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Study on dispersion of genetic variation among Indian garlic ecotypes using agro morphological traits

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Abstract

Garlic (*Allium sativum* L.) a clonally propagated bulbous crop, is of high medicinal value owing to its sulphur-containing compounds. Although asexually propagated, garlic depicts wide genetic diversity in agro-morphological traits and biochemical composition. A study was conducted to dissect the extent of genetic divergence among 625 Indian garlic genotypes considering 21 agro-morphological traits. Pooled analysis exhibited significant variation among accessions for various morphological traits. Ward's clustering method clustered germplasm collection into three distinct groups. Clustering pattern did not correspond with geographical origin of accessions. Strong and positive correlation of marketable yield with plant weight with leaves (r = 0.83), plant weight without leaves (r = 0.84), average bulb weight (r = 0.50), plant height (r = 0.58), pseudostem length (r = 0.59), number of leaves (r = 0.54) and weight of fifty cloves (r = 0.49) was recorded. These traits will be useful for direct selection in crops like garlic. Principal Component analysis minimised 21 components up to 12 vectors which measured nearly 90% variation. Conservation of such vital and diverse garlic genotype is prerequisite to assure successful selection breeding programme.

Key words: Genetic diversity, Principal Component Analysis, correlation, cluster analysis, *Allium sativum* L.

Introduction

Globally garlic (*Allium sativum* L.) is a second most widely consumed *Allium* after onion.Its basic chromosome number ranges from 7 to 9. However, species native to Mediterranean region contain eight chromosomes (Brat 1965). Botanically, garlic is classified as soft neck and hard neck garlic. Soft neck garlic (*A. sativum* ssp*. sativum*) contains 10-20 cloves per bulb in at least three layers and is incomplete bolter type. By contrast, hard neck (*A. sativum* ssp. *ophioscorodon*) possesses 6 to 11 cloves in single round position and produces scape and flower stalks (Volk et al. 2004). This classification elaborated by other researchers (Keller 2002; Hanelt 2001) and further explained its sub-grouping by Maass and Klaas (1995). Based on morphological, isozyme and molecular markers, Etoh and Simon (2002) grouped *A. sativum* species into four classes as *Longicuspis, Subtropical, Ophioscorodon* and *Sativum.*

Garlic is known for its health benefits as it constitutes characteristic organo-suphur compounds (Barboza et al. 2020). Besides, it is an excellent source of flavonoids, antioxidants, lectins, vitamins and minerals (Pizzorno and Murray 2005). These biochemicals not only add identical flavour and pungency to garlic but make it most referable medicine. Medicinal value of garlic was quoted date back 5000 years ago in the history of Egypt, China and India. The typical flavor of garlic has made it a common ingredient in cuisines worldwide. Garlic consumption helps to improve health status by enhancing immunity, reducing cholesterol level, lowering blood pressure level, curing skin allergies and reducing cancer risk (Sterling and Eagling, 2001). Characterization of genotypes in the form of report is necessary to acquaint with evolution process followed in garlic. Therefore, study on genetic diversity, population structure concerning the morphological, enzymatic and molecular level is prerequisite. This information will serve as a stepping stone for improving breeding strategies in this crop through selection. The primary centre of origin of garlic is Central Asia, *i.e.,*

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Kazakhstan, Tajikistan, Turkmenistan, and Uzbekistan (Vavilov 1951) and secondary centre of origin is Mediterranean and Caucasus zone (Etoh and Simon 2002). In their native region, garlic was found to produce fertile flowers and further set real seeds (Hong et al. 2000). Flowering in some garlic clones is often associated with the presence of bulbils formed in the place of flowers (Kamenetsky and Rabinowitch 2001). However, in a country like India that is located near to the place of native origin, short day garlic does not produce scape or seeds and is regenerated through cloves. Such asexual propagation methods are usually essential for maintaining identity and uniformity of a variety or accession as there is no segregation of alleles. But due to presence of phenotypic plasticity and natural mutations, garlic reflects differences in various traits like bulb shape, bulb size, bulb colour, bolting behaviour, storability and maturity (Bradley et al. 1996; Wang et al. 2014). But asexual propagation leads to accumulation of infection from various soil-borne diseases and viruses. In seasonal cultivation of such infected clones, degeneration of yield potential and reduced quality of bulb has been observed.

Analysis of genetic diversity at agro-morphological and molecular levels in germplasm for identifying diverse parents to be used in hybridization to improve varieties has been carried out in various crops such as vegetables (Khar et al. 2011, Dangi et al. 2018), cereals (Boczkowska et al. 2014), oilseeds (Iqbal et al. 2018), medicinal (Ray et al. 2019) and horticultural plants (Veluru et al. 2019). Studies on genetic variation in garlic germplasm concerning morphological, biochemical and molecular levels have also been carried out earlier. To date, many researchers studied garlic properties concerning morphological (Wang et al. 2014; Silva et al. 2014, Ovesna et al. 2007; Panthee et al. 2006), biochemical approaches, isozymes (Ipek et al. 2003; Lallemand et al. 1997; Barboza et al. 2020) allicin content (Baghalian et al. 2005; Wang et al. 2014) and S-amino acids level in garlic (Ovesna et al. 2007). For assessing diversity at molecular level, AFLP (Ovesna et al. 2007; Ipek et al. 2006; Ipek et al. 2005; Volk et al. 2004), RAPD (Paredes et al. 2008; Khar et al. 2008), SSR (Kumar et al. 2019; Cunha et al. 2012; Jo et al.2012; Khar 2012) and SRAP (Chen et al. 2013) have been employed. However the consistency among the genetic distance calculated from phenotypic and genotypic data may not correspond and thus the diversity estimates from phenotypes and DNA markers cannot be compared due to their very different nature and utility for different purposes. This indicates that genetic divergence of genotypes is independent of geographic origin as has also been earlier reported in oilseeds (Zhang et al. 2012; Ramprasad et al. 2017). Garlic has a complex and large genome almost 32.7pg/2C (Evans et al. 1983) thus, molecular analysis and identification of polymorphic molecular markers is becoming difficult in this crop. Hence, assessment of diversity on a morphological basis and the assessing diversity of selected trait specific lines on the molecular basis is a sound strategy.

In India, especially northern and few southern states garlic has been cultivated long ago. But national average productivity of garlic is as low as 5t/ha (FAOSTAT 2017). Presently, nearly 50 improved varieties are available in public domain but growers are using self produced seed material for cultivation. Therefore, Indian garlic seed industry is under threat of genetic erosion, uncontrolled introduction of cultivars etc. Hence, an attempt to assess the morphological diversity of the 625 garlic accessions representing almost 20 states of India, being maintained in field gene bank of ICAR-DOGR, was undertaken in the present study.

Materials and methods

Experimental material consisting of a total of 625 garlic accessions collected from different agro-ecological regions of India since 1996 were used for characterisation. This collection is a composite group of varieties, landraces, improved material and cultivars. The number of accessions studied have been collected from different states, namely, Jammu & Kashmir (8), Himachal Pradesh (6), Punjab (1), Delhi (173), Haryana (15), Uttaranchal (34), Uttar Pradesh (4), Madhya Pradesh (18), Bihar (9), Orissa (18), Rajasthan (23), Gujarat (170), Maharashtra (78), West Bengal (8), Andhra Pradesh (43), Karnataka (7), Jharkhand (3), Tamil Nadu (2), Manipur (2), Arunachal Pradesh (1) and 2 were of unknown origin (Supplementary Table S1). The experiment was carried out at the Directorate of Onion and Garlic Research, Rajgurunagar (18.87ºN 73.90^{o}E) farm during *rabi* 2014-15 and 2015-16. All the entries were planted in alpha lattice design in two replications in a one square metre plot per accession. Spacing between plants was 10cm and row to row distance was maintained at 15 cm. Recommended agronomic practices were followed throughout the crop life cycle. Crop was harvested when there was either neck-fall or all of the leaves showed senescence.

Data recording and statistical analysis

The observations were recorded on 21 agro-morphological traits. After completion of vegetative growth (70 days of planting) data were recorded on traits namely, the number of leaves, fourth leaf width (mm), fourth leaf length (cm), pseudostem length (cm), pseudostem diameter (mm), plant height (cm) and plant architecture. Traits like plant weight with leaves (q/ha), plant weight without leaves (q/ha), total yield (q/ha), marketable yield (q/ha), neck thickness (mm), number of cloves per bulb, average weight of bulb (gm), bulb polar diameter (mm), bulb equatorial diameter (mm), weight of 50 cloves (gm), total soluble solids (°brix), shape of bulb, bulb skin colour and clove skin colour were recorded after harvest and proper curing (60 days after harvest). All these quantitative (17 traits) and qualitative (4 traits) traits were recorded on five random plants in each replication in both the years.

Software "SAS 9.3" was used for processing the replicated data. "Proc GLM" was used for univariate analysis measuring analysis of variance, mean phenotypic differences and interaction effects. SAS JMP Pro10 software was used for multivariate cluster analysis based on Ward's method (Ward 1963) by scoring squared Euclidian distance and principle component analysis.

Results and discussion

The availability of genetic variation within crop is of pivotal importance for its sustainable agriculture as the improvement in any crop is directly proportional to magnitude of its genotypic variability. Germplasm characterization and evaluation is prime necessary for its effective utilization especially when old cultivars are overtaken by new varieties. Globally garlic depicts good genetic dispersion for quantity and quality traits, even though multiplied through the cloves. Considering future threat of genetic erosion and uncontrolled introduction of new cultivars, evaluation of 625 garlic germplasm has been undertaken. Prior to this study, many researchers (Kumar et al. 2019; Singh et al. 2014; Khar 2012 and Khar et al. 2008) have investigated a set of varieties, landraces or elite lines separately but the number of accessions were very less.

