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Comparative Morphological Evaluation of Different Chilli (*Capsicum annuum* L.) Varieties of Andhra Pradesh, India for Agronomic Traits

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In the present study, 20 chilli cultivars were characterized based on morphology as it serves as discrete identification indicator and also propose to evaluate cultivar diversity for yield related parameters. Among the 20 cultivars, different quantitative and qualitative morphological traits like, hypocotyl pubescence, hypocotyl colour, cotyledon leaf shape, cotyledon leaf colour, cotyledon leaf width and cotyledon leaf length were studied. A stem length to first bifurcation ranged from 10.80 cm (LCA-424) to 26.33 cm (LCA-620) among the 20 cultivars, taller and shorter stems, taller, wider plant, longer and wider leaves were noticed. Hence, this character could be used for varietal identification. Fruit, fruit length, fruit width, pedicel length, dry fruit weight, seed weight and seed size might be efficiently used for different the chilli cultivars. Fruit positions were divided into two groups *viz.*, Pendent and Erect. Among them, maximum number of genotypes had pendent fruits while only one by Mycoteja produced erect fruits. The fruit yield varied from 83.95g to 295.10g with a mean of 146.82g. The maximum mean performance was observed for genotype LCA-625 (295.10 g/plant) followed by LCA-620 (249.93 g/plant) and LCA-424 (244.24 g/plant), while the minimum value was observed for LCA-305 (83.95 g/plant) preceded by LCA-960 (92.77 g/plant). The study has spawned some important morphological traits, which can be efficiently employed in differentiating the chilli cultivars for beneficial agronomic traits.

Key words: Morphology, hypocotyl pubescence, pedicel length, dry fruit, genotypes

Chilli (*Capsicum annuum* L.) is one of the most significant crops in India. It belongs to the family Solanaceae and is very important spice and condiment crop used for salad, cooked as vegetable, pickled or processed purpose. In India, *Capsicum annuum* species is well known and most of the cultivated crop varieties belong to *Capsicum annuum*. It has a lot of other names such as hot pepper, chilli, chilli or chilli pepper and sometimes just as pepper. The genus, *Capsicum* includes the peppers and chilies with great nutritional and economic value and is widely grown in the whole world (García-Gaytán *et al.*, 2017).

The Andhra Pradesh state contributes a lion share of the exports from our country. Guntur, Krishna, Prakasam and Kurnool districts contribute approximately 80 per cent of chilli production in this state (Prasad *et al.*, 2013). Although chilli being widely studied crop, systematic studies in varietal characterization is lacking especially for newly developed promising varieties. Thus, characterization of varieties which are of wider acceptance by farming community needs to be studied in order to regulate their genetic purity during their multiplication and seed quality evaluation. Assessing the field level performance and identification of elite cultivars assumes enormous importance in selection and breeding the plant varieties for their stress tolerance and beneficial agronomic characters. Though several varieties have been developed in chillies, but the field level performance for wanted characters were confined to one to two specific varieties. Assessing the field level performance of all known chilli varieties under same experimental condition may lead to the identification of best varieties in terms of morphological characters and yield parameters. Hence, the present work is planned by collecting the 20 known chilli varieties from Horticultural Research Station (HRS), Lam farm, Guntur, to comparatively study the expression of morphological characters or field level performance under similar experimental conditions in A.N.U botanical garden.

The morphological descriptions have traditional importance and have been accepted as a classical taxonomic method for documentation of crop varieties (Oo *et al.*, 2017). Additional keys for identification could be industrialized on the basis of these morphological characters that could serve as a database for identification of cultivars and genetic purity test. Morphological characters are conventionally used for varietal and diversity identification of all vegetable crops (Patel *et al.*, 2001, Garcia-Gusano *et al.*, 2004).

MATERIALS AND METHODS

The experiment was conducted at Acharya Nagarjuna University campus, Guntur. The site of the experiment is situated on 160 2' North latitude and 800 3' East longitudes at an altitude of 31.5m above mean sea level.

Experimental details

Seed material

Fifteen varieties HRS Lam Farm and remaining five varieties collected from local market in Guntur, Andhra Pradesh, India.

