY (t/ ha)	58	25.34	8.02	1469.00	8.29	48.96
DM (%)	58	11.44	1.88	663.62	4.08	15.70
PA (µmol/ ml)	58	3.84	0.72	222.88	2.57	6.32
TPC (mg/ g FW)	58	25.46	4.17	1477.00	16.97	36.96

PH = Plant height; NOL = No of leaves, LL = Leaf length; LW = Leaf width; PsL = Pseudostem length; PsW = Pseudostem width; P = Polar diameter; E = Equatorial diameter; N = Neck thickness; TSS = Total soluble solids; ABW = Av bulb wt; FW = Foliage wt; MY = Marketable yield; GY = Gross yield; DM = Dry matter; PA = Pyruvic acid; TPC = Total phenolic content

Table 2. Characterization of onion accessions based on morphological traits.

Genotype	Status	PH (cm)	NOL (cm)	LL (cm)	LW (cm)	PsL (cm)	PsW (cm)
F_1 Hybrid-1	Hybrid	48.60 ± 0.60	8.87 ± 0.42	34.07 ± 1.90	0.87 ± 0.02	10.05 ± 1.14	1.16 ± 0.05
F_1 Hybrid-2	Hybrid	53.60 ± 1.83	9.60 ± 0.20	40.73 ± 1.51	0.96 ± 0.01	11.20 ± 0.20	1.37 ± 0.04
XP-Red	Hybrid	49.87 ± 1.15	8.67 ± 0.61	38.80 ± 0.92	1.01 ± 0.03	9.60 ± 0.20	1.24 ± 0.02
Arka Kalyan	OPV	47.13 ± 0.23	8.40 ± 0.40	35.13 ± 1.21	0.92 ± 0.02	10.20 ± 0.20	1.31 ± 0.06
Prema 178	OPV	48.80 ± 0.40	8.73 ± 0.70	35.67 ± 0.81	0.90 ± 0.06	10.93 ± 0.23	1.08 ± 0.05
Red Creole1	OPV	38.60 ± 1.31	5.87 ± 0 .23	28.60 ± 1.00	0.88 ± 0.02	9.00 ± 0.35	0.93 ± 0.03
Black Crown	OPV	43.13 ± 0.23	7.60 ± 0.40	32.00 ± 1.10	0.87 ± 0.06	10.93 ± 0.42	1.00 ± 0.03
Indam 4	Hybrid	47.13 ± 0.99	8.67 ± 0.42	34.07 ± 0.76	0.88 ± 0.05	11.13 ± 0.12	1.18 ± 0.04
KSP1191	Hybrid	50.27 ± 0.42	9.93 ± 0.81	36.27 ± 0.83	0.98 ± 0.08	11.53 ± 0.23	1.27 ± 0.06
Phursungi Local	Landrace	55.00 ± 1.78	8.73 ± 0.64	37.13 ± 0.46	1.01 ± 0.06	15.47 ± 0.81	1.18 ± 0.07
Hisar-3	OPV	61.40 + 0.87	8.60 ± 0.35	48.07 ± 1.30	1.11 ± 0.06	12.07 ± 0.12	1.60 ± 0.04
KRR	OPV	55.47 ± 0.64	8.53 ± 0.31	41.80 ± 0.20	0.98 ± 0.04	11.87 ± 0.31	1.23 ± 0.07
Bhima Kiran	OPV	53.73 ± 2.52	7.53 ± 0.31	39.07 ± 1.30	0.83 ± 0.06	12.13 ± 0.42	1.14 ± 0.03
BSS-262	Hybrid	47.07 ± 2.19	8.47 ± 0.23	34.13 ± 2.76	0.73 ± 0.04	9.87 ± 0.50	1.05 ± 0.06
NP-4	Hybrid	46.00 ± 0.53	8.13 ± 0.12	34.33 ± 0.83	0.86 ± 0.05	10.27 ± 0.58	1.09 ± 0.03
Punjab Naroha	OPV	57.93 ± 1.10	9.40 ± 0.35	41.00 ± 1.22	1.01 ± 0.04	14.20 ± 0.20	1.42 ± 0.02
Hisar-2	OPV	57.47 ± 0.95	10.53 ± 0.23	43.73 ± 1.03	1.06 ± 0.03	10.40 ± 0.35	1.53 ± 0.02
Bhima Shweta	OPV	61.33 ± 0.81	10.33 ± 0.31	45.53 ± 0.61	1.00 ± 0.03	14.20 ± 0.53	1.72 ± 0.04
PWR	OPV	54.67 ± 1.30	8.80 ± 0.35	40.07 ± 1.50	0.98 ± 0.01	13.00 ± 0.20	1.42 ± 0.02
PWF	OPV	54.73± 0.64	9.00 ± 0.20	42.73 ± 1.01	0.93 ± 0.01	10.40 ± 0.40	1.39 ± 0.03
Udaipur Local	OPV	49.73 ± 0.83	8.13 ± 0.42	37.47 ± 0.61	0.99 ± 0.05	11.33 ± 0.31	1.30 ± 0.08
Red Creole2	OPV	51.07 ± 0.64	7.27 ± 0.31	37.20 ± 0.53	0.85 ± 0.03	11.53 ± 0.42	1.02 ± 0.01
Red Creole3	OPV	53.40 ± 0.80	7.47 ± 0.58	40.67 ± 0.64	0.83 ± 0.01	11.00 ± 0.40	1.11 ± 0.03
Pusa Red	OPV	60.40 ± 1.06	9.00 ± 0.20	45.73 ± 2.14	0.92 ± 0.03	15.93 ± 0.50	1.49 ± 0.12
AFW	OPV	60.67 ± 0.31	9.60 ± 0.20	44.47 ± 0.31	1.00 ± 0.01	13.87 ± 0.31	1.53 ± 0.01
Sukhsagar1	Landrace	57.13 ± 1.53	8.13 ± 0.31	41.33 ± 0.58	1.11 ± 0.06	13.40 ± 0.35	1.38 ± 0.02
Sel. 325	BL	60.00 ± 0.87	9.53 ± 0.42	44.20 ± 1.91	1.12 ± 0.04	15.13 ± 0.50	1.58 ± 0.11
Bhima Shakti	OPV	58.20 ± 1.20	8.60 ± 0.35	43.13 ± 1.33	1.16 ± 0.05	13.80 ± 0.35	1.62 ± 0.11
Lucifer	Hybrid	47.00 ± 1.00	7.60 ± 0.40	35.73 ± 1.30	0.73 ± 0.07	9.67 ± 0.64	0.95 ± 0.03
106BS3	BL	58.87 ± 0.46	8.93 ± 0.31	43.07 ± 1.10	0.97 ± 0.02	14.47 ± 1.40	1.56 ± 0.12
Superex	Hybrid	44.40 ± 0.53	7.33 ± 0.12	31.87 ± 0.50	0.62 ± 0.02	9.67 ± 0.31	0.78 ± 0.01
Pioneer	Hybrid	54.13 ± 1.70	8.53 ± 0.50	39.47 ± 2.14	0.95 ± 0.03	11.80 ± 0.20	1.16 ± 0.07
BSS258	Hybrid	49.13 ± 0.42	8.80 ± 0.35	37.87 ± 1.33	0.89 ± 0.02	10.07 ± 0.31	1.01 ± 0.06
N-2-4-1	OPV	56.27 ± 0.23	9.53 ± 0.31	41.87 ± 0.95	1.18 ± 0.06	12.60 ± 0.20	1.57 ± 0.05
PRO-6	OPV	50.67 ± 1.21	8.67 ± 0.12	38.13 ± 1.27	0.80 ± 0.03	10.60 ± 0.87	1.29 ± 0.02
Early Grano	OPV	57.33 ± 1.53	10.87 ± 0.76	41.73 ± 0.90	0.85 ± 0.04	13.13 ± 0.61	1.55 ± 0.10
Bhima Shubhra	OPV	56.60 ± 1.25	8.33 ± 0.12	41.73 ± 1.70	0.83 ± 0.04	12.27 ± 0.42	1.30 ± 0.02
Sel.126	OPV	57.27 ± 0.76	8.60 ± 0.35	42.67 ± 1.17	0.95 ± 0.02	13.60 ± 0.20	1.39 ± 0.00
Yellow Grano	OPV	50.40 ± 1.20	7.67 ± 0.31	38.00 ± 0.60	0.88 ± 0.04	10.27 ± 0.12	0.98 ± 0.02
Pusa Riddhi	OPV	57.40 ± 1.15	8.67 ± 0.42	42.93 ± 2.40	1.06 ± 0.02	11.47 ± 0.42	1.39 ± 0.01
Juni	Hybrid	46.60 ± 0.80	6.27 ± 0.31	35.93 ± 0.70	0.71 ± 0.04	8.33 ± 0.50	0.87 ± 0.02
AKON555	Landrace	58.73 ± 1.50	9.47 ± 0.12	44.87 ± 1.29	1.02 ± 0.02	11.53 ± 0.90	1.66 ± 0.06
KSP1121	Hybrid	48.93 ± 1.03	8.00 ± 0.00	34.60 ± 1.00	0.79 ± 0.02	11.60 ± 0.20	1.19 ± 0.02
GWO-1	OPV	53.27 ± 0.58	7.93 ± 0.23	38.27 ± 1.63	0.91 ± 0.04	12.53 ± 0.31	1.40 ± 0.10