A set of 625 Indian garlic lines were studied to reveal the genetic variability present among them. Variability among accessions was significant for yield and other recorded agro-morphological traits, except neck thickness and leaf width. Jabbes et al. (2012) also reported significance for all quantitative traits except days to maturity for Tunisian garlic landraces. In case of Iranian garlic germplasm, Baghalian et al. (2005) recorded significant difference in bulb quantitative traits and non-significance for presence of total cloves per bulb. The results accrued from the present investigation are not in agreement with above reports which may be due to difference in population set, its growing location and agronomic practices.

A substantial magnitude of variation was observed for marketable yield and related yield attributing traits (Table 1). Highest variation was revealed in total yield and marketable yield indicating great scope to develop potential good yielding varieties. The yield contributing trait *viz*., average bulb weight ranged from 1.07 g (51 and 265) to 21.4 g (456), the weight of 50 cloves ranged from 12.11 g to 113g (32), and a number of cloves ranged from 6 to 39.55.

Table 1. Mean performance of 625 garlic accessions concerning various quantitative traits

Traits	Mean	Max.	Min.	Standard Deviation
Plant Height (cm)	40.57	67.8	21.49	4.4
Pseudostem Length (cm)	12.55	21.09	0.7	2.49
Number of Leaves	7.48	9.65	0.85	0.84
4th Leaf Length (cm)	28.38	41.70	12.28	3.08
4th Leaf Width (mm)	1.16	5.30	0.61	0.36
Plant weight with leaves (q/ha)	28.12	75.87	11.0	12.71
Plant weight without leaves (q/ha)	25.70	70.07	13.25	11.48
Total Yield (q/ha)	27.34	164.50	1.46	13.74
Marketable Yield (q/ha)	24.68	70.08	1.33	11.45
Average weight of bulb (gm)	7.39	21.40	1.07	3.3
Polar Diameter (mm)	10.21	16.96	2.72	1.77
Equatorial Diameter (mm)	11.76	23.09	2.64	2.12
Number of Cloves/Bulb (mm)	13.54	39.55	6.00	3.82
Weight of 50 Cloves (gm)	27.15	113.00	12.11	9.72
Pseudostem Diameter (mm)	6.51	13.39	1.61	1.02
TSS (degree Brix)	41.45	46.12	35.40	1.35
Days to Harvest (Days)	124.94	175.50	99.00	5.94

Within accessions, DOGR 401 recorded highest number of cloves per bulb (39.55), genotype DOGR-288 recorded the highest value (46.2°B) for TSS. Twenty three accessions were found early in maturity (99 to 110 days), whereas DOGR-278 matured in 105 days giving 42.9 q/ha yield.

The overall productivity of this set of accessions was low compared to other countries like China and Nepal. Wang et al. (2014) reported that three Chinese accessions yielded more than 15t/ha and Panthee et al. (2006) mentioned the highest yield level as 61 t/ha. Benke et al. (2018) recorded maximum yield up to 3t/ha during the *kharif* under Indian conditions. In qualitative traits, plant architecture divided the whole set into three types (erect, semi-spreading and spreading) among which 81% fell under semi-spreading type. In China, Wang et al. (2014) also reported that semi-spreading type accounted to almost 63% of the population. In case of shape, maximum accessions (60%) had heart-shaped bulbs, i.e., flat at the base and spherical vertically. In colour, wide range of white, violet and violet striped bulb colour was observed. However, whitish coloured bulbs were noted maximum time (55%). As all accessions were screened for two years at same location, significant differences in traits may be of genetic origin (Jabbes et al. 2012).

Cluster analyses

Further 625 garlic genotypes analysed to study genetic diversity, structure of population and to know the presence of duplicates in set. The analysis was performed by Hierarchical clustering computed by Wards method. Based on accessions pair-wise genetic distance magnitudes, dendrogram is constructed to show genetic relations among the genotypes. The dendrogram (Fig. 1) depicts

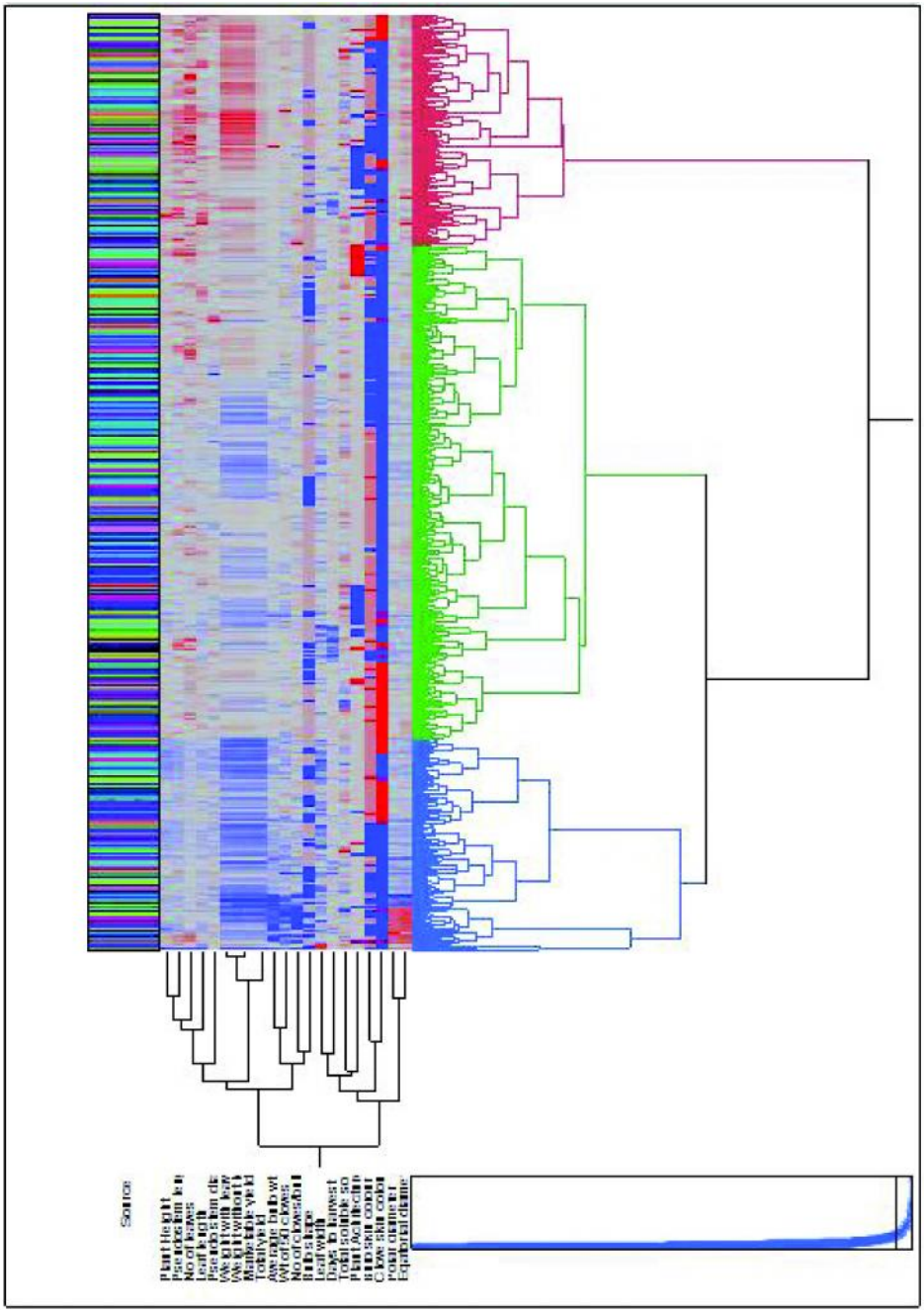

Fig. 1. Distance-based Dendrogram generated by Ward's method of cluster analysis using JMP-Pro 10 software of 625 Indian Garlic germplasm showing three significant groups

three distinct classes with the frequency of 153, 330 and 142 garlic genotypes in each group, respectively. Grouping of such vast number of accessions into three classes indicates the presence of several duplicates in the set as observed and reported by Panthee et al. (2006) in garlic collection from Nepal. Recently, Barboza et al. (2020) conducted a study to characterize 73 Argentinean garlic cultivars for quality traits using SSR markers and observed four major groups based on molecular and organo-sulphur compounds. During 2017, Egea et al. (2017) also obtained three main clusters from 417 garlic genotypes collection which was evaluated using high throughput genotyping DArTSeq method. In China, Wang et al. (2014) clustered 212 garlic accessions into six groups based on morphological traits. Similarly, Panthee et al. (2006) revealed three distinct groups of 179 garlic accessions from Nepal based on phenotypic data. However, Lallemand et al. (1997) assessed diversity among 65 garlic accessions and found a total of six clusters based on morphological traits. All these quoted reports studied accessions covering more than ten countries. Therefore, despite big geographic coverage, classification of Indian ecotypes into three groups is justifiable and reasonable. Among all the genotypes, WG-106 and IC-372980 were found to be most distantly related genotypes (47.90). However, overlapping for both qualitative and quantitative the traits like plant weight with and without leaves, marketable yield, days to harvest, bulb shape and bulb colour has been significantly noted in all clusters. Transportation within states will be the main reason behind this scenario. Main clusters were further sub-divided into thirteen sub-clusters. The first and second major groups comprised of four sub-group each while the third group comprised of five separate sub-groups. Here, no significant relation was found with accession's genetic divergence and geographic origin while clustering, which suggests that these genotypes had good adaptability and not specific to any region. Similar observations were noted by others (Egea et al. 2017; Wang et al. 2014; Siva et al. 2014; Asili et al. 2010; Panthee et al 2006) but for different sets of garlic accessions. This implies that there has been considerable movement of garlic genotypes from one place of India to other place and adaptability made them popular landraces/cultivars of that particular region (Fig. 1).