Identification of key characters of seed, seedlings and plant in chilli cultivars

Seedling Characteristics and Nursery rising

The seedlings for the study were raised by sowing the seeds in nursery beds of 4m x 1m size bringing the soil to a fine tilth. Each bed was mixed with 2kg of Farm Yard Manure (FYM). The beds were leveled and seeds of 20 varieties were sown in lines at 5cm spacing. Mulching was done with dry paddy straw. Nursery beds were frequently watered. The mulch was removed after germination of seeds and beds were kept free from weeds. As a precaution against "damping off" disease of the seedlings, the beds were soaked with copper oxychloride (3g/l) on 12th and 21st day after sowing the nursery and the following observations were recorded when the terminal bud were 1-2 mm in size. Six weeks old, uniform and healthy seedlings from each accession were transplanted in the main experimental plots.

Hypocotyl colour

The hypocotyl colour of the seedlings was recorded using Munsell color chart. Based on the hypocotyl colour, the cultivars were classified as: 1 White, 2 Green, and 3 Purple colour containing cultivars.

Hypocotyl pubescence

The Hypocotyl pubescence of the seedlings were recorded on ten seedlings of each cultivar by using stereo ocular microscope and grouped as follows: 4 Sparse, 5 Intermediate, and 7 Dense.

Cotyledonous leaf color

The cotyledon colour of the seedlings were recorded using Munsell colour chart, when terminal bud was 1-2 mm in size on ten seedlings of each cultivar. Based on cotyledon colour, the cultivars were classified as: light green, green, dark green, light purple, purple, dark purple, variegated, and yellow.

Cotyledonous leaf shape

The cotyledon shapes of the seedlings were observed visually when terminal bud was 1-2 mm in size, on ten seedlings of each cultivar, based on which the cultivars were classified as: Deltoid, Lanceolate, Ovate and Elong-deltoid.

Cotyledonous leaf length [mm]

The average of 10 cotyledon length [mm] of the seedlings were recorded using millimeter scale when terminal bud was 1-2 mm in size on ten seedlings of each cultivar and expressed in millimeter.

Cotyledonous leaf width [mm]

The average of 10 cotyledon width [mm] of the seedlings were recorded using millimeter scale when terminal bud was 1-2 mm in size on ten seedlings of each cultivar and expressed in millimeter.

Layout of experiment

The entire germplasm of chilli was laid out in a Randomized Block Design with two replications (Fig 3). Twelve plants of each genotype were transplanted in each replication in one row. Design: Randomized Block Design (RBD), Number of treatments: 20, Replications: 2, Plot size: One row of 4 m length, Spacing: 75 cm x 30 cm, Number plants per row: 12, Date of transplanting: 3rd August, 2016, Season: Kharif, 2016-18, Location: Acharya Nagarjuna University campus, Guntur.

Experimental material

The experimental material consisted of 20 genotypes obtained from germplasm collection of Horticultural Research Station (HRS), Lam farm, Guntur (Table 1).

Cultural practices

Soil

The soils of the farm are deep, black clay loams with a depth of 6-7ft, pH of 8.3, EC of 0.16 m. mhos/cm and have good moisture holding capacity.

Preparation of experimental plot

The experimental fields were brought to fine tilth by ploughing thrice followed by harrowing. Before final harrowing, FYM @ 25 tonnes/ha was applied as basal dose and incorporated in the soil. The used dose of fertilizers @ 200:60:80 kg NPK/ha were in the form of urea, single super phosphate and murate of potash. Entire dose of P was applied as basal while N and K were applied in three equal splits throughout the crop growth.

Transplanting and after care

Six weeks old seedlings were transplanted to the main field after allotting entries randomly in each replication. The field was irrigated and the seedlings were transplanted by maintaining a spacing of 75cm between the rows and 30cm between the plants with in a row. Immediately after transplanting the field was irrigated lightly. The plots were kept free of weeds and irrigated regularly. Need based plant protection measures were taken up to keep the plot free from pests / diseases and raise a healthy crop.

Plant morphological traits

Numerous morphological traits recorded at different plant growth stages are stem characteristics, plant characteristics, leaf characteristics, inflorescence descriptors, quantitative character's, fruit descriptors, fruit position and yield characteristics. Randomly selected plants from each entry were tagged in each replication for recording observations on different characters as described and the mean values were calculated.

