Indian Journal of Agricultural Sciences **89** (3): 450–7, March 2019/Article
https://doi.org/10.56093/ijas.v89i3.87588

Variability, heritability and trait association studies for bulb and antioxidant traits in onion (*Allium cepa*) varieties

SABINA ISLAM[1], ANIL KHAR[2], SHRAWAN SINGH[3] and B S TOMAR[4]

ICAR-Indian Agricultural Research Institute, New Delhi 110 012

Received: 01 August 2018; Accepted: 10 October 2018

ABSTRACT

Onion (*Allium cepa* L.) is one of the most important vegetable having year round demand and consumed fresh, cooked or processed. It occupies maximum area under vegetables in India. The consumption of onion has been associated with many health benefits. The genetic improvement work mainly focused on improving yield and there has been little effort on improving quality traits. Therefore, information on variability, heritability and trait association of phytochemicals content, antioxidant activity and bulb traits are lacking. The present study was conducted to bridge the gap and generate information on these aspects. A total of eight quality traits and four bulb traits were analyzed in 22 onion genotypes of five different skin colour. The genotypes were procured from diverse geographic region. The total soluble solids content (TSS), pungency, total phenol, flavonoids content, and antioxidant activities as estimated through CUPRAC and FRAP in the onion varieties varied from 10.13-16.65 °Brix, 4.67-12.28 µmol Pyruvic acid/g FW, 740.67-1145.33 µg Gallic acid equivalent/ml, 31.67 - 465.0 µg Quercetin equivalent/ml, 2.23 - 5.14 µmol Trolox/g and 1.60-4.63 µmole Trolox/g, respectively. There was less difference between phenotypic and genotypic components of variance for pungency, total phenols, antioxidant activity and juice recovery, suggesting greater role of genotype in the expression of quality traits and better scope of improvement for these traits. The high heritability estimates (>75%) for bulb diameter, total phenols, flavonoids, pungency and antioxidant activity, and higher value of genotypic correlation co-efficient over phenotypic co-efficient supports greater role of genotype in the expression of quality traits. The high estimate of heritability and comparatively, low estimate of genetic advance and genetic gain suggest the role of both additive and non-additive gene action. Thus hybridization and selection would be the best strategy to improve quality traits in Indian onion genotypes. Future breeding attempt to develop onion varieties with higher health benefits should focus on medium sized varieties without compromising on yield.

Key words: Bioactive compounds, Indian onion varieties, Juice recovery, Trait association, TSS, Variability

Onion (*Allium cepa* L.) occupies prime position in Indian vegetable production scenario contributing 12.58% of total vegetable production as estimated by Department of Agriculture Cooperation & Farmers Welfare (2017). The advantage for diverse geographical locations allows onion growers to grow different types of onion in different locations (>1800 ft above msl to coastal area) and 59 varieties including 2 hybrids have been released from various agricultural institutes (Singh *et al*. 2017). It is an indispensable item of Indian cuisine and consumed fresh (*salad*), cooked and processed (ring, flake, powder, pickle). During the last 10 years (1987-88 to 2009-010), onion consumption has almost doubled in rural area from 4.6 kg to 9.0 kg and in urban households from 6.1 kg to 10.4 kg (NCAER 2014). Apart from food value, it is an important source of dietary phytochemical with proven antioxidant properties, such as organosulfur compounds, phenolic acids, flavonoids, thiosulfinates, and anthocyanins (Zeng *et al*. 2017). It has also been reported to cure, reduce, or prevent some of the health problems such as asthma, cancer, cardiovascular diseases, and possess anti-diabetic, antibiosis, and prebiotic effects (Desjardins 2008). Earlier onion genetic improvement was focused on yield improvement only and as the awareness among masses for natural functional food is increasing, there is need to exploit functional food value of onion, which is quite challenging and can be achieved only in long-term as the work involves a lot of evaluations and subsequent use in breeding (Vision 2050, DOGR). Keeping in view the research gap for breeding onion varieties with higher functional food value in India, the present study was conducted (1) to quantify and report variability for bulb morphological traits, TSS, Dry matter (%), Juice recovery, pungency, Total Phenols, Flavonoids

[1]Sehior Scientist (e mail: tokumkum@gmail.com), [2]Principal Scientist (e mail: anil.khar@gmail.com), [3]Scientist (e mail: singhshrawan@rediffmail.com), [4]Head and Principal Scientist (e mail: bst_spu_iari@rediffmail.com), Division of Vegetable Science.

and antioxidant capacity (FRAP and CUPRAC), (2) to study the genetic component of variation, heritability and (3) relationship between yield and bulb quality parameters for further progress in breeding phytochemical rich onion genotypes.

MATERIALS AND METHODS

The experimental material consisted of 22 genotypes collected from diverse geographical locations covering entire tunic colour group (Table 1). They were evaluated in 3 replications, laid out in randomized block design at Research Farm, IARI (28°38′42″ N, 77°09′17″ E; approx. 725 ft a.m.s.l.) during winter 2015-16 and 2016-17. The crop was unvaryingly fertilized with optimum doses of chemical fertilizers, i.e. 100 kg N, 50 kg P_2O_5, 50 kg K_2O and 50 kg S, per ha, which was supplied as urea, single super phosphate, muriate of potash and gypsum, respectively. Half of the N, and full P_2O_5, K_2O and gypsum were applied as basal dressing at time of ridges preparation, while remaining half dose of N was top-dressed at 30 and 45 days after transplanting. Bulbs were harvested in the month of May and shade cured for seven days before analysis.