Differentiation of some popular varieties and well characterised genotypes in dendrogram is of special interest. Generated colour density map and two way clustering clearly shows that trait marketable yield primarily divides the clusters and later other traits contributed for further branching. Genotypes having high marketable yield (16 t/ha to 8 t/ha) grouped under cluster I, accessions having average marketable yield in between 8 to 1 t/ha sorted in cluster II while poor yielder (less than1t/ha) clubbed together in cluster III. Additionally, other yield attributing traits like average bulb weight, number of cloves per bulb, weight of 50 cloves, plant height, number of leaves and pseudostem length dispersed with similar pattern of marketable yield in cluster formation. Garlic accessions, EC631741, IC141095 and WG593 from cluster III sorted in one sub group exhibited clustering pattern based on their geographic origins. These accessions are native from Jammu and Kashmir hilly area and distinctly differed in traits such as they have spreading plant architecture, broadest leaf width, no bulb differentiation observed at experimental site additionally no leaf senescence found after 150 days to planting. These phenotypic differences are due their requirement of long day condition for bulbification with cool climate. Thus, environmental conditions are not fulfilled at the experimental site. Similarly, garlic accessions evaluated at Spain collected from Japan assessed using DArTSeq analysis by Egea et al. (2017) were also grouped together in one of sub-class. All qualitative traits along with total solids of genotypes dispersed all over population and not restricted to grouping as observed by Barboza et al. (2020) for biochemical and colour traits.

Principal component analyses

Clustering of genotypes was followed by principal component analysis for corroboration of both results. Concordant results observed in both the analyses which distinctly separate the accessions into three sets based on studied traits (Fig. 2). Here, identification of principal components was finalised using eigen-values and eigenvectors. Total of twelve elements were extracted from twenty one studied characters through analysis. First three components explained almost 50% of the variation. The first axis played a vital role in developing adaptation by contributing maximum 34.15% variation and highest eigen-value of 7.2 (Table 2). The most useful traits in the first component (Fig. 2) were the total yield, number of cloves, plant height, days to harvest, leaf length and leaf width. The polar diameter and equatorial diameter influenced effectively on the second axis (9.12%). However, in case of third axis (6.99%) number of leaves, bulb skin colour and clove skin colour influenced effectively (Table 3). Thus,

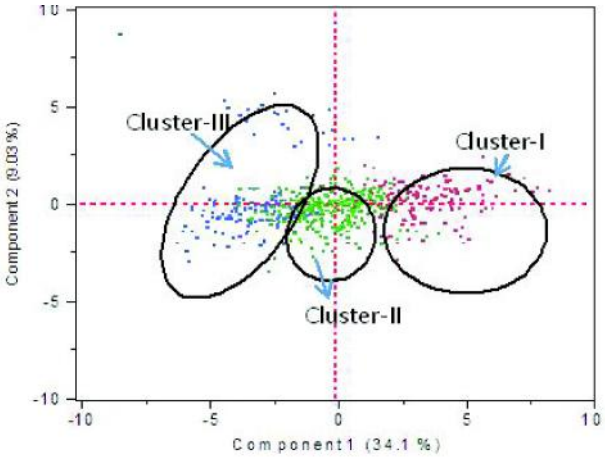

Fig. 2. Principal component analysis of 625 garlic accessions from India

these twelve traits identified as most relevant traits helped to distinguish accessions. The traits identified by PCA are quantitative as well as qualitative, but majorly quantitative play a significant role in contributing to diversity. Jabbes et al. (2012) studied Tunisian landraces of garlic and reported similar observations and the results obtained by Panthee et al. (2006) in a set of Nepalese garlic accessions were also in agreement with present findings. However, the number of accessions, their geographical origin and the number of characters studied were different.

Table 2. Eigen value with per cent contribution per component of PCA

Component	Eigen value	Per cent	Cum percent
1	7.1734	34.159	34.159
2	1.9166	9.127	43.286
3	1.4698	6.999	50.285
4	1.3286	6.327	56.612
5	1.1725	5.583	62.195
6	0.9946	4.736	66.931
7	0.9886	4.708	71.639
8	0.9699	4.618	76.257
9	0.7898	3.761	80.018
10	0.7767	3.698	83.716
11	0.6795	3.236	86.952
12	0.6679	3.18	90.132
13	0.596	2.838	92.971
14	0.446	2.124	95.095
15	0.4218	2.009	97.103
16	0.2838	1.351	98.454
17	0.1351	0.643	99.098
18	0.0913	0.435	99.532
19	0.0854	0.407	99.939
20	0.0128	0.061	100
21	0	0	100

Table 3. PCA analysis of 21 traits in 625 garlic germplasm

PCA	PH	PL	NL	LL	LW	WWL	WOL	TY	MY	ABW	PD
Prin1	0.2999	0.2865	0.2630	0.2444	0.0957	0.3459	0.3471	0.3304	0.3470	0.2387	0.0960
Prin2	-0.1026	-0.1612	-0.1109	-0.085	0.3138	-0.0011	-0.0032	0.0067	0.0000	-0.0791	0.6002
Prin3	0.0204	-0.1083	-0.1417	0.1368	0.0504	-0.0036	-0.0114	-0.0225	-0.0125	0.0823	0.0003
PCA	ED	NC/B	W50C	PSD	TSS%	DTH	BS	BSC	CSC	PA	
Prin1	0.1923	0.1485	0.2291	0.1621	0.073	0.0026	0.0981	-0.0237	-0.0090	-0.0160	
Prin2	0.4978	-0.2830	-0.0480	0.0799	-0.0496	0.3273	-0.0029	-0.0754	-0.0859	-0.1397	
Prin3	0.0457	0.1583	0.0708	0.0336	-0.1626	0.2309	-0.0228	0.6286	0.6488	-0.0953	

PH=Plant height, PL=Pseudostem length, NL=Number of leaves, LL=Leaf length, LW=Leaf width, WWL=Plant weight with leaves, WOL=Plant weight without leaves, TY=Total yield, MY=Marketable yield, ABW=Average bulb weight, PD=Polar diameter, ED=Equatorial diameter, NCB=Number of cloves per bulb, W50C=Weight of 50 Cloves, PSD=Pseudostem diameter, TSS=Total soluble solids, DTH=Days to harvest, BS=Bulb shape, BSC=Bulb skin colour, CSC=Clove skin colour and PA=Plant architecture

Correlation analysis between 21 agro-morphological traits including yield

Garlic is bulbous crop hence vegetative traits and bulb characters are visually correlated with its yield potential. Generally, bulbing period leads to bulb size difference additionally bulb maturity period plays a vital role in ultimate yield trait (Panthee et al. 2006). In this experiment, marketable yield was moderately correlated with vegetative traits *viz*., Plant height (r

Table 4. Pearson correlation coefficient among evaluated traits in 625 garlic germplasm

	PH	PL	NOL	LL	LW	WWL	WOL	ABW	PD	ED	NC/B	W50C	PSD	TSS	DTH	MY
PL	[illegible][a]															
NOL	0.65[a]	0.7[a]														
LL	0.78[a]	0.52b	0.45b													
LW	0.13	0.04	0.03	0.06												
WWL	0.63[a]	0.62[a]	0.57[a]	0.48[b]	0.24											
WOL	0.62[a]	0.63[a]	0.58[a]	0.48[b]	0.24	0.99[a]										
ABW	0.42	0.39	0.37	0.39	0.13	0.53[b]	0.54[b]									
PD	0.14	0.1	0.14	0.11	0.18	0.18	0.18	0.05								
ED	0.34	0.29	0.3	0.31	0.24	0.40	0.40	0.29	0.80[a]							
NC/B	0.30	0.25	0.21	0.30	0.02	0.32	0.32	0.39	-0.21	0.09						
W50C	0.40	0.37	0.38	0.36	0.12	0.52[b]	0.53b	0.54[b]	0.06	0.25	0.24					
PSD	0.36	0.28	0.22	0.35	0.17	0.35	0.35	0.20	0.15	0.20	0.1	0.19				
TSS	0.11	0.18	0.13	0.02	0.13	0.16	0.17	0.08	-0.01	0.03	0.08	0.13	0.08			
DTH	-0.04	-0.2	-0.1	0.01	0.23	0.02	0.01	0.02	0.15	0.15	-0.03	0.07	0.04	-0.04		
MY	0.62[a]	0.63[a]	0.57[a]	0.47[b]	0.24	0.88[a]	0.85[a]	0.54[b]	0.18	0.40	0.32	0.53[b]	0.35	0.17	0.01	
TY	0.58a	0.59[a]	0.54[b]	0.43	0.22	0.83[a]	0.84[a]	0.50[b]	0.18	0.38	0.3	0.49[b]	0.34	0.15	0.02	0.94[a]

PH=Plant height, PL=Pseudostem length, NL=Number of leaves, LL=Leaf length, LW=Leaf width, WWL=Plant weight with leaves, WOL=Plant weight without leaves, TY=Total yield, MY=Marketable yield, ABW=Average bulb weight, PD=Polar diameter, ED=Equatorial diameter, NCB=Number of cloves per bulb, W50C=Weight of 50 Cloves, PSD=Pseudostem diameter, TSS=Total soluble solids, DTH=Days to harvest, BS=Bulb shape, BSC=Bulb skin colour, CSC=Clove skin colour and PA=Plant architecture

=0.62), pseudostem length (r =0.63), number of leaves (r =0.57) and was moderately related with average bulb weight (r = 0.54) and weight of 50 cloves (r =0.53) but no correlation was observed with days to harvest (Table 4). This indicates that the expression of yield potential of garlic is much dependent upon its vegetative growth. These results were in agreement with Figliuolo et al. (2001) who also recorded similarity in traits correlation. Plant weight with leaves and plant weight without leaves are only different forms of total biological yield. Hence, these traits showed a strong correlation among themselves. However, being bulbous crop comprising multiple cloves inside, increase in average bulb weight (r = 0.54) and weight of fifty cloves (r = 0.53) will result in the higher marketable yield. No correlation was observed between the average weight of the bulb and the number of cloves per bulb. This indicates that more number of cloves per bulb do not necessarily show higher bulb weight. Similarly, no significant correlation was recorded between days to harvest and total yield, which also suggests that early maturing accessions can give comparative better yield in garlic. Hence there is scope to develop high yielding early maturing varieties.