Genotype	Status	PH (cm)	NOL (cm)	LL (cm)	LW (cm)	PsL (cm)	PsW (cm)
JNDWO85	OPV	56.87 ± 3.21	9.00 ± 0.72	40.87 ± 2.66	0.89 ± 0.04	13.47 ± 0.23	1.39 ± 0.17
Arka Kirthiman	Hybrid	51.20 ± 1.40	7.40 ± 0.20	38.40 ± 2.71	0.81 ± 0.02	12.67 ± 0.64	0.98 ± 0.02
Pusa Madhavi	OPV	56.67 ± 3.16	9.33 ± 0.31	42.47 ± 1.22	1.07 ± 0.05	12.80 ± 1.06	1.66 ± 0.12
L28	OPV	55.13 ± 1.29	9.60 ± 0.20	40.73 ± 1.85	0.91 ± 0.03	13.60 ± 0.40	1.41 ± 0.06
ALR	OPV	51.73 ± 0.99	7.60 ± 0.53	40.20 ± 2.91	0.85 ± 0.03	11.47 ± 0.61	1.12 ± 0.03
ADR	OPV	51.27 ± 1.60	7.20 ± 0.87	38.13 ± 1.81	0.85 ± 0.07	11.07 ± 0.31	1.04 ± 0.03
L782	OPV	48.73 ± 2.00	8.27 ± 0.42	35.73 ± 1.10	0.87 ± 0.05	11.20 ± 0.20	1.15 ± 0.03
Black Gold	OPV	47.27 ± 1.50	7.60 ± 0.42	33.53 ± 1.63	0.83 ± 0.05	11.27 ±0.42	1.06 ± 0.03
106BS2	BL	50.93 ± 1.10	8.73 ± 0.31	38.13 ± 1.01	0.86 ± 0.03	11.07 ± 0.42	1.49 ± 0.05
106BS10	BL	48.87 ± 1.30	8.27 ± 0.31	34.20 ± 1.00	0.83 ± 0.02	9.87 ± 1.01	1.35 ± 0.03
Krishna	OPV	46.87 ± 0.42	7.20 ± 0.20	33.33 ± 0.42	0.70 ± 0.06	10.73 ± 0.76	1.24 ± 0.04
VL Pyaz	OPV	45.47 ± 1.97	7.00 ± 0.20	32.87 ± 0.64	0.75 ± 0.02	8.93 ± 0.70	1.12 ± 0.02
383BS10	BL	47.47 ± 0.70	7.07 ± 0.50	31.67 ± 2.25	0.67 ± 0.06	10.40 ± 0.72	1.02 ± 0.10
Sukhsagar2	Landrace	45.87 ± 2.25	7.60 ± 0.69	34.40 ± 0.92	0.81 ± 0.05	9.20 ± 1.40	1.16 ± 0.13
Mean		52.30	8.43±0.99	38.63	0.90	11.65	1.26
SE_m		0.682	0.130	0.554	0.015	0.226	0.029
CV (%)		9.93	11.76	10.93	13.39	14.77	17.72

OPV = Open pollinated variety; BL = Breeding line
PH = Plant height; NOL = No of leaves; LL = Leaf length; LW = Leaf width; PsL = Pseudostem length; PsW = Pseudostem width

± 0.17 cm) recorded maximum and Red Creole2 (2.91 ± 0.09 cm) minimum polar diameter. AKON555 (6.00 ± 0.35 cm) recorded maximum whereas106BS10 (4.32 ± 0.48 cm) recorded minimum equatorial diameter. Thickest neck was observed in 106BS2 (1.15 ± 0.20 cm) and thinnest in Superex (0.48 ± 0.17 cm). Variations in leaf length, leaf width, pseudostem length has also been observed in Tunisian (Azoom *et al.*, 2) and Indian onion (Solanki *et al.*, 15). Highest average bulb weight was observed in PWF (75.99 ± 8.60 g) and lowest in Red Creole2 (25.85 ± 4.44 g). Mallor *et al.* (7) reported a bulb weight range of 19.1

Table 3. Characterization of onion accessions based on bulb and yield related traits.