Table 1 Details of experimental materials

Genotypes	Originating Centre	Skin colour
Pusa Riddhi	ICAR- IARI, New Delhi	Dark Red
NHRDF Red L-28	NHRDF, Nashik, Maharastra	Dark Red
NHRDF Red-2 L-355	NHRDF, Nashik, Maharastra	Red
VL Piaz-3	VPKAS, Almora, Uttaranchal	Red
Hissar-2	Haryana Agricultural University, Hissar	Red
Pusa Red	ICAR- IARI, New Delhi	Red
Sel.157	ICAR-IARI, New Delhi	Red
Sel.121(A)	ICAR-IARI	Red
Sel121(B)	ICAR-IARI	Red
Kalyanpur Red Round	CSAUAT, Kanpur	Red
Bhima Shakti	ICAR-DOGR, Pune, Maharstra	Red
Arka Kalyan	ICAR- IIHR, Bangalore	Red
Arka Niketan	ICAR- IIHR, Bangalore	Red
Arka Pragati	ICAR- IIHR, Bangalore	Red
Rosy	National Seed Corporation, Delhi	Red
Early Grano	ICAR- IARI, Katrain	Yellow
NBPGR-2	World Vegetable Centre, Taiwan	Yellow
Arka Pitamber	ICAR- IIHR, Bangalore	Yellow
Pusa Shobha	ICAR- IARI, New Delhi	Brown
Pusa White Flat	ICAR- IARI, New Delhi	White
GWO-1	Gujrat Agriculture University, Junagarh, Gujrat	White
Akola White	PKV, Akola, Mahrastra	White

Observations were recorded on 10 randomly selected bulbs in each replication for neck thickness of bulb (mm), bulb equatorial and polar diameter (mm) was measured by using digital Vernier Calliper, average bulb weight (g) by using digital weighing balance. For quality trait analysis, three replicates of 10 bulbs from each cultivar, were used.

The representative samples were thoroughly macerated in juicer mixer and the juice was collected in amber bottle. Total soluble solid (TSS) (°Brix) was measured immediately by using a digital refractometer.

Juice volume was measured in standard measuring cylinder and juice recovery was expressed as (%). For estimation of dry matter (%), known quantity of onion was skinned and finely chopped with stainless steel knife and dried in oven dryer at 65±2°C till constant weight was obtained.

A colorimetric procedure following Anthon and Barret (2003) based on the reaction of pyruvic acid with 2,4-dinitrophenylhydrazine (DNPH) was used to estimate the pungency levels of onion genotypes. To a suitably diluted onion juice, 1.0 mL of 0.25 g/l DNPH in 1M HCl was added and the samples were placed at 37°C in a water bath for 10 minutes. The reaction was stopped by adding 1.0 ml of 1.5M NaOH and absorbance was measured at 515 nm using UV-Vis spectrophotometer. The pyruvic acid concentration of the onion juice was determined by using reference standard curve, developed with known concentration of pyruvate and expressed as µmol Pyruvic Acid/g FW.

Total phenol content was estimated spectrophotometrically by using Folin-Ciocalteu reagent, as described by Singleton *et al*. (1999), using gallic acid as a standard. 100 µl of the suitably diluted sample extract was mixed with 2.9 ml of distilled water and 0.5 ml of Folin- Ciocalteu reagent and after 3 minutes 2.0 ml of 20% Na_2CO_3 solution was added. The mixture was allowed to stand for 1 min in boiling water bath, cooled to ambient temperature and absorption was measured at 760 nm using UV-Vis spectrophotometer. The amount of total phenol was expressed as µg gallic acid equivalents (GAE)/ml.

Total flavonoid content was analyzed according to Zhishen *et al*. (1999). To a suitably diluted sample (0.3 mL), 2.1 ml of 80% ethanol was added followed by addition of 0.3 ml 5% $NaNO_2$ and allowed to stand for five minutes. The reaction was further advanced by addition of 0.3 mL of 10% $AlCl_3$ and allowed to stand for another five minutes and 2 mL of 1 M NaOH was added. The absorbance was measured immediately against blank at 510 nm and flavonoid content was expressed as µg quercetin equivalents/ml.

Antioxidant Activity (AOX) as expressed by Cupric Reducing Antioxidant Capacity (CUPRAC), was estimated by following the method developed by Apak *et al*. (2004). 100 µl of suitably diluted sample was added with the reaction mixture containing 1 ml of cupper chloride solution 10^{-2} M, 1 ml of ammonium acetate (pH 7.0) and 1 ml of freshly prepared neucoproine solution (7.5×10^{-3} M in ethanol) and the total volume was made to 4.1 ml by adding double distilled water. The tubes were stoppered and after one hour, the absorbance at 450 nm was recorded against a reagent blank. Results were expressed as µmol Trolox/g.

The FRAP assay for antioxidant activity was estimated following Benzie and Strain (1996). 100 µl sample was mixed thoroughly with 3 ml FRAP reagent consisting of 10 mM 2,4,6- tripyridyl-S-triazine (TPTZ) in 40 mM HCl and 20 mM ferric chloride in 300 mM sodium acetate buffer (pH 3.6) in the ratio of 1:1:10 (v/v). After standing at ambient temperature (20°C) for 4 min, absorbance at 593 nm was noted against water blank. Results were expressed as µmolTrolox/g.