Statistical analysis

The statistical analysis was carried out for the each observed character under the study using MS-Excel, SPSS 16.0 and SPAR 2.0 packages, respectively. The mean values of data were subjected to analysis of variance as described by Gomez & Gomez (1984).

RESULTS AND DISCUSSION

The results of the current study relating to varietal characterization based on seed, seedling and plant morphology have been shown in this below tables 2-7; figures 1 – 4.

Seedling Morphology

The anthocyanin coloration of all seedling morphological characters *viz.*, hypocotyl pubescence, hypocotyl color, cotyledon leaf shape, cotyledon leaf color, cotyledon leaf width and cotyledon leaf length are presented in Table 2 and figures 1 - 3.

Hypocotyl color

Hypocotyl color of the plantlets were pragmatic visually on ten plantlets of each cultivar as well as grouped obsessed by three categories *viz.*, light purple, medium purple and dark purple (Table 2 & Figure 1). 16 of the cultivars had medium purple hypocotyls, nine cultivars had dark purple hypocotyl and four cultivars *viz.*, Surya teja, Super-10, L.C.A-625 had light purple hypocotyl.

Hypocotyl pubescence

Hypocotyl pubescence of the seedlings of each cultivar was clustered into three categories *viz.*, sparse, intermediate and dense (Table 2 & Figure 2). Majority of the cultivars had dense pubescence on their hypocotyls, four cultivars *viz.*, Mycoteja, LCA-206, Super-10 and Vajra showed intermediate pubescence while solitary had sparse pubescence on its hypocotyl.

Cotyledon leaf color

The cultivars showed three types of leaf color for the cotyledon, light green, green and dark green (Table 2 & Figure 3). Most of the cultivars had green cotyledon leaf color. G-4, LCA-206, L.C.A-305, L.C.A-353, L.C.A-620, Aparna, Super-10, Vajra, Rabbi, Mycoteja, L.C.A-625 and G-3 showed dark green cotyledon color, while, L.C.A-960, L.C.A-424, L.C.A-436,L.C.A-334 were with light green cotyledon leaf color.

Cotyledon leaf shape

The cotyledon shape of the seedlings were observed visually when terminal bud was 1-2 mm in size, on ten seedlings of each cultivar, based on which the cultivars were classified as: Deltoid, Lanceolate, Ovate, and Elong-deltoid. All the cultivars displayed lanceolate leaf shape (Table 2).

Cotyledon leaf length (mm)

Cotyledon leaf length for the cultivars is presented in Table 3. Significant differences were noticed for cotyledon leaf length among the cultivars. The cultivar Suryateja recorded significantly highest cotyledon length (15.45 mm) which was on par with the cotyledon leaf lengths of cultivars, Aparna, Super-10, Vajra, Rabbi, LCA-206, L.C.A-305, L.C.A-353, L.C.A-620, Mycoteja, L.C.A-625, Suryateja. Significantly lowest cotyledon leaf length was recorded in cultivars G-3, G-5, 999, L.C.A-235. However, there were no significant differences for cotyledon length.

Cotyledon leaf width (mm)

Cotyledon width for the cultivars is presented in Table 3; significant differences were noticed for cotyledon width among the cultivars. The cultivar Vajra recorded significantly highest cotyledon width (5 mm) which was on par with the cotyledon widths of cultivars Aparna, Super-10, Vajra, Rabbi, LCA-206, and L.C.A-305. Significantly lowest cotyledon length was recorded in cultivars G-3, G-5, 999, L.C.A-235. However, there were no significant differences for cotyledon width for the cultivars.

Plant morphological traits

The plant morphological traits of the 20 cultivars were recorded at different stages of plant growth period. The data pertaining to these traits are presented in Tables 3 to 7 and Figure 4

Stem length to first bifurcation (cm)

The results on stem length to first bifurcation as partial by, cultivars and their interaction are presented in Table 3. Significant differences were noticed for stem length to first bifurcation among the cultivars for the two seasons. Significantly higher stem length to first bifurcation was noticed (18.61 cm). The cultivar Mycoteja recorded significantly highest stem length to first bifurcation (28.42 cm), while significantly lowest stem length to first bifurcation was recorded in Vajra (22.73 cm) cultivar which was found to be on par with the cultivars L.C.A-305, 999 and, L.C.A-620. The highest Stem length to first bifurcation was observed for

the cultivar (28.42 cm) which was found to be on par with the stem lengths of cultivars.