Genotype	P (cm)	E (cm)	N (cm)	ABW (g)	FW (kg)	MY (t/ ha)	GY (t/ ha)
F1 Hybrid-1	3.61 ± 0.10	5.23 ± 0.48	0.67 ± 0.14	48.35 ± 6.43	0.65 ± 0.08	20.15 ± 3.81	25.40 ± 3.95
F1 Hybrid-2	3.64 ± 0.21	5.10 ± 0.26	0.72 ± 0.02	49.85 ± 8.63	0.49 ± 0.15	23.63 ± 4.11	26.67 ± 2.78
XP-Red	3.82 ± 0.25	5.05 ± 0.30	0.78 ± 0.10	55.97 ± 5.31	0.58 ± 0.09	29.63 ± 6.11	32.30 ± 7.33
Arka Kalyan	3.68 ± 0.14	4.92 ± 0.23	0.75 ± 0.15	53.39 ± 6.08	0.41 ± 0.08	23.26 ± 2.38	30.44 ± 3.86
Prema 178	3.30 ± 0.28	5.03 ± 0.12	0.63 ± 0.12	46.13 ± 2.07	0.52 ± 0.16	20.07 ± 2.06	23.59 ± 1.70
Red Creole1	3.54 ± 0.34	5.05 ± 0.57	0.59 ± 0.10	39.28 ± 6.74	0.22 ± 0.05	13.78 ± 4.37	17.56 ± 4.06
Black Crown	3.46 ± 0.30	5.09 ± 0.33	0.76 ± 0.18	41.93 ± 4.45	0.57 ± 0.06	17.48 ± 3.69	21.26 ± 2.23
Indam 4	3.47 ± 0.08	4.70 ± 0.15	0.74 ± 0.04	39.66 ± 3.97	0.43 ± 0.06	17.85 ± 0.84	21.11 ± 1.18
KSP1191	3.61 ± 0.19	4.87 ± 0.09	0.81 ± 0.08	44.79 ± 3.79	0.51 ± 0.08	22.89 ± 1.94	25.78 ± 1.76
Phursungi Local	3.67 ± 0.27	5.02 ± 0.18	0.75 ± 0.15	53.06 ± 6.84	0.43 ± 0.08	25.70 ± 5.68	28.96 ± 4.56
Hisar-3	3.61 ± 0.19	5.03 ± 0.09	0.76 ± 0.04	62.43 ± 4.87	0.71 ± 0.28	29.93 ± 4.85	33.70 ± 5.15
KRR	3.57 ± 0.23	5.22 ± 0.21	1.02 ± 0.03	48.58 ± 4.45	0.35 ± 0.04	19.41 ± 1.85	24.07 ± 1.30
Bhima Kiran	3.70 ± 0.22	4.99 ± 0.17	0.78 ± 0.01	45.62 ± 3.77	0.45 ± 0.09	22.37 ± 6.11	25.26 ± 5.33
BSS-262	3.64 ± 0.44	4.73 ± 0.27	0.49 ± 0.13	34.34 ± 2.05	0.41 ± 0 .15	10.74 ± 3.80	15.33 ± 5.05
NP-4	3.53 ± 0.28	4.89 ± 0.23	0.86 ± 0.08	41.78 ± 3.56	0.32 ± 0.08	15.63 ± 4.03	19.78 ± 4.44
Punjab Naroha	3.72 ± 0.30	5.08 ± 0.16	0.83 ± 0.15	57.96 ± 4.56	0.61 ± 0.11	19.56 ± 2.04	29.19 ± 3.24
Hisar-2	3.73 ± 0.17	5.57 ± 0.25	0.82 ± 0.07	59.95 ± 6.03	0.82 ± 0.16	17.70 ± 5.21	27.78 ± 7.64