The treatment difference and genotypic component of variance was calculated following Panse and Sukhatme (1967), phenotypic variance following Warner (1952), genotypic and phenotypic co-efficient of variation and broad sense heritability as ratio between genotypic and phenotypic variance following Burton and De Vane (1953). Genetic advance and genetic gain were calculated according to Lush (1949) and Johnson *et al*. (1955), respectively. The correlation co-efficients was calculated by using variances and co-variances as per formula given by Al-Jibouri *et al*. (1958). The significance of correlation co-efficient was tested using t-test at n-2 degree of freedom. Data were analyzed using SAS software 9.3.

RESULTS AND DISCUSSION

Onion is universally regarded as functional food due to its inherent richness in several bio-active compounds associated with various health benefits. Like yield and other related traits, variability in the germplasm collection serves the base material for improvement of desired phytochemical traits. But in no case the yield aspect can be overlooked. Therefore, we selected the released/improved varieties which have already been tested for their yield potential, to study the variability for different quality traits and their association with bulb traits like average weight and diameter. Significant variations were observed for average bulb weight, polar diameter of bulb, neck thickness but no significant variations for equatorial diameter. Sel. 121(A) had the highest bulb equatorial diameter followed by VL Piaz-3 and Hissar-2. Lowest neck thickness was observed in Early Grano and highest in Hissar-2. The mean performance of genotypes for bulb quantitative traits, TSS and dry matter (%) is presented in Table 2. Bulb equatorial diameter is a crucial factor which determine the spacing of the crop. The medium sized varieties (3.5-5.0 cm) are more preferred in the market due to nuclear family nature and whole bulb can be consumed in one go. In a medium sized variety the spacing can be reduced to 10 × 10 cm^2 compared to standard 15 × 10 cm^2, which can lead to yield increase of more than 1.0 tonne/ha. Variability for various morphological traits and bulb traits were earlier reported by Kushal *et al*. (2016), Aditika *et al.* (2017) and many others in onion collections from diverse origin and our results are in conformity with them regarding bulb traits.

The winter (*rabi*) onion is harvested in April-May and stored for 5-6 months under ambient condition with proper ventilation and supplied to market, a significant amount of onion is also dehydrated. By contributing 22.1%, in global trade, India ranks second in global scenario. Total soluble solids (TSS) and dry matter (DM) are the two major factors which determine their suitability for storage and dehydration purpose. The high DM varieties are preferred for processing (flakes, rings, powder) while low DM lines are preferred for fresh consumption as salad. Estimation of total soluble solids (TSS) gives an indirect estimate for the recovery of dehydrated onion. The TSS variation in studied genotypes is presented in Fig 1. High TSS white coloured onion varieties are most suitable for drying and processing as no blackening or discoloration is noticed in the processed product. Highest TSS was observed for Kalyanpur Red Round followed by Sel. 121(A) and Pusa Shobha. Among these, only Pusa Shobha meets the color requirement for high TSS varieties and the other two are red colored. Highest dry matter was observed in Sel. 157, Sel. 121(A) and Arka Pitamber and except Arka Pitamber both were red coloured genotypes. The typical sweet variety Early Grano had the least TSS. The major genes controlling bulb carbohydrate content have been reported to be located on chromosomes 5 and 8 (Masuzaki *et al*. 2007) and play independent role for higher amounts of soluble carbohydrates.

There is no report on association of skin colour and TSS at genetic level, but at expression levels red genotypes have been reported to posses higher TSS than yellow or white onions (Lee *et al.* 2015) and our findings are also similar to the USA onion lines with few exceptions. Numerous volatile sulfur compounds are responsible for onion pungency which are produced upon tissue maceration and activation of allinase enzyme. The pungency is measured by pyruvic acid (PA) content and based on PA content, the genotypes are classified into three groups: low pungent or sweet (0-3 µ mol pyruvic acid/g FW), medium (3-7 µ mol pyruvic acid/g FW) and high (above7 µ mol pyruvic acid/g FW) (Dhumal *et al.* 2007). The mean pyruvic acid content in the present

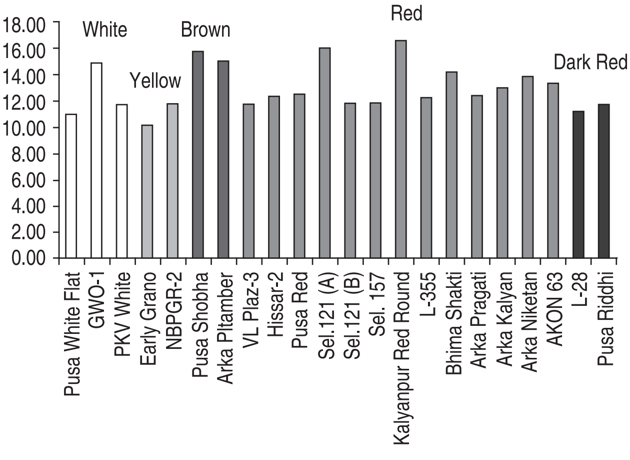

Fig 1 TSS variation in different skin color onion genotypes (skin color is indicated above bar).