A moderately positive correlation between bulb yield in garlic and maturity was observed by Panthee et al. (2006). This is in contrast to present studies where no significant correlation was observed between yield and maturity period. Wang et al. (2014) recorded a positive correlation between yield and bulb weight and are in consonance with our present findings. Figliuolo et al. (2001) found a significant strong positive correlation of plant height with yield in garlic. Baghalian et al. (2005) evaluated 24 garlic ecotypes in Iran and observed that bulb mean weight was strongly correlated with clove mean weight while negatively correlated with the clove number per bulb. Our results are in conformity with the results of other authors.

The actual quantum of diversity present and expressed diversity depends upon tools used to measure it. This study revealed that the 625 Indian originated garlic accessions are distinct and possess significant genetic diversity. Principal component analysis was concordant to the results obtained from cluster analysis. This study highlighted the presence

of redundancy in the population and role of transportation in overlapping of traits among clusters. Hence it will be interesting to screen the whole set by molecular markers such as SRAP, SSR or ISSR, which shows the difference even between distantly closed ecotypes. The morphological characterisation of these accessions has significant value in regard to the record, preparation of the catalogue, classification as per traits and primary understanding of breeder to carry advance research. This study also acts as a base material for the formulation of a core group of Indian garlic gene pool which will be a significant achievement.

Author's contribution

Conceptualization of research (AK, APB); Designing of experiments (AK, APB) Contribution of experimental material (AK, APB); Execution of field experiments and data collection (AK, APB); Analysis of data and interpretation (AK, APB, VM, AJG, MS); Preparation of manuscript (APB, AK).

Declaration

The author declares no conflict of interest.

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Supplemenatry Table S1. Details of garlic (Allium sativum L.) accessions collected from different agro-ecological regions of India

S.No.	Institute Name	plant Arcitecture	IC No	F14	Bulb Skin Colour	bulb shape
				State		
1	WG-106	Semi-spreading	IC-0610966	Gujrat	White	circular
2	IC-372980	Spreading	IC-372980	New delhi	White	circular
3	M-281	Erect	IC-0610967	Gujrat	White	circular
4	WG-41	Semi-spreading	IC-0610968	MS	White	circular
5	RG-7	Semi-spreading		Gujrat	White	circular
6	RG-91			MS	Purple	circular
7	WG-7	Semi-spreading		Gujrat	White	Heart
8	647	Semi-spreading	IC-0610969	Orissa	White	circular
9	IC-373010	Spreading	IC-373010	Gujarat	White	circular
10	RG-274	Semi-spreading		MS	Purple	circular
11	M-12	Semi-spreading		Gujarat	Purple	circular
12	M-276			Gujrat	White	circular
13	IC-3729718	Semi-spreading		Gujrat	Purple	circular
14	WG-17	Erect	IC-49373	Gujarat	White	circular
15	606	Semi-spreading		MP	White	Heart
16	IC-344857	Semi-spreading	IC-344857	Uttaranchal	White	circular
17	IC-372953	Erect	IC-372953	New delhi	Purple	circular
18	650	Semi-spreading	IC-0610971	Orissa	White	circular
19	RG-282	Erect		Rajasthan	Purple	circular
20	RG-95	Erect	EC-244949	New delhi	Purple	circular
21	IC-372917	Erect	IC-372917	New delhi	White	Ovate
22	WG-98	Semi-spreading	IC-0610972	Gujrat	White	circular
23	WG-100	Semi-spreading	IC-0610973	Gujrat	White	Heart
24	VL-GARLIC-1	Semi-spreading		Uttarakhand	White	circular
25	IC-372900	Semi-spreading	IC-372900	Gujarat	White	circular
26	M-205	Spreading		Haryana	Purple	circular
27	646	Spreading	IC-0610974	Orissa	White	circular
28	IC-345682	Erect	IC-345682	Uttaranchal	White	Ovate
29	M-352	Spreading	IC-0610975	MS	White	Ovate
30	IC-372904	Semi-spreading		Gujarat	White	circular
31	M-185	Semi-spreading		Haryana	White	Heart
32	WG-38	Erect	IC-0610976	Gujarat	White	Ovate
33	IC-48628	Semi-spreading	IC-48628	MS	White	circular
34	643	Semi-spreading	IC-0610977	Orissa	White	circular
35	IC-372992	Semi-spreading	IC-372992	Gujarat	White	circular
36	RG-79	Semi-spreading	IC-0610978	Gujarat	Purple	circular
37	WG-12	Semi-spreading		Gujarat	White	circular
38	WG-82	Semi-spreading	IC-0610979	Gujarat	White	Heart
39	M-162	Semi-spreading		Gujrat	White	Heart

40	633	Erect	IC-0610980	karnataka	Purple	circular
41	WG-92	Semi-spreading	NIC-0079	New Delhi	White	circular
42	IC-372987	Erect	IC-372987	Gujarat	White	circular
43	IC-375046	Semi-spreading	IC-375046	J&k	Purple	circular
44	M-274	Semi-spreading		Haryana	Purple	Ovate
45	WG-19	Spreading		Gujarat	White	circular
46	IC-372910	Semi-spreading	IC-372910	Gujarat	White	circular
47	WG-54	Semi-spreading	IC-0610981	Gujarat	White	Ovate
48	IC-58299	Semi-spreading	IC-58299	New Delhi	Purple	circular
49	572	Semi-spreading	IC 572003	AP	VIOLET STRIS	Heart
50	M-343	Semi-spreading		MS	White	circular
51	WG-43	Semi-spreading		Haryana	White	circular
52	M-284	Erect		Gujrat	Purple	Heart
53	WG-94	Semi-spreading	EC-158250	New Delhi	White	circular
54	RG-77	Semi-spreading	IC-0610982	Gujrat	White	circular
55	IC-49322	Semi-spreading	IC-49322	MS	White	circular
56	WG-95	Semi-spreading		New Delhi	White	circular
57	WG-42	Semi-spreading	IC-0610983	Gujrat	White	circular
58	514	Semi-spreading	IC-0610984	WB	White	circular
59	WG-76	Semi-spreading	IC-0610985	Gujrat	White	circular
60	RG-315	Semi-spreading	IC-0610986	AP	White	Heart
61	WG-75	Semi-spreading		AP	White	circular
62	IC-374989	Semi-spreading	IC-374989	Rajasthan	Purple	circular
63	IC-49360	Semi-spreading	IC-49360	New Delhi	White	Heart
64	IC-372829	Semi-spreading	IC-372829	New Delhi	Purple	circular
65	IC-372898	Semi-spreading	IC-372898	Gujarat	Purple	circular
66	618	Semi-spreading	IC-0610987	MP	White	circular
67	IC-212355	Semi-spreading	IC-212355	New Delhi	Purple	circular
68	IC-141246	Semi-spreading	IC-141246	MS	White	circular
69	IC-361305	Semi-spreading	IC-361305	New Delhi	White	circular
70	WG-103	Semi-spreading	IC-0610988	Gujarat	White	Ovate
71	RG-31	Semi-spreading		MS	Purple	circular
72	WG-87	Spreading	IC-48157	New Delhi	White	circular
73	WG-63	Semi-spreading	IC-0610989	Gujrat	White	circular
74	IC-375035	Semi-spreading		Rajasthan	White	Ovate
75	RG-46	Semi-spreading		MS	Purple	circular
76	IC-372944	Semi-spreading	IC-372944	Gujarat	Purple	circular
77	INDORE LOCAL	Semi-spreading		MP	White	circular
78	IC-37302	Semi-spreading		Gujarat	Purple	circular
79	IC-49057	Spreading	IC-49057	New Delhi	White	circular
80	IC-32274	Semi-spreading	IC-32274	New Delhi	White	circular
81	IC-45628	Semi-spreading	IC-45628	New Delhi	White	circular
82	IC-19084	Semi-spreading	IC-19084	New Delhi	Purple	circular