Genotype	P (cm)	E (cm)	N (cm)	ABW (g)	FW (kg)	MY (t/ ha)	GY (t/ ha)
Bhima Shweta	4.39 ± 0.18	5.27 ± 0.19	0.82 ± 0.13	61.26 ± 2.55	0.47 ± 0.09	27.41 ± 0.56	31.93 ± 0.71
PWR	4.25 ± 0.26	5.47 ± 0.21	0.87 ± 0.13	55.64 ± 9.48	0.63 ± 0.17	29.70 ± 9.62	33.11 ± 9.37
PWF	4.23 ± 0.52	5.92 ± 0.71	0.77 ± 0.24	75.99 ± 8.60	0.69 ± 0.14	46.74 ± 8.08	48.96 ± 7.32
Udaipur Local	3.69 ± 0.13	5.08 ± 0.09	0.83 ± 0.13	56.09 ± 3.45	0.41 ± 0.10	28.15 ± 2.02	30.89 ± 2.56
Red Creole2	2.91 ± 0.09	4.37 ± 0.38	0.51 ± 0.15	25.85 ± 4.44	0.41 ± 0.03	10.26 ± 3.64	13.48 ± 3.16
Red Creole3	3.31 ± 0.01	4.52 ± 0.13	0.85 ± 0.03	32.47 ± 1.80	0.43 ± 0.31	8.52 ± 1.45	13.33 ± 0.22
Pusa Red	3.66 ± 0.06	5.27 ± 0.16	0.93 ± 0.14	57.10 ± 5.03	0.79 ± 0.28	28.00 ± 4.70	31.78 ± 4.26
AFW	3.53 ± 0.23	5.13 ± 0.19	0.84 ± 0.08	60.67 ± 7.59	0.58 ± 0.10	30.81 ± 1.64	34.74 ± 3.80
Sukhsagar1	4.52 ± 0.17	4.92 ± 0.13	0.68 ± 0.12	57.78 ± 0.83	0.36 ± 0.10	19.19 ± 8.74	21.41 ± 9.50
Sel. 325	3.85 ± 0.14	4.90 ± 0.21	0.83 ± 0.12	66.13 ± 6.29	0.79 ± 0.31	27.26 ± 3.83	33.33 ± 4.08
Bhima Shakti	3.94 ± 0.20	5.18 ± 0.07	0.82 ± 0.14	55.63 ± 4.56	0.56 ± 0.23	30.07 ± 2.58	31.63 ± 1.92
Lucifer	3.48 ± 0.23	5.24 ± 0.25	0.71 ± 0.03	43.65 ± 3.28	0.39 ± 0.12	17.63 ± 4.58	21.70 ± 2.48
106BS3	4.47 ± 0.09	5.05 ± 0.27	1.04 ± 0.04	60.05 ± 5.43	0.73 ± 0.17	30.22 ± 6.05	35.48 ± 6.28
Superex	4.10 ± 0.50	5.26 ± 0.20	0.48 ± 0.17	65.26 ± 7.12	0.23 ± 0.03	32.89 ± 10.34	36.89 ± 9.89
Pioneer	4.03 ± 0.13	4.68 ± 0.30	0.66 ± 0.24	40.84 ± 2.19	0.30± 0.07	13.85 ± 3.25	17.04 ± 2.53
BSS258	3.48 ± 0.40	4.81 ± 0.12	0.50 ± 0.06	42.61 ± 1.86	1.47 ± 0.16	18.96 ± 6.23	21.48 ± 5.21
N-2-4-1	3.94 ± 0.07	5.13 ± 0.25	0.77 ± 0.05	61.54 ± 1.72	0.61 ± 0.25	29.11 ± 3.53	34.81 ± 4.10
PRO-6	3.96 ± 0.34	5.11 ± 0.09	0.75 ± 0.10	57.75 ± 8.16	0.51 ± 0.09	25.04 ± 6.49	32.00 ± 4.67
Early Grano	3.81 ± 0.35	4.49 ± 0.04	0.68 ± 0.07	40.94 ± 3.61	0.41 ± 0.16	8.81 ± 1.61	17.70 ± 1.68
Bhima Shubhra	4.05 ± 0.17	5.10 ± 0.29	0.92 ± 0.26	60.27 ± 2.11	0.53 ± 0.13	27.19 ± 3.59	33.78 ± 2.91
Sel.126	4.08 ± 0.37	5.12 ± 0.42	0.83 ± 0.06	54.06 ± 2.07	0.49 ± 0.05	20.59 ± 7.40	27.93 ± 5.65
Yellow Grano	4.51 ± 0.42	4.88 ± 0.25	0.66 ± 0.05	55.71 ± 9.23	0.41 ± 0.12	21.70 ± 4.78	28.30 ± 4.90
Pusa Riddhi	3.93 ± 0.18	4.99 ± 0.02	0.85 ± 0.14	54.90 ± 1.35	0.79 ± 0.16	21.56 ± 6.09	28.22 ± 3.15
Juni	3.58 ± 0.23	4.57 ± 0.29	0.74 ± 0.04	38.67 ± 6.11	0.33 ± 0.07	13.93 ± 4.71	17.63 ± 4.33
AKON555	3.84 ± 0.33	6.00 ± 0.35	0.98 ± 0.34	70.87 ± 1.15	1.37 ± 0.27	32.00 ± 1.90	37.78 ± 4.46
KSP1121	3.97 ± 0.27	5.09 ± 0.22	0.71 ± 0.19	54.44 ± 6.06	0.57 ± 0.14	25.41 ± 3.98	29.70 ± 3.68
GWO-1	3.70 ± 0.05	5.04 ± 0.16	0.82 ± 0.05	48.63 ± 9.45	0.46 ± 0.13	26.15 ± 7.90	29.41 ± 7.83
JNDWO85	3.79 ± 0.36	4.70 ± 0.32	0.75 ± 0.08	48.19 ± 6.08	0.57 ± 0.38	19.78 ± 3.27	23.78 ± 4.59
Arka Kirthiman	3.99 ± 0.14	4.34 ± 0.27	0.64 ± 0.16	39.19 ± 9.37	0.41 ± 0.19	11.78 ± 5.61	17.41 ± 5.95
Pusa Madhavi	4.33 ± 0.17	5.08 ± 0.33	0.88 ± 0.31	64.34 ± 5.87	0.67 ± 0.17	25.85 ± 8.53	32.07 ± 7.81
L28	3.72 ± 0.37	4.82 ± 0.47	0.80 ± 0.19	45.23 ± 5.77	0.64 ± 0.16	16.89 ± 6.22	21.11 ± 5.39
ALR	4.04 ± 0.11	5.11 ± 0.47	0.91 ± 0.06	52.74 ± 3.39	0.59 ± 0.34	23.85 ± 5.75	28.22 ± 6.19
ADR	3.47 ± 0.14	4.96 ± 0.47	0.61 ± 0.22	44.66 ± 8.48	0.32 ± 0.03	18.07 ± 5.56	20.52 ± 3.76
L782	3.82 ± 0.56	4.66 ± 0.30	0.87 ± 0.19	51.71 ± 4.78	0.59 ± 0.22	23.19 ± 6.93	27.26 ± 7.25
Black Gold	3.34 ± 0.45	4.59 ± 0.66	0.63 ± 0.07	36.01 ± 7.71	0.37 ± 0.13	8.74 ± 7.33	12.37 ± 6.37
106BS2	4.09 ± 0.34	4.99 ± 0.27	1.15 ± 0.20	44.11 ± 6.35	0.70 ± 0.05	11.48 ± 3.99	17.48 ± 2.69
106BS10	4.01 ± 0.30	4.32 ± 0.48	1.10 ± 0.15	43.06 ± 8.35	1.02 ± 0.29	6.22 ± 6.74	16.52 ± 7.92
Krishna	3.39 ± 0.20	4.85 ± 0.29	0.82 ± 0.06	40.61 ± 4.60	0.43 ± 0.23	10.89 ± 2.70	15.22 ± 2.92
VL Pyaz	3.37 ± 0.19	4.96 ± 0.54	0.76 ± 0.22	44.37 ± 6.50	0.28 ± 0.18	5.71 ± 2.06	8.29 ± 2.81
383BS10	4.19 ± 0.31	4.44 ± 0.17	0.96 ± 0.31	43.07 ± 6.02	0.49 ± 0.04	7.04 ± 3.68	12.37 ± 3.15
Sukhsagar2	3.91 ± 0.24	4.44 ± 0.22	0.69 ± 0.03	39.98 ± 4.32	0.37 ± 0.08	12.22 ± 2.69	14.11 ± 1.28
Mean	3.79	4.97	0.77	50.26	0.54	20.73	25.33
SE_m	0.043	0.043	0.018	1.324	0.030	1.069	1.053
CV (%)	8.17	6.68	17.88	20.06	42.31	39.28	31.65