Table 2 Mean performance, and level of significance for different traits

Genotype	Average bulb weight (g)	Equatorial diameter (mm)	Polar diameter (mm)	Neck thickness (mm)	TSS (°Brix)	Dry matter (%)
Hissar-2	56.67±3.33^{abcd}	52.01±1.13^{abcd}	37.34±1.33^{cdefg}	8.56±0.26^{a}	12.33±1.10^{cdefgh}	10.16±0.42^{bcdefg}
Pusa Shobha	63.33±3.33^{ab}	46.97±0.72^{efgh}	40.80±1.80^{bcd}	6.86±0.16^{abcdef}	15.78±0.92^{ab}	10.03±0.39^{bcdefg}
Pusa Red	43.33±3.33^{d}	47.24±0.88^{defgh}	39.23±0.26^{cdef}	7.35±0.40^{abcd}	12.47±1.35^{cdefgh}	10.23±1.76^{bcdefg}
Rosy	50.00±5.77^{bcd}	48.05±1.40^{defg}	36.47±0.56^{efg}	6.97±0.45^{abcdef}	13.37±1.38^{bcdefg}	9.92±0.43^{bcdefgh}
Kalyanpur Red Round	50.00±5.77^{bcd}	45.19±2.36^{gh}	35.44±0.99^{fg}	7.14±0.62^{abcde}	16.65±0.52^{a}	11.09±1.67^{bcd}
Pusa Riddhi	53.33±3.33^{abcd}	49.83±1.36^{bcdef}	38.27±0.60^{cdef}	6.93±0.58^{abcdef}	11.68±0.47^{efgh}	9.73±1.37^{bcdefgh}
Arka Niketan	53.33±8.82^{abcd}	48.59±1.43^{cdefg}	38.51±2.06^{cdef}	6.66±0.42^{bcdefg}	13.82±0.16^{bcdef}	7.95±1.44^{efghi}
VL Piaz-3	60.00±0.00^{abc}	52.35±1.86^{abc}	36.74±0.65^{defg}	6.65±1.06^{bcdefg}	11.77±1.13^{efgh}	9.51±0.90^{bcdefgh}
Sel. 121(B)	66.67±6.67^{a}	50.41±0.75^{bcdef}	40.07±1.65^{bcde}	6.57±0.32^{bcdefg}	11.77±0.38^{efgh}	8.41±1.03^{defgh}
Bhima Shakti	56.67±3.33^{abcd}	46.55±0.79^{fgh}	39.09±1.16^{cdef}	6.59±0.42^{bcdefg}	14.20±1.37^{abcde}	7.87±0.81^{fghi}
NBPGR-2	50.00±5.77^{bcd}	45.39±2.27^{gh}	48.26±1.53^{a}	5.05±0.85^{gh}	11.68±1.50^{efgh}	11.05±0.24^{bcde}
Early Grano	43.33±3.33^{d}	43.56±1.74^{h}	38.16±2.25^{cdef}	4.52±0.36^{h}	10.13±0.41^{h}	7.31±1.00^{ghi}
L-28	66.67±6.67^{a}	46.01±1.85^{a}	36.54±0.29^{efg}	7.00±0.89^{abcdef}	11.20±0.38^{fgh}	9.13±0.59^{cdefgh}
JWO-1	46.67±6.67^{cd}	47.10±2.84^{efgh}	38.12±0.79^{cdef}	6.20±0.59^{cdefgh}	14.87±1.01^{abcd}	12.39±0.17^{ab}
Arka Pragati	50.00±5.77^{bcd}	46.38±2.42^{fgh}	37.46±1.14^{cdefg}	7.92±0.52^{ab}	12.38±0.43^{cdefgh}	6.82±0.47^{hi}
PKV White	43.33±3.33^{d}	45.64±0.20^{gh}	35.51±1.64^{fg}	5.41±0.62^{fgh}	11.73±0.96^{efgh}	10.80±0.77^{bcdef}
L-355	46.67±6.67^{cd}	46.61±1.62^{fgh}	39.72±0.76^{bcde}	5.72±0.43^{defgh}	12.18±1.07^{defgh}	11.66±0.55^{abc}
Pusa White Flat	60.00±0.00^{abc}	50.75±1.19^{bcde}	39.46±0.19^{cdef}	7.42±0.61^{abc}	10.97±0.15^{gh}	7.83±1.39^{fghi}
Arka Kalyan	53.33±8.82^{abcd}	48.97±0.89^{bcdefg}	39.16±2.59^{cdef}	6.15±1.21^{cdefgh}	13.02±0.98^{cdefg}	4.87±1.02^{i}
Sel. 121 (A)	63.33±3.33^{ab}	52.85±1.44^{ab}	41.10±2.72^{bc}	6.41±0.62^{bcdefg}	16.02±1.68^{ab}	14.42±0.27^{a}
Sel. 157	56.67±16.67^{abcd}	50.38±2.39^{bcdef}	43.78±1.90^{b}	6.63±0.48^{bcdefg}	11.83±0.87^{efgh}	14.58±2.87^{a}
Arka Pitamber	43.33±3.33^{d}	49.02±0.76^{bcdefg}	33.61±1.18^{g}	5.63±0.51^{efgh}	15.02±0.32^{abc}	14.40±0.47^{a}
General Mean	53.48	48.17	38.76	6.56	12.95	10.01
P-value	0.0351	<0.0001	<.0001	0.0080	0.0002	<.0001

**Means with at least one letter common are not statistically significant using Fisher's Least Significant Difference

study ranged between 4.67 µmol (Early Grano) to 12.81 µ mol (Hissar-2) and based on the above classifications, 19 varieties were highly pungent and 3 moderately pungent (Table 3), and there was no correlation with skin color. The dark red colored genotypes L-28 had 9.62 µmol, L-355 had 10.01 µmol while Pusa Riddhi had 6.61 µmol. White colored Pusa White Flat had 8.24 µmol, PKV white had 8.03 µmol and the yellow coloured Arka Pitamber had 10.66 µmol and brown coloured Pusa Shobha had 10.03 µmol. The independent distribution of pungency and skin color were earlier reported by Lee *et al.* (2015) from a set of 15 genotypes grown in Texas, America but Dhumal *et al*. (2007) reported lower pungency level in white onions grown in India. Liguori *et al*. (2017) also reported high pungency values ranging from 9.0 to 14.0 µmol/g FW in Italian white onion landraces. In Indian onion genotypes, the report on such association is rather limited.