Stem diameter (cm)

The results on stem diameter in chilli cultivars are presented in Table 4. No significant differences were noticed for stem diameter. Among the cultivars, L.C.A-960 had significantly thinner stem (0.562 cm), whereas cultivar L.C.A-206, L.C.A-305 had the thickest stem (1.23cm) which was found to be on par with the stem diameter of cultivars Rabbi, 999, L.C.A-625, Mycoteja. The interaction effect was found to be significant for the stem diameter. Super-10, Vajra, L.C.A-334 had significantly lowest stem diameter (0.334 cm), while, the highest stem diameter was noticed in the cultivar L.C.A-436(1.34 cm) which was on par with the stem diameters of cultivars.

Stem Shape

The stem shape was found to be angular for all the cultivars are shown in Table 4.

Stem color

The cultivars exhibited three types of stem color *viz.*, green, green with purple stripes and purple(Table 4 & Figures 1 – 3). All but three cultivars had green with purple stripes colored stem. Cultivars LCA-206, Super-10 and G-5 had Intermediate colored stems (Table 4).

Stem pubescence

The stem pubescence was recorded on mature plants from each cultivar, excluding the first two nodes below the shoot (Table 4). The cultivars either had sparse, intermediate or dense pubescence on their stems. Eight of the 20cultivars had dense pubescence on their stems while six cultivars had sparse and the remaining six cultivars had intermediate stem pubescence.

Nodal Anthocyanin

The nodal anthocyanin was recorded at plant maturity. The cultivars had their nodes colored either light purple or purple or dark purple (Table 5 & Figure 3). Ten of the 20 cultivars had purple nodes, twelve had light purple and remaining eight cultivars had dark purple nodal anthocyanin.

Plant growth habit

The Plant growth habit was observed when 50 per cent of the plants had ripe fruits. The plants were both intermediate or prostrate in their growth habits of the 20 cultivars used in the study 18 of them had intermediate type of plant growth and two cultivars had erect type of plant growth.

Branching Habit

The plant branching habit was observed at plant maturity. The branching habit was either sparse or intermediate or dense. Twenty cultivars showed intermediate type of branching habit and six of them had sparse and dense branching habit.

Tillering

The plant tillering habit was observed at plant maturity. The tillering habit of the cultivars could be grouped into either sparse or intermediate or dense. Of the 20 cultivars, of them had intermediate tillering habit.

Plant height (cm)

The results on plant height was influenced by seasons, cultivars and their interaction are presented in Table 6. Significant differences were noticed for plant height among the cultivars. Significantly taller plants were noticed with 114.60cm height. The cultivar recorded significantly G-4 highest plant height (114.60cm), while significantly low plant height (63.87cm) was recorded in G-5 cultivar.

Morphological characters of chilli genotypes

Morphological traits like fruit position, mature green fruit color and number of fruits per axil of all successions are given in Table 6.

Fruit position

Totally 20 genotypes, based on fruit position were divided into two groups *viz.*, Pendent and Erect. Among them, maximum number of genotypes had pendent fruits while only one Mycoteja produced erect fruits. These results are similar to those reported by Arup *et al*. (2011) with maximum genotypes having pendent fruits.

Mature green fruit color

Based on immature fruit color, the genotypes were divided into three group's *viz.*, Green, Parrot Green and Dark Green. Among them, maximum genotypes had green fruits and three of them (LCA-334, LCA-625,999) had parrot green fruits while only five (LCA-305, LCA-424, LCA-436, LCA-960 and Mycoteja) had dark green

fruits and thus results are in line with similar observations recorded by Arup *et al*. (2011).

Fruits per axil

The genotypes, based on fruits per axil were divided into two groups *viz.*, Solitary and Cluster. Among them, maximum genotypes produced solitary fruits except Mycoteja, Rabbi, and Vajra, which had cluster bearing habit.

Mean performance of genotypes

The data on the mean performance, which was recorded for ten quantitative and six qualitative characters, are presented in Table 7 and Figure 4.