P = Polar diameter; E = Equatorial diameter; N = Neck thickness; ABW = Av bulb wt; FW = Foliage wt; MY = Marketable yield; GY = Gross yield g to 588.3 g. It is worth to be noted that short day varieties have an average bulb weight of less than 100 g since they mature in 120-150 days whereas long day varieties take more than 240 days to mature. PWF (46.74 ± 8.08 t/ha) was the high marketable yielder while VL Pyaz (5.71 ± 2.06 t/ha) was the least yielder. Significant differences in onion yield were noted in studies reported from India (Solanki *et al.*, 15), Spain (Mallor *et al.*, 7) and Tunisia (Azoom *et al.*, 2). High coefficient of variation was observed in gross yield and marketable yield which implies a wider variability in onion genotypes assessed. Due to the continuous onion cultivation by the farmers for the last 5000 years and its adaptation, onion, which is predominantly a long day type, got converted into short day type onion for cultivation in India. It may be said that short day onions show greater genetic diversity because they have been maintained as landraces and open pollinated cultivars over a wide geographic area. Based on microsatellite analysis, it has been observed that short day onions form a separate group from long day onion and it was hypothesized that Indian region may have potential to provide novel germplasm resources.

Total soluble solids in all genotypes varied significantly with an overall mean of 11.52°B (Table 4). Maximum TSS was recorded in 106BS2 (15.30 ± 3.03°B) and minimum in Superex (7.03 ± 0.25°B). Soluble solid content (SSC) or TSS is one of the important quality factor that determines storage life, pungency and firmness (Sinclair *et al.*, 13). The reported TSS values were greater than reported: 8.63-11.83 (Solanki *et al.*, 15), 5.8-12.8 (Mallor *et al.*, 7), 6.8-12.3 (Vagen and Slimestad, 16), 11.3-13.3 (Dhumal *et al.*, 3), 5.67-10.98 (Sharma *et al.*, 12), and less than 7.2-15.8 reported by Jaime *et al.* (5). Genotypes also depicted significant variation in the bulb dry matter content and the highest percentage of dry matter was noticed in Arka Kalyan (15.70 ± 0.57%) and lowest in Superex (4.08 ± 0.57%). Sharma *et al.* (12) also reported dry weight in 18 Korean cultivars ranging from 5.67-10.98%. The amount of pyruvic acid yielded enzymatically upon homogenization is an appropriate measure of the action of alliinase on the flavour precursors and has been proven to be associated with perceived onion pungency (Anthon and Barrett, 1). In addition, pyruvic acid (PA) content also plays a significant role in storage of onion and is associated with dormancy breakage. Pyruvic acid (PA) content of the bulbs varied from 2.57 μmol/ ml to 6.32 μmol/ ml with a mean of 3.48 μmol/ ml. Pyruvic acid was highest in Red Creole3 (6.32 ± 0.17 μmol/ ml) and minimum in Superex (2.57 ± 0.06 μmol/ ml). On the basis of guidelines used by sweet onion industry, onions have been classified as low pungency/sweet (0-3 μmol/ g FW), medium pungency (3-7 μmol/ g FW) and high pungency (above 7 μmol/ g FW) (Dhumal *et al.*, 3). Based on this criterion, all the genotypes were categorized under low and medium pungency

Table 4. Characterization of onion accessions based on biochemical traits.

Genotype	TSS (°B)	DM (%)	PA (μmol/ ml)	TPC (mg/ g FW)
F1 Hybrid-1	11.73 ± 0.25	13.34 ± 0.68	5.05 ± 0.06	22.75± 0.73
F1 Hybrid-2	11.73 ± 0.67	12.00 ± 1.59	3.90 ± 0.04	31.51 ± 2.68
XP-Red	9.01 ± 0.61	10.01 ± 0.34	4.77 ± 0.08	35.78 ± 0.50
Arka Kalyan	11.70 ± 1.06	15.70 ± 0.57	3.71 ± 0.01	19.66 ± 2.81
Prema 178	12.13 ± 0.40	12.26 ± 0.61	3.76 ± 0.01	21.67 ± 2.85
Red Creole1	9.07 ± 1.59	11.70 ± 2.51	3.70 ± 0.04	30.83 ± 0.62
Black Crown	13.90 ± 3.21	13.68 ±0.28	3.86 ± 0.05	24.76 ± 0.99
Indam 4	11.27 ± 0.83	11.96 ± 0.44	4.52 ± 0.47	19.43 ± 1.31
KSP1191	10.93 ± 1.01	12.91 ± 0.19	4.85 ± 0.07	22.80 ± 1.53
Phursungi Local	14.00 ± 3.70	12.18 ± 0.67	3.73 ± 0.07	19.25 ± 2.28
Hisar-3	11.70 ± 0.17	14.10 ± 0.99	3.83 ± 0.05	28.39 ± 0.73
KRR	11.89 ± 0.18	14.84 ± 0.55	3.90 ± 0.04	17.84 ± 2.39
Bhima Kiran	11.23 ± 0.50	13.05 ± 0.86	3.52 ± 0.01	16.97 ± 1.02
BSS-262	10.87 ± 0.35	11.55 ± 0.96	3.97 ± 0.02	20.10 ± 0.90
NP-4	11.17 ± 0.42	12.03 ± 0.15	3.68 ± 0.02	23.81 ± 0.90
Punjab Naroha	11.13 ± 0.91	13.39 ± 1.02	5.03 ± 0.11	23.56 ± 0.99
Hisar-2	11.67 ± 0.29	12.20 ± 0.61	5.06 ± 0.02	27.17 ± 0.90