Total phenols (TP) offer a variety of health benefits to human because of their antioxidant nature. The TP content varied from 740.67 (µg GAE/ml) to 1145.33 (µg GAE/ ml) (Table 3) with a 1.5 fold variations among the genotypes. Hissar 2, Pusa Red, Arka Kalyan, L 28 (Dark red), Arka Pitamber (Yellow) and JWO-1 (White) were the most preferred genotypes. Here also we did not notice any correlation with skin colour, however, there is an earlier report mentioning superiority of red cultivars over white (Kaur *et al*. 2009). The flavonoids content varied widely with 14.68 fold difference (Table 3) among the genotypes – the highest variations among genotypes for a particular trait. White variety Pusa White Flat (31.67 µg QE/ ml) had the least flavonoids content and the yellow variety Arka Pitamber (465.00 µg QE/ ml) had the highest. The genotypes were categorized into 3 groups; low (<200 µg GAE/ ml), medium (200-300 µg GAE/ ml) and high (>300 µg GAE/ 100 ml). Nine varieties were included in the high category (Hissar-2, Pusa Red, Kalyanpur Red Round, Pusa Riddhi,

Table 3 Mean performance, and level of significance for different traits

Genotype	Pungency (µmol/gFW)	Total phenols (µg GAE/mL)	Total flavonoids (µg QE/mL)	FRAP (µmol Trolox/g)	CUPRAC (µmol Trolox/g)	Juice recovery (%)
Hissar-2	12.28±0.04^{a}	1145.33±4.37^{a}	431.00 ± 19.04 ^{ab}	3.92 ± 0.04 ^{b}	5.13 ± 0.01 ^{a}	36.36 ± 1.61 ^{efg}
Pusa Shobha	7.87±0.46^{e}	1036.67±8.36^{bc}	283.67 ± 20.00 ^{efg}	2.92 ± 0.06 ^{c}	3.77 ± 0.06 ^{f}	32.70 ± 6.21 ^{ghij}
Pusa Red	9.65±0.40^{c}	1120.33±15.07^{a}	348.67 ± 19.81 ^{cd}	2.53 ± 0.04 ^{de}	4.61 ± 0.02 ^{cd}	32.94 ± 0.60 ^{ghij}
Rosy	9.39±0.62^{cd}	740.67±2.18^{i}	146.33 ± 16.27 ^{ijk}	2.46 ± 0.02 ^{e}	4.80 ± 0.01 ^{bc}	33.07 ± 0.68 ^{ghij}
Kalyanpur Red Round	11.90±0.11^{a}	994.00±10.26 ^{cd}	344.67 ± 43.72 ^{cd}	2.07 ± 0.01 ^{f}	4.18 ± 0.07 ^{e}	47.98 ± 0.55 ^{ab}
Pusa Riddhi	6.61±0.23^{f}	893.67 ± 13.64 ^{fg}	395.00 ± 18.58 ^{bc}	2.87 ± 0.02 ^{c}	5.07 ± 0.03 ^{a}	42.46 ± 1.02 ^{cd}
Arka Niketan	6.56±0.37^{f}	1050.00 ± 3.51 ^{b}	330.00 ± 5.86 ^{de}	2.87 ± 0.04 ^{c}	2.72 ± 0.02 ^{i}	34.94 ± 0.86 ^{efgh}
VL Piaz-3	8.51±0.43^{de}	885.33 ± 8.01 ^{fg}	229.00 ± 6.25 ^{gh}	1.83 ± 0.04 ^{gh}	4.42 ± 0.10 ^{d}	39.54 ± 1.24 ^{de}
Sel. 121(B)	8.68±0.60^{de}	967.67 ± 17.23 ^{de}	150.00 ± 3.79 ^{ij}	2.41 ± 0.14 ^{e}	3.76 ± 0.03 ^{f}	25.28 ± 0.98 ^{lm}
Bhima Shakti	11.81±0.15^{a}	848.00 ± 2.52 ^{gh}	88.67 ± 2.96 ^{klm}	1.73 ± 0.03 ^{hi}	2.98 ± 0.11 ^{h}	37.68 ± 0.97 ^{ef}
NBPGR-2	9.61±0.30^{c}	1141.33 ± 1.32 ^{a}	196.67 ± 27.09 ^{hi}	2.86 ± 0.02 ^{c}	4.95 ± 0.08 ^{ab}	38.06 ± 1.16 ^{def}
Early Grano	4.67±0.25^{g}	821.00 ± 39.68 ^{h}	72.00 ± 8.54 ^{lm}	1.77 ± 0.02 ^{hi}	3.91 ± 0.12 ^{f}	32.99 ± 0.30 ^{ghij}
L-28	9.62±0.36^{c}	1136.33 ± 4.09 ^{a}	328.00 ± 23.69 ^{def}	4.63 ± 0.02 ^{a}	5.10 ± 0.02 ^{a}	27.54 ± 0.42 ^{kl}
JWO-1	12.20±0.03^{a}	1125.33 ± 12.35 ^{a}	303.00 ± 41.07 ^{def}	3.01 ± 0.02 ^{c}	3.25 ± 0.05 ^{g}	21.34 ± 0.49 ^{m}
Arka Pragati	8.57±0.26^{de}	862.00 ± 15.72 ^{gh}	203.33 ± 19.10 ^{hi}	1.70 ± 0.04 ^{hi}	2.97 ± 0.13 ^{h}	44.58 ± 1.05 ^{bc}
PKV White	8.03±0.05^{e}	928.00 ± 27.51 ^{ef}	393.33 ± 15.62 ^{bc}	1.67 ± 0.01^{hi}	3.17 ± 0.05 ^{gh}	29.32 ± 0.66 ^{jkl}
L-355	10.01±0.13^{bc}	995.67 ± 2.96 ^{cd}	75.67 ± 9.49 ^{lm}	1.99 ± 0.04 ^{fg}	3.14 ± 0.13 ^{gh}	30.58 ± 0.71 ^{hijk}
Pusa White Flat	8.24±0.14^{e}	1011.33 ± 26.69 ^{bcd}	31.67±12.01^{m}	1.60 ± 0.12^{i}	2.23 ± 0.03 ^{j}	29.19 ± 0.13 ^{jkl}
Arka Kalyan	9.97±0.16^{bc}	1106.67±13.86 ^{a}	105.67±4.37 ^{jkl}	1.69 ± 0.14 ^{hi}	2.58 ± 0.03 ^{i}	30.34 ± 1.74 ^{ijk}
Sel. 121 (A)	8.01±0.14^{e}	1007.00 ± 34.24 ^{bcd}	115.00 ± 20.82 ^{jkl}	1.63 ± 0.14 ^{i}	3.33 ± 0.07 ^{g}	30.47 ± 0.44 ^{hijk}
Sel. 157	9.30±0.11^{cd}	923.00 ± 11.59 ^{ef}	268.67 ± 13.13 ^{fg}	2.64 ± 0.05 ^{d}	4.79 ± 0.12 ^{bc}	50.32 ± 0.72 ^{a}
Arka Pitamber	10.66±0.59^{b}	1132.67 ± 6.12 ^{a}	465.00 ± 52.09 ^{a}	3.84 ± 0.02 ^{b}	5.14 ± 0.01^{a}	34.88 ± 1.61 ^{fghi}
General mean	10.92	994.18	241.14	2.48	3.91	34.66
P-value	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