Plant height (cm)

The plant height ranged from 63.87 cm to 114.60 cm with a mean of 88.18 cm. The genotype G-4 recorded maximum plant height (114.60 cm) followed by Super-10 (112.30 cm) while the genotype G-5 recorded the minimum plant height (63.87 cm).

Number of primary branches per plant

The number of primary branches per plant was in the range of 2.75 to 4.90 with a mean of 3.60. The genotypes, LCA-206 and LCA-620 recorded the highest number of primary branches (4.90) followed the lowest was observed for G-3 (2.3).

Days to 50 per cent flowering

Days to 50 per cent flowering ranged from 25 to 40 with a mean of 31.40 days. The genotype Vajra recorded maximum no. of days to 50 per cent flowering (40) followed by LCA-235 (38), while Rabbi (25) and Mycoteja (31.00) were the earliest to flower.

Fruit set per cent

The fruit set per cent varied from 18 to 80 with a mean of 51.40. The maximum fruit set per cent was observed for LCA-625 (80) followed by LCA-436 (78) and LCA-353 (76), whereas the minimum per cent was recorded G-3 (18) proceeded by LCA-334 (64) and LCA-235 (32).

Number of fruits per plant

The number of fruits per plant ranged from 116.70to 390 with a mean of 179.55. This trait exhibited maximum mean value for the genotype Rabbi (389.50) followed by LCA-625 (345.40),while the minimum mean value was recorded for Super-10 (77.50) proceeded by 999 (78.90).

Fruit diameter (cm)

The range of fruit diameter varied from 0.82 cm to 2.55 cm with a mean of 1.32 cm. The maximum diameter was recorded by the genotype LCA-625 (2.0 cm) followed by LCA-334 (1.22 cm) and LCA-960 (1.99 cm), whereas the minimum diameter was recorded by LCA-235 (0.82 cm) proceeded by Mycoteja (1.45 cm).

Fruit length (cm)

The fruit length had the range of 6.78 cm to 12.90 cm with a mean of 9.50 cm. The maximum fruit length was observed for the genotype LCA-353 (12.97 cm) followed by Super-10(8.61 cm) and LCA-235 (8.60 cm) while the minimum was recorded by LCA-620 (9.60 cm) preceded by G-5 (4.42 cm).

Average dry fruit weight (g)

The range of this character varied from 0.72 g to 1.65 g with a mean of 1.10 g. The maximum fruit weight was noticed in 999 (1.65 g) followed by LCA-235 (1.59 g) and LCA-960 (1.52 g) and the minimum was in Rabbi (0.72 g).

Number of seeds per fruit

The number of seeds per fruit ranged from 45.90 to 96.50 with a mean of 72.88. The highest mean performance for this trait was recorded for genotype the Rabbi (96.50) followed by LCA-235 (59.00), whereas the lowest for LCA-625 (78.40) preceded by Vajra (60.00).

Yield per plant

The range of this character varied from 85.99 g to 305.50 g with a mean of 159.51 g. The maximum mean performance was observed for genotype LCA-625 (305.50 g) followed by LCA-620 (251.90 g) and LCA-424 (164.50 g) while the minimum value was observed for LCA-305 (131.81 g) preceded by LCA-960 (96.30 g).

In the present study, a high range of variability was observed for all the characters. Variability was maximum for number of fruits per plant (45.99 to 305.50). The characters showing wide range of variation provide an ample scope for selecting desired types. These results are in accordance with those reported by earlier workers (Vani et all., 2007; Farhad *et al.*, 2008; Kumari *et al.*, 2010; Naresh *et al.*, 2011; Gupta *et al.* ,2009). These

findings recommend that it is possible to isolate superior genotypes during the field level selection process.

The typical taxonomic method to identify a selection for both varietal purity testing and varietal identification is by the use of plant diagnostic characters. Seed, seedling and plant characters are considered to be major constituents of variety identification since they provide reliable and dependable data. However, it is difficult to identify cultivars based on single morphological trait. Instead, morphological traits are essential to distinguish the cultivars (Oo *et al.*, 2017). In the present study, quantitative characters were studied and dissimilarity was observed in almost all quantitative and seedling morphological characters.