Genotype	TSS (°B)	DM (%)	PA (µmol/ ml)	TPC (mg/ g FW)
Bhima Shweta	12.20 ± 0.26	12.34 ± 1.03	3.43 ± 0.07	31.39 ± 0.10
PWR	11.53 ± 0.29	11.02 ± 1.81	3.40 ± 0.02	30.53 ± 0.94
PWF	12.00 ± 0.72	10.27 ± 0.56	3.47 ± 0.07	23.42 ± 0.93
Udaipur Local	11.83 ± 0.15	11.28 ± 1.32	3.89 ± 0.08	25.56 ± 2.44
Red Creole 2	12.37 ± 1.16	13.68 ± 0.28	3.98 ± 0.68	29.94 ± 0.64
Red Creole 3	11.23 ± 0.42	11.19 ± 1.71	6.32 ± 0.17	31.12 ± 0.42
Pusa Red	10.97 ± 0.76	12.03 ± 0.82	3.78 ± 0.07	28.16 ± 2.82
AFW	11.47 ± 0.38	14.50 ± 0.59	5.05 ± 0.02	24.55 ± 2.85
Sukhsagar1	10.33 ± 0.85	10.17 ± 0.55	2.77 ± 0.08	25.76 ± 0.54
Sel. 325	12.19 ± 1.31	10.98 ± 0.07	3.39 ± 0.08	23.74 ± 1.42
Bhima Shakti	12.04 ± 0.37	11.33 ± 1.67	3.13 ± 0.10	22.73 ± 1.22
Lucifer	11.47 ± 0.32	9.99 ± 0.02	2.84 ± 0.06	26.34 ± 1.31
106BS3	12.17 ± 1.43	10.89 ±0.29	3.93 ± 0.04	33.20 ± 0.84
Superex	7.03 ± 0.25	4.08±0.57	2.57 ± 0.06	27.86 ± 0.57
Pioneer	9.20 ± 2.00	13.31 ± 0.32	2.98 ± 0.03	27.82 ± 2.53
BSS258	11.47± 0.40	9.65 ± 0.75	3.17 ± 0.09	24.21 ± 0.66
N-2-4-1	11.00 ± 0.44	11.72 ± 0.42	3.74 ± 0.10	28.42 ± 0.44
PRO-6	11.73 ± 0.23	13.37 ± 1.34	3.41 ± 0.04	22.17 ± 1.04
Early Grano	11.57 ± 0.21	11.17 ± 0.87	3.22 ± 0.02	21.22 ± 0.50
Bhima Shubhra	13.77 ± 3.79	10.64 ± 0.20	3.44 ± 0.11	23.96 ± 1.29
Sel.126	13.07 ± 1.31	12.22 ± 0.52	3.43 ± 0.17	26.27 ± 0.62
Yellow Grano	8.22 ± 1.61	6.24 ± 0.45	3.25 ± 0.10	27.73 ± 0.24
Pusa Riddhi	11.43 ± 0.81	10.45 ± 0.27	4.89 ± 0.03	24.07 ± 0.98
Juni	10.75 ± 0.70	9.81 ± 0.82	3.75 ± 0.02	36.96 ± 2.00
AKON555	11.50 ± 0.17	11.08 ± 0.77	2.89 ± 0.05	20.73 ± 0.82
KSP1121	11.43 ± 0.64	10.43 ± 0.86	3.51 ± 0.01	23.45 ± 1.27
GWO-1	11.43 ± 0.35	12.04 ± 0.68	4.73 ± 0.01	25.40 ± 2.17
JNDWO85	11.67 ± 0.12	11.37 ± 1.28	3.66 ± 0.03	26.88 ± 1.11
Arka Kirthiman	13.73 ± 1.78	12.54 ± 0.76	3.40 ± 0.01	22.42 ± 1.45
Pusa Madhavi	10.77 ± 0.61	12.39 ± 0.27	4.85 ± 0.10	26.63 ± 1.32
L28	11.80 ± 0.52	10.28 ± 0.93	3.88 ± 0.03	21.68 ± 0.44
ALR	11.33 ± 0.21	11.52 ± 0.65	3.59 ± 0.02	27.91 ± 1.02
ADR	9.90 ± 0.89	9.66 ± 0.08	3.36 ± 0.03	24.89 ± 1.20
L782	13.47 ± 3.50	12.10 ± 0.45	4.77 ± 0.02	27.18 ± 1.80
Black Gold	12.10 ± 0.26	9.74 ± 0.16	3.79 ± 0.03	24.82 ± 1.82
106BS2	15.30 ± 3.03	11.48 ± 1.26	3.94 ± 0.02	23.17 ± 1.21
106BS10	11.37 ± 0.67	10.47 ± 1.58	4.88 ± 0.03	26.02 ± 0.30
Krishna	11.60 ± 0.17	9.61 ± 1.21	3.24 ± 0.02	23.90 ± 1.57
VL Pyaz	11.23 ± 0.29	10.71 ± 1.43	3.14 ± 0.01	30.04 ± 0.47
383BS10	12.53 ± 0.91	9.53 ± 1.74	3.81 ± 0.04	21.00 ± 0.92
Sukhsagar2	11.06 ± 0.23	9.44 ± 1.96	3.37 ± 0.01	27.11 ± 0.70
Mean	11.52	11.44	3.84	25.45
SE_m	0.176	0.246	0.094	0.547
CV (%)	11.68	16.4	18.7	16.37

TSS = Total Soluble Solids; DM = Dry matter; PA = Pyruvic acid; TPC = Total phenolic content with majority under medium pungency. Popularity for low pungency onion has increased (Dhumal *et al.*, 3) which makes it necessary to breed for low pungency onions for export market. In India, medium to high pungency onions are preferred for curry preparation. Mallor *et al.* (7) reported a highly pungent line, BGHZ-1354 having a pungency value of 18.1 µmol/ g FW which is higher than any of the genotype reported in our studies. McCallum *et al*. (8) reported average concentration of 4.66 µmol/ml in mild pungent and 8.89 µmol/ml in pungent onion. According to this criterion, 91% of the genotypes studied can be considered as mild onions that is more than percent (15%) reported by Mallor *et al.* (7). The mean CV of the pungency (18.7%) was less than 50% which has been reported by Mallor *et al.* (7) but equal to 21.3% CV reported by Yoo *et al.* (17). Phenolic components serve as antioxidant, anti-mutagenic, and are scavenging agents on free radicals, thereby, preventing pathologies such as cancer and cardiovascular heart disease (Sharma *et al.*, 12). Besides, the health enhancing properties of phenolic compounds, its role in systemic acquired resistance (SAR) and use as biochemical markers for fungal and bacterial resistance in onion and other plant species is well known. The total phenolic content (TPC) of the leaves ranged from 16.97 mg/ g FW to 36.96 mg/ g FW with an average total phenolic content of 25.46 mg/ g FW. These results are in agreement with the findings of Sharma *et al.* (12) where significant variation for total phenolic contents was observed.