**Means with at least one letter common are not statistically significant using Fisher's Least Significant Difference

Arka Niketan, L-28, JWO-1, PKV White, Arka Pitamber) and 9 were in low category. Our study contradicts the earlier report stating that the white onion varieties contain less flavonoids (Hermann, 1976) and supported by Lee *et al*. 2015. White variety Pusa White Flat had the least flavonoid content (31.67 µg GAE/mL) while the other white variety JWO-1 had comparatively higher flavonoid content (303.00 µg GAE/mL), higher than some dark red and red coloured varieties like L-355, Arka Pragati, Sel. 157 and VL Piaz-3. Sharma *et al.* (2014) reported highest flavonoids content of 2873.95±60.01 µg Q/g DW in Korean onion cultivar Sunpower.

Antioxidant activity as measured by FRAP and CUPRAC ranged from (1.60-4.63 µmol Trolox/g Fresh weight) and (2.23-5.14 µmol Trolox/g Fresh weight), respectively (Table 3) and in both the cases, white genotype Pusa White Flat had the poorest performance and dark red genotype L-28 had the highest value. White genotype JWO-1, which scored high for TSS, dry matter %, TP and TF content have comparatively poor performance for antioxidant activity. Lu *et al.* (2011) reported FRAP value of different onion types grown in USA ranges from 2.48 µmol Trolox/g (sweet onion varieties) to 5.76 µmol Trolox/g (red onion varieties), which is similar to our findings.

Importance of onion juice content has not received due attention till today but with the change in mindset from synthetic drugs to natural therapy to reduce the undesirable side effects of synthetic drug, juice recovery is getting attention with breeders focusing on breeding for more juicer varieties. The high dry matter varieties are more suitable for dehydration purpose while juicy varieties for juice extraction and fresh consumption. The varieties were classified into 3 categories based on juice content. The more juicy (>40%) varieties were Pusa Riddhi, Kalyanpur Red Round and Arka Pragati and the least were Pusa White Flat, JWO-1, NHRDF Red and Arka Kalyan (Table 3). Pusa White Flat and JWO-1 being less juicy gives indirect advantage as they will be more suitable for processing and higher recovery of processed product.

The genotypic and phenotypic estimate of variance, coefficient of variation, heritability, genetic advance and percent genetic gain over mean value was estimated

Table 4 Estimates of variance, coefficient of variance, heritability, genetic advance (GA), GA as percentage of mean for bulb and quality traits

Trait	Vg	Vp	GCV	PCV	Heritability (%)	Genetic advance	Genetic advance as % of mean
Bulb weight	27.71	57.65	9.84	20.27	48.06	7.52	14.06
Equatorial diameter	6.91	8.94	5.41	7.42	77.26	3.18	6.61
Polar diameter	7.29	9.33	6.96	9.45	78.06	5.89	15.20
Neck thickness	0.49	0.85	10.68	19.01	58.16	1.49	22.78
TSS	2.29	3.18	11.68	17.21	71.90	3.30	25.48
Pungency	3.56	3.66	20.54	21.38	97.29	3.93	36.03
Total phenols	14037.33	14297.09	11.92	12.24	98.18	246.19	24.76
Flavonoids	16468.72	16920.95	53.22	55.37	97.33	267.69	111.01
FRAP	0.70	0.71	33.73	34.01	99.46	1.73	69.78
CUPRAC	0.90	0.90	24.24	24.46	99.40	1.96	50.05
Juice recovery	48.30	50.90	20.05	21.61	94.90	14.64	42.24
Percent dry matter	4.57	5.81	21.26	28.61	78.73	4.67	46.62