Appearance of different characteristics of seedlings like pubescence, pigmentation is found to be varietal specific and helps in early identification of chilli cultivars at seedling stage itself. In the present study, 20 seedling morphological characters like, hypocotyl color, hypocotyl pubescence, cotyledon leaf color, cotyledon leaf shape, cotyledon leaf length and cotyledon leaf width were used to characterize the chilly cultivars. Colour of hypocotyl is triggered by the deposition of several flavonoids in the hypocotyl tissues, the pigment malvidin with small amounts of delphinidin and petunidin (Maji, Banerji, 2016). These dyes are under genetic control and the pleotropic effects cause color variation (Peters, 1984) and hence it can be used for characterization. Based on hypocotyl color cultivars were categorized into three groups *viz.*, light purple, medium purple and dark purple. While, most of the cultivars were found to have medium purple colored hypocotyls, only four cultivars *viz.* LCA-424, Vajra, G-3 had light purple hypocotyl and can be utilized to identify these cultivars (Figures 1 – 3). Hypocotyl pubescence observed on the seedlings was sparse, intermediate or dense. Majority of the cultivars had dense pubescence on their hypocotyls, while only Mycoteja had sparse pubescence on its hypocotyl. Therefore, this character can be readily employed as an efficient marker to identify Mycoteja cultivar. Most of the cultivars had green cotyledon leaf color, while, Mycoteja and Vajra were the only two cultivars with light green cotyledon leaf color. As all the cultivars possessed lanceolate leaf shape this trait was not suitable even for grouping of the cultivars.

Cotyledon leaf length varied between 15.66 mm (LCA-305) to 17.66 mm (Aparna), while the Cotyledon leaf width varied between 3.33 mm (G-5) to 5 mm (LCA-960) among the cultivars used for the study. As the variances between the highest and lowest values for cotyledon leaf length and width was very slight among the cultivars, only the cultivars at the either end of the scale could be recognized by using these two characters.

Therefore, midst seedling morphological traits, hypocotyl color and pubescence were found to be suitable for broader classification of genotypes into dissimilar groups but not for identification of distinct variety. Although, these characters are in use for a long time till today (Harris W. and Beever, 2000; Křístková *et al.*, 2008) for varietal characterization, but their full exploitation was not achieved.

Plant morphological traits

Plant morphological characters have been used for classification of several crop varieties like lettuce (Křístková *et al.*, 2008), in chilli, (Adetula and Olakojo, 2006), cabbage (Harris and Beever, 2000). This is an outmoded method of varietal identification in which plants have to be maintained till maturity.

Plant growth traits

In the present study, plant growth traits were studied. Large variations were noticed for stem length to first bifurcation among the cultivars. Stem length to first bifurcation ranged from 10.80 cm (LCA-424) to 26.33 cm (LCA-620) among the cultivars, taller and shorter stems were noticed. Hence, this character could be used for varietal identification. Stem diameter showed wide variations among the cultivars and it ranged from 0.562 cm (LCA-960) to 1.23 cm (LCA-305) among the cultivars. Based on stem color, cultivars LCA-206 and LCA-305 which had purple colored stems and Suryateja with green colored stem could be clearly distinguished from the rest of the cultivars which had stems of green with purple colored stripes. Hence, this character was found to be more useful in varietal identification. The stem figure was found to be angular for all the cultivars. Most of the cultivars had dense pubescence on their stalks while the remaining cultivars had either

intermediate or sparse stem pubescence was found for all the cultivars.

The pigment, Anthocyanin which imparts purple color in plant may be used as the marker for effective varietal identification. The nodal anthocyanin pigmentation is known to be controlled by an incompletely dominant gene and a modifier gene which intensifies the purple color (Peterson, 1959; Reyes, 2004). The pigment, Anthocyanin which imparts purple color in plant may be used as the marker for effective varietal identification. The nodal anthocyanin pigmentation is known to be controlled by an incompletely dominant gene and a modifier gene which intensifies the purple color (Manju and Sreelathakumary, 2002; Bozokalfa and Turhan, 2009; Padma *et al.*, 2017; Hasan *et al.*, 2014). Varieties within most species exhibit heritable and sometimes dramatic, differences in their growth and morphology. Plant architecture is very important because it affects shoot length, flowering node, branch presence and orientation, habit, growth determinacy, fruit number, fruit size and the final yield (Alvarez *et al.*, 1992; González *et al.*, 2016). It is mostly under the control of single gene and the genetic changes operate at the level of the whole plant (Gottlie 1986). Hence, provides excellent characters for characterization and identification of varieties.