Onion genotypes were characterized for nine quality traits *i.e.,* waxiness (WX), general bulb shape (BS), basic colour of dry skin (BC), adherence of skin (AS), firmness of flesh (FM), colour of epidermis of fleshy scale (CE), position of root disc (PA), predominant number of axes (PNA) and bulb cross section (BCS). Waxiness was noticed only in 22.4% genotypes and 77.6% were non-waxy. Similarly, 39.6%, 37.9%, 19.0%, and only 3.4% genotypes, respectively had flat globe, globe, oval, and flat types of bulb shape. Most of the genotypes were pink coloured (27.6%) followed by dark red (25.9%), white (20.7%), light red (19.0%), brown (5.2%), and yellow (1.7%). Maximum number of genotypes had medium (89.6%) adherence of skin followed by weak (6.9%), and strong (3.4%). 87.9% genotypes were found with strong bulb firmness and only 12.1% had medium firmness. Likewise, genotypes with white (19.0%), yellowish (6.9%) and purplish (74.1%) type of epidermis were also recorded. Majority of the genotypes (67.2%) were noticed to have surface type position of root disc and 32.7% genotypes depicted exerted type of root disc. Single axis bulbs were maximum and were recorded in 58.6 % genotypes whereas 41.4% genotypes were observed to have multiple axis. 94.8% genotypes were categorized as having symmetrical bulbs and only 5.2% were categorized with asymmetrical bulbs. Single centeredness, a desirable trait in onion improvement is also a trait that is associated with bulb firmness and better storability. Considerable variability in foliage traits, bulb traits, adherence of skin and predominant number of axis has been reported by Solanki *et al.* (15).

Correlation coefficient studies give reliable evidence on nature, magnitude, and direction of selection when assorting a novel plant type. Plant height was very highly and significantly correlated with the number of leaves, leaf length, leaves width, pseudostem length, pseudostem width, average bulb weight and gross yield with the positive direction (Fig. 1). Solanki *et al.* (15) also noticed similar association with number of leaves. Bulb polar diameter correlated very highly significantly with average bulb weight and gross yield in positive direction. Surprisingly, polar diameter also correlated significantly but negatively with bulb dry matter. Average bulb weight, gross yield and marketable yield correlated positively and very highly significantly with equatorial diameter. Foliage weight demonstrated positive and very highly significantly correlation with number of leaves and pseudostem width. Gross yield of the onion positively and very highly significantly correlated with plant height and other morphological traits, average bulb weight, and marketable yield. Marketable yield expressed correlation positively and very highly significantly with plant height, leaf length, leaf width, pseudostem width, equatorial diameter, average bulb weight, and gross yield of onion. Likewise, correlation with gross and marketable yield was also reported by Solanki *et al.* (15).

Total soluble solids correlated positively and very highly significantly with dry matter of the bulb but negatively and significantly with total phenolic content. Significant and positive genetic and phenotypic correlations have been observed between soluble solids content (SSC), dry matter (DM %), pungency and onion-induced in vitro antiplatelet activity (OIAA) (Galmarini *et al.*, 4). Similarly, SSC is highly correlated with dry matter content (Nieuwhof *et al.*, 10; Sinclair *et al.*, 13). Unambiguously, dry matter content of the bulb correlated positively and very highly significantly with total soluble solids. Similarly, dry matter content correlated with leaf width, pseudostem width, and pyruvic acid content. However, dry matter also showed

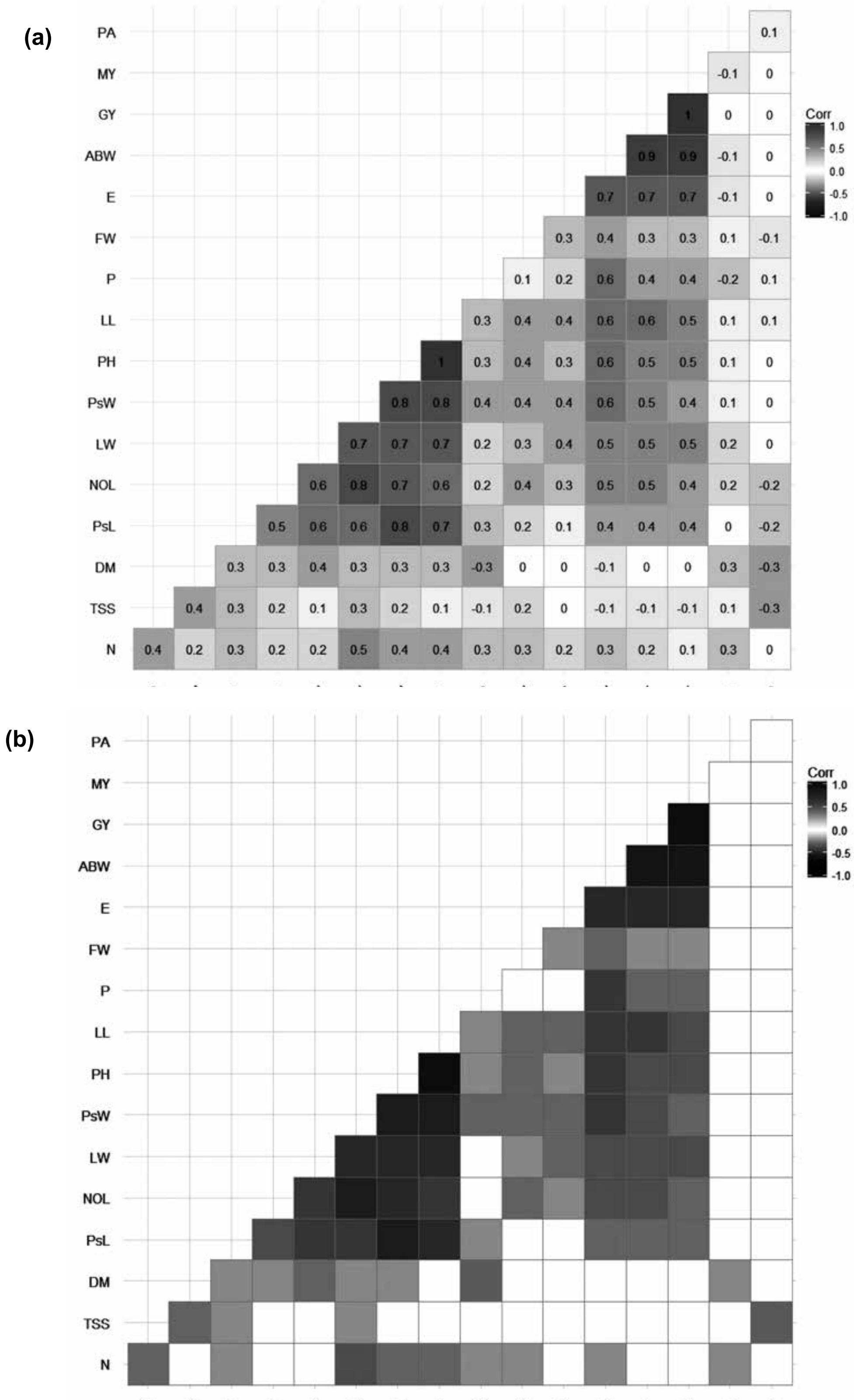

Fig. 1. Pearson's correlation coefficient analysis among various morphological and biochemical traits of onion (a) All correlation values (b) significant correlations.