83	WG-68	Semi-spreading		Gujrat	White	circular
84	M-289	Semi-spreading		Gujrat	Purple	circular
85	IC-375116	Erect	IC-375116	MS	Purple	Heart
86	IC-35313	Semi-spreading	IC-35313	New Delhi	Purple	circular
87	IC-2790	Semi-spreading	IC-2790	New Delhi	White	circular
88	IC-373011	Spreading	IC-373011	Gujarat	White	Heart
89	IC-344844		IC-344844	Uttaranchal	White	circular
90	IC-4937-1	Semi-spreading	IC-4937-1	New Delhi	White	circular
91	GODAVARI	Semi-spreading	IC-570696	MS	Purple	circular
92	RG-11	Semi-spreading		Gujarat	Purple	circular
93	IC-373003	Semi-spreading	IC-373003	Gujarat	White	circular
94	IC-32881	Semi-spreading	IC-32881	New Delhi	Purple	circular
95	WG-40	Semi-spreading	IC-0610991	MS	White	circular
96	2	Semi-spreading		MS	White	Heart
97	IC-375707	Semi-spreading		Gujarat	Purple	circular
98	113	Spreading	IC-0610992	Gujarat	White	circular
99	IC-375041	Semi-spreading	IC-375041	New Delhi	White	circular
100	43	Semi-spreading		Gujarat	White	circular
101	IC-375058	Erect	IC-375058	Rajasthan	Purple	Ovate
102	581	Erect	IC-0610993	Bihar	White	Heart
103	IC-372954	Semi-spreading	IC-372954	Gujarat	White	circular
104	RG-61	Semi-spreading	IC-0610994	Gujarat	Purple	circular
105	IC-375110	Erect	IC-375110	UP	Purple	circular
106	IC-33618	Semi-spreading		Gujarat	Purple	circular
107	RG-86	Semi-spreading	IC-43398	New Delhi	Purple	Heart
108	NO-59	Semi-spreading	IC-0610995	Gujarat	White	circular
109	21	Semi-spreading		Gujarat	Purple	circular
110	IC-322975	Semi-spreading	IC-322975	New Delhi	White	circular
111	48	Erect		Gujarat	Purple	circular
112	IC-375069	Spreading	IC-375069	Rajasthan	Purple	Heart
113	NO-19	Spreading		Gujarat	White	circular
114	IC-372907	Erect	IC-372907	Gujarat	White	circular
115	IC-344045	Semi-spreading	IC-344045	New Delhi	Purple	Heart
116	WG-10	Semi-spreading		Gujarat	White	circular
117	IC-87880	Semi-spreading		Gujarat	White	circular
118	RG-82	Erect	IC-0610996	Gujarat	White	circular
119	WG-20	Semi-spreading		Gujarat	White	circular
120	WG-96	Semi-spreading		Gujarat	White	circular
121	522	Semi-spreading	IC-0610997	WB	White	circular
122	M-97	Semi-spreading	IC-0610998	Gujarat	White	circular
123	IC-375119	Erect	IC-375119	Haryana	White	circular
124	RG-41	Semi-spreading	IC-0610999	MS	Purple	circular
125	IC-14138	Semi-spreading	IC-14138	New Delhi	White	circular

126	574	Semi-spreading	IC-572005	AP	White	circular
127	IC-373009	Semi-spreading	IC-373009	Gujarat	White	circular
128	IC-141224		IC-141224	Rajasthan	White	circular
129	599	Spreading		Rajasthan	White	circular
130	555	Semi-spreading	IC-571929	A.P.	Purple	circular
131	IC-373003		IC-373003	New Delhi	White	circular
132	IC-100518	Semi-spreading	IC-100518	Uttaranchal	Purple	circular
133	608	Semi-spreading		Uttaranchal	White	circular
134	IC-372959	Semi-spreading	IC-372959	Gujarat	White	circular
135	IC-48157	Semi-spreading	IC-48157	Rajasthan	White	circular
136	622	Semi-spreading		MP	White	circular
137	IC-375057	Semi-spreading		Rajasthan	White	circular
138	WG-60	Semi-spreading	IC-0611000	Gujarat	White	circular + Heart
139	IC-35881	Semi-spreading	IC-35881	New Delhi	Purple	circular
140	IC-375119	Spreading	IC-375119	Haryana	White	circular
141	IC-344860	Semi-spreading	IC-344860	New Delhi	White	Heart
142	564	Semi-spreading	IC 571979	AP	White	circular
143	IC-2323	Semi-spreading	IC-2323	New Delhi	Purple	circular
144	IC-87880	Semi-spreading	IC-87880	New Delhi	White	circular
145	IC-17236	Erect	IC-17236	New Delhi	White	circular
146	IC-49851	Semi-spreading	IC-49851	New Delhi	White	circular
147	586	Semi-spreading		Bihar	White	circular
148	IC-375028	Semi-spreading	IC-375028	Gujarat	White	Heart
149	IC-372927	Semi-spreading	IC-372927	HP	White	circular
150	RG-15	Semi-spreading		Gujarat	Purple	circular
151	IC-3342-1	Semi-spreading	IC-3342-1	New Delhi	White	Ovate
152	637	Erect	IC-0611001	Karnataka	White	circular
153	M-118	Semi-spreading		Uttarpradesh	Purple	circular
154	RG-5	Erect		MS	White	circular
155	WG-73	Semi-spreading		Gujarat	White	circular
156	IC-372939	Semi-spreading	IC-372939	Gujarat	White	circular
157	IC-135013	Erect	IC-135013	New Delhi	White	circular
158	IC-141153	Semi-spreading	IC-141153	Uttaranchal	White	Heart
159	IC-49132	Semi-spreading		UP	White	circular
160	M-220	Semi-spreading		Haryana	White	circular
161	M-90	Semi-spreading		New Delhi	White	circular
162	IC-372999	Semi-spreading	IC-372999	New Delhi	White	circular
163	IC-375115	Erect	IC-375115	Tamil Nadu	White	Heart
164	WG-48	Semi-spreading		Gujarat	White	circular
165	IC-100472	Semi-spreading	IC-100472	Uttaranchal	White	circular
166	RG-63	Semi-spreading	IC-0611002	Gujarat	White	circular
167	IC-25599	Semi-spreading	IC-25599	New Delhi	White	circular
168	WG-83	Semi-spreading		MS	White	circular

169	RG-418	Semi-spreading		Andhra Pradesh	PURLE	Heart
170	RG-17	Erect	IC-49373	Gujrat	Purple	Heart
171	587	Semi-spreading		Bihar	White	circular
172	M-323	Semi-spreading		Orrisa	White	circular
173	M-7	Semi-spreading		MS	White	circular
174	M-302	Semi-spreading	IC-0611003	Gujarat	White	circular
175	AKG-2	Semi-spreading		Gujarat	White	circular
176	WG593	Semi-spreading		J&K	Purple	circular
177	602	Semi-spreading		Gujrat	White	circular
178	IC-337433	Semi-spreading	IC-337433	Gujrat	Purple	circular
179	IC-305075	Semi-spreading	IC-305075	New Delhi	White	circular
180	632	Semi-spreading		MP	White	circular
181	IC-375010	Semi-spreading	IC-375010	J&K	White	circular
182	IC-32323	Semi-spreading	IC-32323	New Delhi	White	circular
183	IC-373011	Spreading	IC-373011	New Delhi	White	Heart
184	IC-32274	Semi-spreading	IC-32274	New Delhi	Purple	circular
185	IC-375070	Semi-spreading	IC-375070	Rajasthan	White	Heart
186	IC-375002	Semi-spreading	IC-375002	Uttranchal	White	circular
187	IC-374951	Erect	IC-374951	Uttranchal	White	Ovate
188	WG-61	Erect		Gujarat	White	circular
189	613	Spreading		MP	White	Heart
190	IC-49066	Semi-spreading	IC-49066	New Delhi	Purple	circular
191	IC-100578	Semi-spreading	IC-100578	New Delhi	White	circular
192	IC-375107	Semi-spreading	IC-375107	MP	White	Heart
193	IC-372896	Semi-spreading	IC-372896	New Delhi	White	circular
194	SLN-2001/01	Semi-spreading		New Delhi	White	circular
195	G-1	Semi-spreading	IC 570660	MS	White	circular
196	M-G-P-5	Semi-spreading		MS	White	circular
197	IC-375002	Semi-spreading	IC-375002	Uttranchal	White	Heart
198	RG-30	Semi-spreading		MS	Purple	circular
199	IC-49375	Semi-spreading	IC-49375	New Delhi	White	circular
200	IC-37506	Semi-spreading	IC-37506	New Delhi	White	circular
201	YAMUNA SAFED	Semi-spreading		MS	White	circular
202	WG-47	Erect		Gujarat	White	Heart
203	IC-52338	Semi-spreading	IC-52338	New Delhi	White	circular
204	IC-141244	Semi-spreading	IC-141244	New Delhi	White	Heart
205	607	Semi-spreading		UP	White	circular
206	IC-32265	Semi-spreading	IC-32265	New Delhi	White	circular
207	568	Semi-spreading	IC-571992	AP	White	circular
208	IC-255606	Semi-spreading	IC-255606	Uttaranchal	Purple	circular
209	RG-112	Semi-spreading		Gujarat	Purple	circular
210	IC-48628-1	Semi-spreading	IC-48628-1	New Delhi	Purple	circular
211	IC-45624	Semi-spreading	IC-45624	New Delhi	Purple	circular