Table 5 Correlation coefficient between bulb weight, TSS, pungency, total phenols and antioxidant activity in onion

		Bulb wt	ED	PD	NT	TSS	Pungency	TP	FL	FRAP	CUPRAC	Juice recovery	% dry
Bulb weight	g	1.00	0.84**	0.25	0.65*	0.05	-0.06	0.09	-0.29	0.21	-0.05	-0.14	0.04
	p	1.00	0.66*	0.22	0.27	0.00	-0.05	0.02	-0.16	0.11	0.00	-0.05	-0.25
Equ. diameter	g		1.00	-0.08	0.65*	-0.17	0.07	0.30	0.15	0.48	0.28	-0.18	0.24
	p		1.00	-0.09	0.28	-0.06	0.06	0.21	0.10	0.36	0.21	-0.11	0.02
Polar diameter	g			1.00	-0.49	-0.19	-0.13	0.15	-0.45	-0.13	-0.03	0.09	0.14
	p			1.00	0.02	-0.15	-0.08	0.17	-0.28	-0.09	0.00	0.12	0.09
Neck thick	g				1.00	0.09	0.41	0.07	0.33	0.27	0.08	0.32	-0.22
	p				1.00	0.16	0.23	0.06	0.15	0.14	0.06	0.18	-0.13
TSS	g					1.00	0.50	0.24	0.25	0.02	-0.13	0.03	0.44
	p					1.00	0.31	0.13	0.16	0.03	-0.08	0.09	0.35
Pungency	g						1.00	0.41	0.22	0.28	0.15	0.00	0.34
	p						1.00	0.39	0.20	0.27	0.13	0.02	0.22
Total phenols	g							1.00	0.41	0.57	0.12	-0.33	0.25
	p							1.00	0.38	0.55	0.11	-0.30	0.21
Flavonoids	g								1.00	0.66*	0.56	0.21	0.41
	p								1.00	0.63*	0.54	0.20	0.32
FRAP	g									1.00	0.67*	-0.10	0.31
	p									1.00	0.66*	-0.10	0.23
CUPRAC	g										1.00	0.33	0.48
	p										1.00	0.31	0.33
Juice recovery	g											1.00	0.13
	p											1.00	0.10
Percent dry matter	g												1.00
	p												1.00

g -genotypic, p- phenotypic correlation coefficient, *significant at 5% level of significance; **significant at 1% level of significance to analyze role of genotype and possible influence of environment for the expression of various traits (Table 4). Lower difference between phenotypic and genotypic variance was observed for TSS, pungency and antioxidant activity suggesting strong role of genotypes in the expression of the above traits. Similarly, lower difference between phenotypic and genotypic coefficient of variation was observed for pungency, total phenol and antioxidant activity. The genetic advance as percent of mean ranged from 6.61 to 111.01. It was highest for total flavonoids followed by FRAP, CUPRAC, percent dry matter, juice recovery and least for bulb diameter and average bulb weight. The quality traits like pungency, total phenol, flavonoids, CUPRAC and FRAP value had higher heritability (>90%) and comparatively less for percent dry matter (78.73%), TSS (71.90%) and average bulb weight (48.06%). High heritability along with high genetic advance was observed for total phenols and flavonoids indicating possible role of selection for the improvement of these traits. The traits having lower genetic advance suggest possible role of non-additive gene action and these traits can be improved following hybridization and recurrent selection. The information on heritability, genetic advance and genetic gain for phytochemical traits in onion are rather limited. Singh *et al*. (2017) reported high heritability for total phenol and antioxidant activity in pigmented radish.

The magnitude and direction of association among various traits were estimated through calculation of correlation co-efficient (genotypic and phenotypic). The genotypic correlation coefficient was higher compared to phenotypic, supporting greater role of genotype in the expression of the traits (Table 5). Average bulb weight had significant positive association with bulb equatorial diameter and other associations were non-significant. Total soluble solids had positive association with bulb weight but negative association with bulb diameter. TSS and pungency exhibited non-significant positive association and both of them did not have any significant association with either phenols or antioxidant activity. This is in contrast to the general notion that higher pungent varieties offer greater health benefits and supported by Lee *et al*. (2015) in USA onion collection and Pérez *et al*. (2018) in Western Europe onion collection. They also suggested independent distribution of pungency and antioxidant activity in onion collection. This necessitates more focused breeding effort to develop anti-oxidant rich onion varieties and suggest possibilities of breeding sweet onion varieties rich in health benefits.

Wide variations were observed for all the traits particularly higher for flavonoids. Greater role of genotypes was observed for most of the traits. The quality traits like TSS, pungency, total phenols, antioxidant activity were independent of the skin colour group, therefore, they can be improved in the entire skin colour group to cater to the need of the people in diverse zone. In some geographic region white coloured onion varieties are preferred over red and reverse in other region. Onion is particularly rich source of flavonoids with great health benefits and systemic breeding for improvement of this trait will yield positive result which can be commercialized for pharmaceutical preparations. There is a need to study the role of specific genes for the biosynthesis of antioxidant compounds as has been done for TSS genes. Therefore, the present study can serve as a reference for further improvement of health related traits of Indian onion varieties.