significant correlation with polar diameter of the bulb but in negative direction. McCollum (9) reported a negative genetic correlation between SSC and bulb size. Pyruvic acid content showed highly significant correlation only with the bulb dry matter. Total phenolic content of the leaves correlated significantly but negatively with total soluble solids. Pyruvate concentrations correlated positively with perceived onion pungencies (Schwimmer and Guadagni, 11), as well as with total solids and soluble solids content (SSC) (Galmarini *et al*., 4; McCallum *et al*., 8; Lin *et al*., 6). Soluble solids content was strongly correlated with onion dry weight: r = 0.95 (Vågen and Slimestad, 16), r = 0.94 (McCallum *et al*., 8) and r = 0.98 (Jaime *et al*., 5). The correlation between dry weight content and pyruvate content was found to be quite low (r=0.38) (Vågen and Slimestad, 16). Other authors have also found medium correlation (r from 0.42 to 0.57) (Schwimmer and Guadagni, 11; Lin *et al*., 6; Galmarini *et al*., 4). In contrast, Yoo *et al.* (17) indicated that there was no consistent trend between these traits in four different clones grown at Welsaco. The relationship found in this study may be explained because the compounds responsible for onion pungency also contribute to total dissolved solids. Therefore, in agreement with Lin *et al.* (6), part of the positive correlation between SSC and pungency is due to the partial identity of the traits.

Present studies showed the existence of considerable genetic variability among all the morphological, biochemical and qualitative traits. It was observed that higher values for most of the traits were recorded in open pollinated varieties than in hybrids which can be explained by the fact that most of the hybrids were exotic in nature and will take time to adapt to our local conditions. A systematic breeding effort at local level is needed to breed high yield hybrids. Significant correlations ($p<0.001$) between gross yield and most of the morphological traits were observed which will aid in selecting germplasm based on the identified traits. Highly significant correlation between TSS and dry matter, pyruvic acid and dry matter and significant and negative correlation between TSS and TPC were observed. TSS< dry matter, pyruvic acid and phenols are the traits which are of paramount important for breeding onion having high processing ability, storage and resistance to insect pests and diseases. Similarly, recorded genotypes with waxiness can be used for breeding of disease and insect resistant material. These results obtained will augment in identifying key genotypes for introgression of important traits, breeding new germplasm resources and also selecting diverse parents for heterosis breeding programme in short day tropical onion.

REFERENCES

1. Anthon, G.E. and Barrett, D.M. 2003. Modified method for the determination of pyruvic acid with dinitrophenylhydrazine in the assessment of onion pungency. *J. Sci. Food Agr*. **83**: 1210-13.
2. Azoom, A.A.A., Zhani, K. and Hannachi, C. 2014. Performance of eight varieties of onion. *Not. Sci. Biol*. **6**: 220-24.
3. Dhumal, D., Datir, S. and Pandey, R. 2007. Assessment of bulb pungency level in different Indian cultivars of onion (*Allium cepa* L.). *Food Chem*. **100**: 1328-30.
4. Galmarini, C.R., Goldman, I.L. and Havey, M.J. 2001. Genetic analyses of correlated solids, flavor, and health-enhancing traits in onion (*Allium cepa* L.). *Mol. Genet. Genomics*, **265**: 543-51.
5. Jaime, L., Martínez, F., Martín-Cabrejas, M.A., Molla, E., López-Andréu, F.J., Waldron, K.W. and Esteban, R.M. 2001. Study of total fructan and fructooligosaccharide content in different onion tissues. *J. Sci. Food Agric*. **81**: 177-82.
6. Lin, M.W., Watson, J.F. and Baggett, J.R. 1995. Inheritance of soluble solids and pyruvic acid content of bulb onions. *J. American Soc. Hortic. Sci*. **120**: 119-22.
7. Mallor Giménez, C., Carravedo Fantova, M., Estopañán Muñoz, G. and Mallor Giménez, F. 2011. Characterization of genetic resources of onion (*Allium cepa* L.) from the Spanish secondary centre of diversity. *Span. J. Agric. Res*. **9**: 144-55.
8. McCallum, J.A., Grant, D.G., McCartney, E.P., Scheffer, J., Shaw, M.L. and Butler, R.C. 2001. Genotypic and environmental variation in bulb composition of New Zealand adapted onion (*Allium cepa*) germplasm. *New Zealand J. Crop Horti. Sci*. **29**: 149-58.
9. McCollum, G.D. 1968. Heritability and genetic correlation of soluble solids, bulb size and shape in white sweet Spanish onion. *Canadian J. Genet. Cytol*. **10**: 508-14.
10. Nieuwhof, M., De Bruyn, J. W. and Garretsen, F. 1973. Methods to determine solidity and dry matter content of onions (*Allium cepa* L.). *Euphytica*, **22**: 39-47.

11. Schwimmer, S. and Guadagni, D.G. 1962. Relation between olfactory threshold concentration and pyruvic acid content of onion juice. *J. Food Sci*. **27**: 94-97.

12. Sharma, K., Assefa, A.D., Kim, S., Ko, E.Y., Lee, E.T. and Park, S.W. 2013. Evaluation of total phenolics, flavonoids and antioxidant activity of 18 Korean onion cultivars: a comparative study. *J. Sci. Food Agric*. **94**: 1521-29.

13. Sinclair, P.J., Blakeney, A.B. and Barlow, E.W.R. 1995. Relationships between bulb dry matter content, soluble solids concentration and non-structural carbohydrate composition in the onion (*Allium cepa*). *J. Sci. Food Agric*. **69**: 203-09.

14. Singleton, V.L. and Rossi, J.A. 1965. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American J. Enol. Vitic*. **16**: 144-58.

15. Solanki, P., Jain. P.K., Prajapati, S., Raghuwanshi, N., Khandait, R.N. and Patel, S. 2015. Genetic analysis and character association in different genotypes of onion (*Allium cepa* L.). *Int. J. Agric. Environ. Biotechnol*. **8**: 783-93.

16. Vågen, I.M. and Slimestad, R. 2008. Amount of characteristic compounds in 15 cultivars of onion (*Allium cepa* L.) in controlled field trials. *J. Sci. Food Agric*. **88**: 404-11.

17. Yoo, K.S., Pike, L., Crosby, K., Jones, R. and Leskovar, D. 2006. Differences in onion pungency due to cultivars, growth environment, and bulb sizes. *Sci. Horti*. **110**: 144-49.

Received : November, 2017; Revised : May, 2018;
Accepted : May, 2018