212	IC-375073	Semi-spreading	IC-375073	HP	Purple	circular
213	448	Semi-spreading	IC-0611004	AP	White	circular
214	M-199	Erect		Haryana	Purple	circular
215	IC-278259	Semi-spreading	IC-278259	Uttaranchal	Purple	Heart
216	M-162	Semi-spreading		Gujarat	White	circular
217	IC-372923	Semi-spreading	IC-372923	New Delhi	White	circular
218	IC-35288	Semi-spreading	IC-35288	New Delhi	White	circular
219	IC-372951	Spreading	IC-372951	Gujarat	White	circular
220	594	Semi-spreading		J&K	White	circular
221	IC-100377	Semi-spreading	IC-100377	New Delhi	White	circular
222	IC-375069	Semi-spreading	IC-375069	Rajasthan	White	Heart
223	IC-49362	Semi-spreading	IC-49362	New Delhi	Purple	circular
224	IC-264905	Semi-spreading	IC-264905	Uattaranchal	Purple	circular
225	IC-35272-1	Semi-spreading	IC-35272-1	New Delhi	Purple	circular
226	M-18	Spreading	IC-59383	Gujrat	White	circular
227	IC-375014	Semi-spreading	IC-375014	HP	White	circular
228	IC-49321	Semi-spreading	IC-49321	New Delhi	White	circular
229	IC-49132	Semi-spreading	IC-49132	New Delhi	White	Heart
230	IC-372958	Semi-spreading	IC-372958	Gujarat	Purple	circular
231	IC-375000	Semi-spreading	IC-375000	Uttranchal	White	circular
232	IC-372899	Semi-spreading	IC-372899	Gujarat	Purple	circular
233	529	Semi-spreading		JK	Purple	circular
234	IC-49067	Semi-spreading	IC-49067	New Delhi	Purple	circular
235	562	Semi-spreading	IC-571977	Andhra Pradesh	White	circular
236	563	Semi-spreading	IC-571978	Andhra Pradesh	White	circular
237	IC-372942	Semi-spreading	IC-372942	New Delhi	White	circular
238	RG-55	Semi-spreading		MS	Purple	Heart
239	M-40	Semi-spreading		MS	Purple	circular
240	ADG-1/72	Semi-spreading		New Delhi	White	circular
241	NO-59	Erect		Gujrat	White	circular
242	IC-48623	Erect	IC-48623	New Delhi	Purple	circular
243	IC-265040	Semi-spreading	IC-265040	Uttaranchal	Purple	Heart
244	IC-372938	Semi-spreading	IC-372938	New Delhi	White	Heart
245	M-48	Semi-spreading	IC-0611005	Gujarat	White	Heart
246	IC-141227	Spreading	IC-141227	New Delhi	White	circular
247	IC-372927	Semi-spreading	IC-372927	HP	Purple	circular
248	IC-375022	Semi-spreading	IC-375022	MS	White	circular
249	WG-39	Semi-spreading		Gujarat	White	Ovate
250	IC-49381	Semi-spreading	IC-49381	New Delhi	Purple	Heart
251	WG-116	Semi-spreading		New Delhi	White	circular
252	IC-375079	Semi-spreading	IC-375079	Jharkhand	White	circular
253	IC-344833	Semi-spreading	IC-344833	New Delhi	Purple	circular
254	IC-372934	Semi-spreading	IC-372934	Gujarat	White	circular

255	638	Semi-spreading	IC-0611006	Karnatka	Purple	circular
256	IC-373000	Semi-spreading	IC-373000	MS	White	Heart
257	IC-344833	Semi-spreading	IC-344833	New Delhi	Purple	circular
258	IC-372924	Erect	IC-372924	Gujarat	White	circular
259	IC-49381	Semi-spreading	IC-49381	MS	Purple	circular
260	RG-45	Semi-spreading		MS	Purple	Heart
261	WG-99	Semi-spreading		Gujrat	White	circular
262	635	Semi-spreading	IC-0611007	Karnatka	Purple	circular
263	NO-7	Semi-spreading		MS	White	circular
264	646	Erect		Orissa	White	circular
265	IC-49304	Semi-spreading	IC-49304	MS	White	circular
266	NO-15	Semi-spreading		MS	Purple	circular
267	645	Semi-spreading		Orissa	Purple	circular
268	OOTY LOCAL	Semi-spreading		Rajasthan	Purple	circular
269	RG-93	Semi-spreading		New Delhi	Purple	circular
270	M-74	Semi-spreading		Gujrat	Purple	circular
271	RG-310	Semi-spreading		MS	Purple	circular
272	IC-372974	Semi-spreading	IC-372974	New Delhi	White	Heart
273	IC-372977	Semi-spreading	IC-372977	Gujarat	White	circular
274	WG-51	Semi-spreading	IC-0611008	MS	White	circular
275	578	Semi-spreading		Bihar	Purple	circular
276	RG-110	Semi-spreading	IC-0611009	Gujarat	Purple	circular
277	WG-167	Erect		Gujarat	Purple	circular
278	611	Semi-spreading		MP	White	Heart
279	RG-63	Semi-spreading	IC-0611010	Gujarat	Purple	circular
280	WG-73	Semi-spreading		Gujarat	White	circular
281	WG-56	Semi-spreading		Gujarat	White	circular
282	WG-71	Semi-spreading	IC-0611011	Gujarat	Purple	Heart
283	RG-106	Semi-spreading		Gujarat	Purple	circular
284	IC-372946	Semi-spreading	IC-372946	Gujarat	Purple	Ovate
285	IC-372965	Semi-spreading	IC-372965	Gujarat	White	circular
286	IC-15642	Semi-spreading	IC-15642	New Delhi	White	circular
287	IC-46662	Semi-spreading	IC-46662	New Delhi	White	circular
288	WG-196	Semi-spreading		Haryana	White	Heart
289	IC-37303	Semi-spreading	IC-37303	New Delhi	White	circular
290	RG-109	Semi-spreading	IC-0611012	Gujarat	Purple	Ovate
291	WG-418	Semi-spreading	IC-0611013	AP	Purple	circular
292	M-199	Semi-spreading		Karnatak	White	circular
293	DWDG-1	Semi-spreading		New Delhi	Purple	circular
294	IC-372995	Erect	IC-372995	Gujarat	White	Heart
295	IC-44944	Semi-spreading	IC-44944	New Delhi	Purple	circular
296	IC-372959	Semi-spreading	IC-372959	Gujarat	Purple	circular
297	G-378	Semi-spreading	IC-597833	New Delhi	White	circular

298	WG-65	Semi-spreading	IC-0611014	Gujarat	White	Heart
299	WG-49	Semi-spreading	IC-0611015	Gujarat	White	circular
300	RG-94	Semi-spreading		New Delhi	Purple	circular
301	RG-58	Semi-spreading		Gujarat	Purple	circular
302	IC-338629	Semi-spreading	IC-338629	Uttaranchal	Purple	circular
303	621	Semi-spreading		MP	White	Heart
304	IC-32654	Semi-spreading	IC-32654	MS	White	circular
305	WG-7	Semi-spreading		Gujrat	White	Ovate
306	NO-P-40	Semi-spreading		MS	Purple	circular
307	IC-373002	Semi-spreading	IC-373002	Gujarat	White	circular
308	IC-374964	Semi-spreading	IC-374964	Haryana	Purple	circular
309	IC-278343	Semi-spreading	IC-278343	Uttaranchal	White	Heart
310	IC-58299	Semi-spreading	IC-58299	New Delhi	Purple	circular
311	WG-378	Semi-spreading		AP	White	circular
312	IC-38268	Semi-spreading	IC-38268	New Delhi	White	circular
313	WG-35	Semi-spreading		MS	White	Heart
314	IC-2970	Semi-spreading	IC-2970	New Delhi	Purple	circular
315	IC-49307	Semi-spreading	IC-49307	New Delhi	White	circular
316	IC-375079	Semi-spreading	IC-375079	Jharkhand	White	circular
317	IC-48602	Semi-spreading	IC-48602	New Delhi	White	Heart
318	IC-338618	Erect	IC-338618	Uttranchal	White	circular
319	RG-343	Semi-spreading		MS	White	circular
320	RG-464	Semi-spreading	IC-0611016	AP	Purple	circular
321	IC-42970	Semi-spreading	IC-42970	New Delhi	White	circular
322	RG-463	Semi-spreading		AP	Purple	circular
323	IC-375070	Semi-spreading	IC-375070	Rajasthan	Purple	circular
324	M-71	Spreading		Panchamahal	White	circular
325	RG-453	Erect		AP	White	Heart
326	IC-175327	Semi-spreading	IC-175327	New Delhi	White	circular
327	WG-3	Semi-spreading		MS	White	Heart
328	IC-141095	Semi-spreading	IC-141095	J&K	White	circular
329	RG-5	Semi-spreading		MS	Purple	circular
330	M-87	Semi-spreading	IC-48157	New Delhi	White	circular
331	IC-373015	Semi-spreading	IC-373015	Gujarat	Purple	Heart
332	M-579	Semi-spreading		Bihar	Purple	Heart
333	WG-37	Semi-spreading	IC-0611017	Gujarat	White	circular
334	IC-372940	Semi-spreading	IC-372940	New Delhi	White	circular
335	IC-375035	Spreading	IC-375035	Rajasthan	White	circular
336	IC-372937	Erect	IC-372937	Gujarat	Purple	Ovate
337	WG-86	Semi-spreading	IC-43398	New Delhi	White	Ovate
338	547	Semi-spreading	IC-571936	AP	White	circular
339	M-176	Semi-spreading	IC-0611018	Panchamahal	White	Heart
340	IC-141272	Semi-spreading	IC-141272	MS	Purple	circular