REFERENCES

Al-Jibouri H W, Millar P A and Robinson H F. 1958. Genotypic and environmental variance and co-variance in an upland cotton cross of interspecific origin. *Agronomy Journal* **50**: 633–7.

Aditika, Dod P and Sharma V N M. 2017. Variability studies in Rabi onion (*Allium cepa* var cepa L) for yield and yield contributing traits. *International Journal of Farm Sciences* **7**(1): 123–6.

Anthon G E and Barrett D M 2003. Modified method for the determination of pyruvic acid with dinitrophenylhydrazine in the assessment of onion pungency. *Journal of the Science of Food and Agricultural* **83**(12): 1210–3.

Apak R, Güçlü K, Özyürek M and Karademir S E. 2004. Novel total antioxidant capacity index for dietary polyphenols and vitamins C and E, using their cupric ion reducing capability in the presence of neocuproine: CUPRAC method. *Journal of Agricultural Food Chemistry. Food Chem.* **52**(26): 7970–81.

Benzie I F and Strain J J. 1996. The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": the FRAP assay. *Analytic Biochemistry* **239**(1): 70–6.

Desjardins Y. 2008. Onion as a nutraceutical and functional food. *Cronica Horticulturae* **48**: 8–14.

Dhumal K, Datir S and Pandey R. 2007. Assessment of bulb pungency level in different Indian cultivars of onion (*Allium cepa* L.). *Food Chemistry* **100**(4): 1328–30.

Johnson H W, Robinson H F and Comstock R. 1955. Estimates of genetic and environmental variability in soybeans 1. *Agronomy Journal* **47**(7): 314–8.

Kaur C, Joshi S and Kapoor H C. 2009. Antioxidants in onion (*Allium cepa* L) cultivars grown in India. *Journal of Food Biochem.* **33**: 184–200.

Kushal M G, Patil J M, Nidagundi D G, Satihal M and Venkatesh K. 2015. Studies on performance of onion (*Allium cepa* L.) genotypes for agro-morphological traits during Rabi Season. *International Journal of Tropical Agriculture* **33**(4): 2827–30.

Lee E J, Patil B S and Yoo K S. 2015. Antioxidants of 15 onions with white, yellow, and red colors and their relationship with pungency, anthocyanin, and quercetin. *LWT – Food Science and Technology* **63**: 108–14.

Liguori L, Califano R, Albanese D, Raimo F, Crescitelli A and Di Matteo M. 2017. Chemical composition and antioxidant properties of five white onion (*Allium cepa* L.) landraces. *Journal of Food Quality* **2017**: 1–9.

Lu X, Wang J, Al-Qadiri H M, Ross C F, Powers J R, Tang J and Rasco B A. 2011. Determination of total phenolic content and antioxidant capacity of onion (*Allium cepa*) and shallot (*Allium oschaninii*) using infrared spectroscopy. *Food Chemistry* **129**(2): 637–44.

Lush J L. 1949. Heritability of quantitative characters in farm animals. *Hereditas* **35**(S1): 356–75.

Masuzaki S, Yahuchi S, Yamauchi N and Shigyo M. 2007. Morphological characterisation of multiple alien addition lines of Allium reveals the chromosomal locations of gene(s) related to bulb formation in *Allium cepa* L. *Journal of Horticultural Science and Biotechnology* **82**: 393–6.

NCAER. 2014. An Analysis of Changing Food Consumption Pattern in India. National Council of Applied Economic Research, Parisila Bhawan, I P Estate, New Delhi.

Panse V G and Sukhatme P V. 1967. *Statistical Methods for Agricultural Workers*. Indian Council of Agricultural Research (ICAR), New Delhi, India.

Raines S, Henson C and Havey M J. 2009. Genetic analyses of soluble carbohydrate concentrations in onion bulbs. *Journal of American Society for Horticultural Science* **134**: 618–23.

Singh A K, Janakiram T, Singh M and Mahajan V 2017. Onion cultivation in India- a way forward. *Indian Horticulture* **62**(6): 3–8.

Singh B K, Koley T K, Karmakar P, Tripathi A, Singh B and Singh M. 2017. Pigmented radish (*Raphanus sativus*): Genetic variability, heritability and inter-relationships of total phenolics, anthocyanins and antioxidant activity. *Indian Journal of Agricultural Sciences* **87**(12): 1600–6.

Singleton V L, Orthofer R and Lamuela-Raventos R M. 1999. Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. *Methods in Enzymology* **299**: 152–78.

Sharma K, Assefa A D, Kim S, Ko E Y, Lee E T and Park S W. 2014. Evaluation of total phenolics, flavonoids and antioxidant activity of 18 Korean onion cultivars: a comparative study. *Journal of the Science of Food and Agriculture* **94**(8): 1521–9.

Vision. 2050. Directorate of Onion and Garlic Research Rajgurunagar, Pune, Maharashtra, India.

Warner J N. 1952. A method for estimating heritability. *Agronomy Journal* **44**(8): 427–30.

www. agriexchange.apeda.gov.in accessed on 30 April, 2017.

www.agricoop.nic.in accessed on 30 April, 2017.

Zeng Y, Li Y, Yang J, Pu X, Du J, Yang X and Yang S. 2017. Therapeutic role of functional components in *Alliums* for preventive chronic disease in human being. *Evidence-Based Complementary and Alternative Medicine* **2017**: 1–13.

Zhishen J, Mengcheng T and Jianming W. 1999. The determination of flavonoids contents in mulberry and their scavenging effects on superoxide radicals. *Food Chemistry* **64**: 555–9.