341	IC-344880	Semi-spreading	IC-344880	New Delhi	White	circular
342	IC-244959	Semi-spreading	IC-244959	New Delhi	Purple	circular
343	IC-392903	Semi-spreading	IC-392903	New Delhi	White	circular
344	RG-155	Semi-spreading		New Delhi	Purple	circular
345	604	Spreading		Gujrat	Purple	Heart
346	636	Semi-spreading	IC-0611019	Karnataka	White	Heart
347	WG-22	Semi-spreading		Gujrat	Purple	circular
348	WG-367	Semi-spreading	IC-0611020	Ap	White	circular
349	M-208	Semi-spreading		Haryana	White	circular
350	IC-344864	Semi-spreading	IC-344864	Rajasthan	White	circular
351	M-152	Semi-spreading		Ms	Purple	circular
352	M-17	Semi-spreading		Gujrat	White	circular
353	M-281	Semi-spreading	IC-0611021	Gujarat	Purple	circular
354	G-282	Semi-spreading		Ms	White	circular
355	IC-372921	Semi-spreading	IC-372921	New Delhi	White	circular
356	IC-37279	Semi-spreading	IC-37279	New Delhi	White	circular
357	IC-375056	Semi-spreading	IC-375056	New Delhi	White	circular
358	IC-375053	Semi-spreading	IC-375053	Rajasthan	White	circular
359	RG-399	Semi-spreading		AP	Purple	circular
360	M-164	Semi-spreading		MS	Purple	circular
361	M-330	Semi-spreading		Orissa	Purple	circular
362	IC-375075	Semi-spreading	IC-375075		White	circular
363	RG-10	Semi-spreading		Gujrat	Purple	circular
364	WG-323	Semi-spreading		Orissa	White	circular
365	WG-80	Semi-spreading		Tn	White	circular
366	IC-375087	Semi-spreading	IC-375087	Gujarat	Purple	circular
367	WG-432	Semi-spreading	IC-0611022	AP	White	circular
368	M-112	Semi-spreading	IC-0611023	Gujarat	White	circular
369	546	Semi-spreading	IC-571928	AP	White	Ovate
370	RG-92	Semi-spreading	NIC 0079	New Delhi	Purple	circular
371	IC-372967	Erect	IC-372967	New Delhi	Purple	circular
372	IC-372969	Semi-spreading	IC-372969	Gujarat	White	circular
373	IC-338528	Erect	IC-338528	Uttaranchal	Purple	circular
374	IC-14138	Semi-spreading	IC-14138	New Delhi	Purple	circular
375	WG-14	Erect		Gujrat	White	circular
376	647	Semi-spreading		HP	Purple	circular
377	IC-375044	Semi-spreading	IC-375044	New Delhi	Purple	circular
378	IC-151090	Semi-spreading	IC-151090	New Delhi	Purple	circular
379	GG-2	Semi-spreading		Gujrat	White	circular
380	IC-372948	Semi-spreading	IC-372948	Gujarat	Purple	circular
381	RG-66	Semi-spreading		Gujarat	White	circular
382	IC-374956	Semi-spreading	IC-374956	Bihar	White	Heart
383	IC-32320	Semi-spreading	IC-32320	New Delhi	Purple	circular

384	615	Spreading		MP	White	Heart
385	IC-37097	Semi-spreading	IC-37097	New Delhi	White	circular
386	RG-401	Semi-spreading	IC-0611024	AP	White	Heart
387	IC-375054	Semi-spreading	IC-375054	Gujrat	White	circular
388	RG-50	Semi-spreading	IC-0611025	Gujarat	White	circular
389	IC-375036	Semi-spreading	IC-375036	Rajasthan	White	circular
390	IC-49356	Semi-spreading	IC-49356	New Delhi	White	circular
391	RG-335	Erect		MS	Purple	circular
392	477	Semi-spreading		MS	Purple	circular
393	IC-374984	Semi-spreading	IC-374984	Gujarat	White	circular
394	628	Spreading		Gujrat	White	circular
395	IC-372908	Semi-spreading	IC-372908	Gujarat	Purple	Heart
396	IC-374998	Semi-spreading	IC-374998	Rajasthan	White	circular
397	RG-338	Semi-spreading	IC-0611026	MS	Purple	circular
398	544	Semi-spreading	IC-571918	Andhra Pradesh	Purple	circular
399	RG-67	Semi-spreading	IC-0611027	Gujarat	White	circular
400	IC-372905	Semi-spreading	IC-372905	Gujarat	Purple	circular
401	WG-14	Semi-spreading		Gujrat	White	circular
402	IC-42330	Semi-spreading	IC-42330	New Delhi	White	circular
403	IC-100536	Semi-spreading	IC-100536	New Delhi	White	Heart
404	IC-278270	Semi-spreading	IC-278270	Uattaranchal	White	circular
405	IC-375090	Semi-spreading	IC-375090	New Delhi	White	Heart
406	IC-344816	Semi-spreading	IC-344816	New Delhi	Purple	Heart
407	M-293	Semi-spreading	IC-0611028	Gujrat	White	circular
408	IC-374968	Semi-spreading	IC-374968	New Delhi	White	circular
409	IC-278365	Semi-spreading	IC-278365	Uattranchal	White	Heart
410	IC-32274	Semi-spreading	IC-32274	New Delhi	Purple	circular
411	RG-101	Erect		Gujarat	Purple	circular
412	BHIMA Purple	Semi-spreading	IC-570742	Orissa	Purple	circular
413	WG-6	Spreading		Gujarat	White	circular
414	RG-49	Semi-spreading	IC-0611029	Gujarat	Purple	Heart
415	IC-375032	Semi-spreading	IC-375032	Gujarat	Purple	circular
416	IC-35281	Semi-spreading	IC-35281	New Delhi	Purple	circular
417	IC-375107	Semi-spreading	IC-375107	MP	White	Ovate
418	RG-12	Semi-spreading		Gujarat	Purple	circular
419	RG-356	Erect		MS	Purple	Ovate
420	G-378	Semi-spreading		AP	White	Heart
421	603	Semi-spreading		Gujarat	White	Ovate
422	RG-17	Semi-spreading		Gujarat	Purple	circular
423	IC-344858	Semi-spreading	IC-344858	New Delhi	White	circular
424	IC-372991	Semi-spreading	IC-372991	Gujarat	Purple	Heart
425	NO-23	Semi-spreading		MS	White	circular
426	WG-48	Semi-spreading		Gujrat	White	circular

427	517	Semi-spreading	IC-0611030	WB	Purple	Heart
428	IC-372950	Erect	IC-372950	Gujarat	White	circular
429	RG-321	Erect		Orissa	Purple	circular
430	WG-376	Semi-spreading	IC-0611031	AP	White	circular
431	IC-141241	Spreading	IC-141241	New Delhi	White	circular
432	644	Semi-spreading		Orissa	Purple	circular
433	IC-372956	Semi-spreading	IC-372956	Gujarat	White	circular
434	WG-28	Erect		MS	White	circular
435	IC- 344813	Semi-spreading	IC- 344813	MS	White	circular
436	WG-23	Semi-spreading		MS	White	circular
437	IC-141310	Erect	IC-141310	Uttaranchal	Purple	circular
438	IC-372907	Semi-spreading	IC-372907	New Delhi	White	circular
439	597	Semi-spreading	EC-631743	J&K	White	circular
440	WG-409	Semi-spreading	IC-0611032	AP	White	Heart
441	RG-312	Erect	IC-0611033	Orissa	Purple	circular
442	IC-375075	Semi-spreading	IC-375075	Gujarat	White	circular
443	IC-372992	Semi-spreading	IC-372992	New Delhi	White	circular
444	569	Erect	IC-571996	AP	Purple	circular
445	IC-344816	Semi-spreading	IC-344816	New Delhi	White	Heart
446	M-40	Semi-spreading		MS	White	circular
447	RG-38	Semi-spreading		Gujrat	Purple	circular
448	EC-286083	Semi-spreading	EC-286083	MS		
449	IC-49327	Erect	IC-49327	New Delhi	Purple	circular
450	IC-75642	Semi-spreading	IC-75642	New Delhi	White	circular
451	IC-ADG-166	Semi-spreading		New Delhi	White	circular
452	IC-372930	Semi-spreading	IC-372930	Gujarat	White	circular
453	IC-48628	Semi-spreading	IC-48628	New Delhi	Purple	Ovate
454	IC-48913	Erect	IC-48913	New Delhi	White	circular
455	IC-64363	Semi-spreading	IC-64363	New Delhi	White	Heart
456	IC-48651	Spreading	IC-48651	New Delhi	White	circular
457	IC-264326	Semi-spreading	IC-264326	New Delhi	White	circular
458	596	Semi-spreading	EC-631748	J&K	White	circular
459	653	Semi-spreading		Manipur	White	circular
460	IC-372905	Semi-spreading		Gujarat	White	Ovate
461	IC-336815	Semi-spreading	IC-336815	New Delhi	White	circular
462	RG-336	Erect	IC-0611034	MS	Purple	circular
463	IC-141142	Semi-spreading	IC-141142	Uttaranchal	Purple	circular
464	645	Semi-spreading		Orissa	Purple	circular
465	IC-3225-1	Semi-spreading	IC-3225-1	New Delhi	White	circular
466	IC-375057	Semi-spreading	IC-375057	Rajasthan	Purple	circular
467	IC-372966	Semi-spreading	IC-372966	New Delhi	Purple	circular
468	IC-375097	Semi-spreading	IC-375097	Delhi	White	circular
469	WG-275	Semi-spreading	IC-0611035	Gujrat	White	circular

470	652	Semi-spreading		Manipur	Purple	circular
471	RG-482	Semi-spreading		MS	White	circular
472	IC-48988	Semi-spreading	IC-48988	New Delhi	Purple	circular
473	IC-48662-1	Semi-spreading	IC-48662-1	New Delhi	White	Heart
474	IC-486342	Semi-spreading	IC-486342	New Delhi	White	circular
475	IC-48654	Semi-spreading	IC-48654	New Delhi	White	circular
476	653	Semi-spreading			White	circular
477	RG-60	Semi-spreading		Gujrat	Purple	circular
478	WG-365	Erect	IC-0611036	AP	Purple	Heart
479	WG-102	Semi-spreading		Gujrat	White	circular
480	584	Semi-spreading		Bihar	White	Heart
481	IC-344844	Semi-spreading	IC-344844	Uttaranchal	White	circular
482	WG-50	Semi-spreading	IC-0611037	Gujarat	White	circular
483	IC-375041	Semi-spreading	IC-375041	New Delhi	White	circular
484	624	Spreading	IC-0611038	Rajastan	White	circular
485	571	Erect	IC-572002	Adilabad	Purple	circular
486	520	Semi-spreading	IC-0611039	WB	White	Ovate
487	IC-33682	Semi-spreading	IC-33682	New Delhi	Purple	circular
488	549	Semi-spreading	IC-571966	AP	White	circular
489	GG-3	Semi-spreading		Gujarat	White	Ovate
490	174	Semi-spreading	IC-0611040	Gujarat	Purple	circular
491	RG-37	Semi-spreading	IC-0611041	Gujarat	Purple	circular
492	IC-375002	Semi-spreading	IC-375002	Uttranchal	Purple	circular
493	PHULE BASWANT	Erect		MS	Purple	circular
494	62	Semi-spreading	IC-0611042	Gujarat	White	circular
495	521	Erect		WB	White	circular
496	IC-290449	Erect	IC-290449	New Delhi	Purple	circular
497	590	Semi-spreading		Bihar	White	circular
498	543	Semi-spreading	571917	AP	White	Heart
499	IC-345588	Erect	IC-345588	Uttranchal	Purple	circular
500	401	Erect	IC-0611043	AP	Purple	circular
501	IC-82882	Semi-spreading	IC-82882	New Delhi	Purple	circular
502	IC-141249	Semi-spreading	IC-141249	New Delhi	White	circular
503	548	Semi-spreading	571961	AP	White	circular
504	IC-141107	Semi-spreading	IC-141107	Haryana	White	Heart
505	IC-372967	Spreading	IC-372967	Gujarat	White	Heart
506	M-109	Semi-spreading		MS	Purple	circular
507	58	Semi-spreading		Gujarat	White	circular
508	AC-201	Semi-spreading		Gujarat	White	circular
509	IC-372829	Semi-spreading	IC-372829	New Delhi	White	circular
510	88	Semi-spreading	IC 49345	New Delhi	White	circular
511	IC-372995	Spreading	IC-372995	Gujarat	White	circular
512	IC-32262	Erect	IC-32262	New Delhi	White	circular

513	551	Spreading		AP	White	circular
514	IC-48870	Semi-spreading	IC-48870	New Delhi	Purple	circular
515	IC-338479	Semi-spreading	IC-338479	Uttaranchal	White	circular
516	M-175	Semi-spreading		MS	White	circular
517	507	Semi-spreading		Punjab	White	circular
518	RG-54	Semi-spreading	IC-0611044	Gujarat	Purple	circular
519	IC-344837	Semi-spreading	IC-344837	New Delhi	White	circular
520	IC-372895	Semi-spreading	IC-372895	Gujarat	Purple	circular
521	WG-34	Semi-spreading		MS	White	Heart
522	IC-372982	Semi-spreading	IC-372982	HP	Purple	circular
523	IC-48357	Semi-spreading	IC-48357	New Delhi	White	circular
524	IC-ADR-1-172	Semi-spreading	IC-ADR-1-172	New Delhi	Purple	Heart
525	IC-394974	Erect	IC-394974	New Delhi	Purple	Heart
526	IC-19084	Semi-spreading	IC-19084	New Delhi	Purple	Ovate
527	523	Semi-spreading	IC-0611045	WB	Purple STRIPS	circular
528	IC-372944	Semi-spreading	IC-372944	Gujarat	White	circular
529	IC-49327	Semi-spreading	IC-49327	MS	White	circular
530	IC-141250	Semi-spreading	IC-141250	New Delhi	White	circular
531	IC-141151	Semi-spreading	IC-141151	Uttaranchal	White	circular
532	IC-34465	Semi-spreading	IC-34465	New Delhi	White	circular
533	IC-372943	Semi-spreading	IC-372943	Gujarat	White	circular
534	101	Semi-spreading		Rajsthan	WHTE	Heart
535	IC-49357	Semi-spreading	IC-49357	MS	White	circular
536	IC-48681	Erect	IC-48681	Haryana	Purple	circular
537	519	Semi-spreading	IC-0611046	WB	Purple	circular
538	644	Erect		Orissa	Purple	circular
539	WG-63	Semi-spreading		Gujrat	White	Heart
540	GG-4	Spreading		Gujrat	White	Heart
541	452	Semi-spreading	IC-0611047	AP	White	circular
542	IC-141325	Semi-spreading	IC-141325	New Delhi	White	circular
543	471	Semi-spreading	IC-0611048	AP	White	circular
544	IC-375158	Semi-spreading	IC-375158	New Delhi	White	circular + Heart
545	IC-375052	Semi-spreading	IC-375052	Rajasthan	White	circular
546	IC-141273	Semi-spreading	IC-141273	MS	Purple	circular
547	575	Semi-spreading	IC-572009	AP	White	circular
548	IC-372905	Semi-spreading	IC-372905	Gujarat	White	Heart
549	IC-46662	Semi-spreading	IC-46662	New Delhi	Purple	circular
550	IC-374999	Semi-spreading	IC-374999	MS	White	circular
551	371	Semi-spreading	IC-0611049	AP	White	Heart
552	WG-29	Semi-spreading		MS	White	circular
553	IC-375097	Semi-spreading	IC-375097	Delhi	Purple	circular
554	RG-64	Semi-spreading	IC-0611050	Gujarat	White	circular
555	IC-375010	Semi-spreading	IC-375010	J&K	White	circular

556	WG-416	Semi-spreading		AP	White	circular
557	IC-374940	Semi-spreading	IC-374940	New Delhi	White	Heart
558	WG-183	Semi-spreading		Haryana	Purple	circular
559	M-279	Erect		Gujarat	White	circular
560	IC-375042	Semi-spreading	IC-375042	New Delhi	Purple	circular
561	G-50	Erect		MS	White	Ovate
562	M-297	Semi-spreading		Gujarat	White	Heart
563	IC-374981	Semi-spreading	IC-374981	Arunachal Pra	White	circular
564	WG-107	Semi-spreading	IC-0611051	Gujarat	Purple	circular
565	IC-372997	Semi-spreading	IC-372997	MS	Purple	circular
566	RG-114	Semi-spreading		Gujarat	Purple	circular
567	609	Semi-spreading	IC-0611052	MP	Purple	circular
568	OTUR 555	Spreading	IC-0611053	MS	White	Heart
569	M-282	Semi-spreading		Rajasthan	White	circular
570	BHIMA OMKAR	Semi-spreading	IC 569789	Bihar	White	circular
571	IC-372947	Semi-spreading	IC-372947	Gujarat	Purple	circular
572	IC-372977	Semi-spreading	IC-372977	Gujarat	White	circular
573	IC-35466	Semi-spreading	IC-35466	New Delhi	Purple	circular
574	649	Semi-spreading	IC-0611054	Orissa	White	circular
575	RG-34	Semi-spreading		MS	Purple	circular
576	WG-4	Semi-spreading		MS	White	circular
577	RG-344	Semi-spreading		MS	Purple	circular
578	IC-338528	Semi-spreading	IC-338528	Uttaranchal	White	Heart
579	562	Semi-spreading	IC-571977	Andhra Pradesh	White	Heart
580	WG-1	Semi-spreading		MS	White	circular
581	M-45	Semi-spreading		MS	White	Heart
582	IC-48628	Semi-spreading	IC-48628	New Delhi	Purple	circular
583	G-282	Spreading		MS	White	circular
584	WG-126	Semi-spreading		Gujarat	White	circular
585	IC-48967	Semi-spreading	IC-48967	New Delhi	White	Heart
586	IC-411227	Semi-spreading	IC-411227	New Delhi	Purple	circular
587	635	Semi-spreading		Karnatka	Purple	circular
588	IC-49381	Semi-spreading	IC-49381	New Delhi	White	circular
589	IC-49382	Erect	IC-49382	New Delhi	Purple	Heart
590	516	Semi-spreading	IC-0611055	West Bangal	White	circular
591	IC-345680	Semi-spreading	IC-345680	Uttaranchal	Purple	circular
592	545	Erect	IC-571923	Andhra Pradesh	White	Heart
593	IC-279574	Semi-spreading	IC-279574	Uttaranchal	Purple	circular
594	605	Semi-spreading		Gujarat	White	circular
595	IC-32274	Spreading	IC-32274	New Delhi	White	circular
596	IC-355085	Semi-spreading	IC-355085	New Delhi	White	circular
597	648	Semi-spreading	IC-0611056	Orissa	Purple	Ovate
598	WG-183	Erect		Haryana	White	Ovate

599	RG-95	Semi-spreading	EC-244949	New Delhi	Purple	circular
600	M-161	Semi-spreading		MS	White	circular
601	IC-141159	Semi-spreading	IC-141159	New Delhi	White	circular
602	IC-375005	Semi-spreading	IC-375005	New Delhi	White	Heart
603	IC-100725	Semi-spreading	IC-100725	New Delhi	Purple	circular
604	IC-337421	Erect	IC-337421	Uttaranchal	White	Heart
605	RG-58	Semi-spreading		Gujarat	Purple	circular
606	M-33	Semi-spreading		MP	White	circular
607	IC-49967	Semi-spreading	IC-49967	New Delhi	White	Heart
608	WG-323	Semi-spreading	IC-0611058	Orissa	White	circular
609	IC-372398	Erect	IC-372398	New Delhi	Purple	circular
610	RG-56	Erect		Uttaranchal	Purple	circular
611	IC-372919	Semi-spreading	IC-372919	New Delhi	White	circular
612	IC-372933	Semi-spreading	IC-372933	New Delhi	Purple	Ovate
613	554	Semi-spreading	IC-571920	Andhra Pradesh	White	circular
614	IC-373000	Spreading	IC-373000	MS	White	Heart
615	IC-32654	Semi-spreading	IC-32654	New Delhi	White	circular
616	RG-337	Semi-spreading	IC-0611057	MS	Purple	circular
617	RG-88	Semi-spreading	IC- 49345	New Delhi	Purple	circular
618	M-287	Semi-spreading		MP	White	Heart
619	IC-374987	Semi-spreading	IC-374987	MP	White	circular
620	600	Semi-spreading		MP	White	circular
621	M-238	Semi-spreading		MP	White	circular
622	570	Erect	IC -572000	AP	Purple	circular
623	RG-P-109	Erect		MP	Purple	circular
624	G-41	Semi-spreading	IC- 570698	MS	White	circular
625	IC-141208	Erect	IC-141208	MS	Purple	circular