Most of the cultivars had either intermediate or erect type of plant growth habit and only Mycoteja cultivar showed prostrate type of plant growth. Hence, this character would be very useful to identify Mycoteja cultivar. Cultivars LCA-353, LCA-620, LCA-625 were the only cultivars with dense bifurcating habit and could be utilized for identification of these cultivars. Intermediate tillering habit was found to be more common among the cultivars and only three cultivars *viz.*, Vajra, Super-10, LCA-620, and LCA-235 showed dense tillering habit. This character was particularly useful for explicit identification of LCA-235, LCA-625 cultivars. All these three characters *viz.*, plant growth habit, branching habit and tillering habit did not vary between the seasons for any of the cultivars. Such changes in plant growth habit and branching habit midst the cultivars were reported by different authors (Adetula and Olakojo, 2006; Manju and Sreelathakumary 2002; Bozokalfa and Turhan 2009) in chilli. Plant height and plant spread are significant characters of variety identification especially for identification of off type at the time of field inspection. Plant height cultivars were studied ranged from 63.87 cm (G-5) to 114.60 cm (G-4), while plant spread ranged from 29.00 cm (Mycoteja) to 101.75 cm (LCA-424).

Table-1. Source of the Chilli genotypes (*Capsicum annuum* L.)

Treatment	Accession Number	Source
1	G-3	HRS, Lam farm, Guntur
2	G-4	HRS, Lam farm, Guntur
3	G-5	HRS, Lam farm, Guntur
4	LCA-206	HRS, Lam farm, Guntur
5	LCA-235	HRS, Lam farm, Guntur
6	LCA-305	HRS, Lam farm, Guntur
7	LCA-353	HRS, Lam farm, Guntur
8	LCA-334	HRS, Lam farm, Guntur
9	LCA-424	HRS, Lam farm, Guntur
10	LCA-436	HRS, Lam farm, Guntur
11	LCA-620	HRS, Lam farm, Guntur
12	LCA-625	HRS, Lam farm, Guntur
13	LCA-960	HRS, Lam farm, Guntur
14	APARNA	HRS, Lam farm, Guntur
15	VAJRA	Local market, Guntur
16	RABBI	Local market, Guntur
17	SUPER 10	Local market, Guntur
18	999	Local market, Guntur
19	SURYA TEJA	Local market, Guntur
20	MYCO TEJA	Local market, Guntur

Table-2. Hypocotyl color, hypocotyl pubescence, cotyledon leaf color and cotyledon leaf shape in Chilli cultivars

Cultivars	Hypocotyl color	Hypocotyl Pubescence	Cotyledon leaf color	Cotyledon leaf shape
G-3	Light purple	Intermediate	Green	Lanceolate
G-4	Dark purple	Dense	Green	Lanceolate
G-5	Medium purple	Dence	Green	Lanceolate
LCA-206	Dark purple	Intermediate	Green	Lanceolate
LCA-235	Light purple	Intermediate	Green	Lanceolate
LCA-305	Medium purple	Intermediate	Green	Lanceolate
LCA-353	Light purple	Dence	Green	Lanceolate
LCA-334	Medium purple	Dence	Green	Lanceolate
LCA-424	Light purple	Intermediate	Green	Lanceolate
LCA-436	Medium purple	Intermidiate	Green	Lanceolate
LCA-620	Medium purple	Intermediate	Green	Lanceolate
LCA-625	Light purple	Intermidiate	Green	Lanceolate
CA-960	Dark purple	Intermediate	Green	Lanceolate
APARNA	Medium purple	Dense	Green	Lanceolate
VAJRA	Light purple	Intermidiate	Green	Lanceolate
RABBI	Medium purple	intermediate	Green	Lanceolate
SUPER 10	Light purple	Intermidiate	Green	Lanceolate
999	Medium purple	Dense	Green	Lanceolate

Figure 1. Hypocotyl color of chilli cultivars

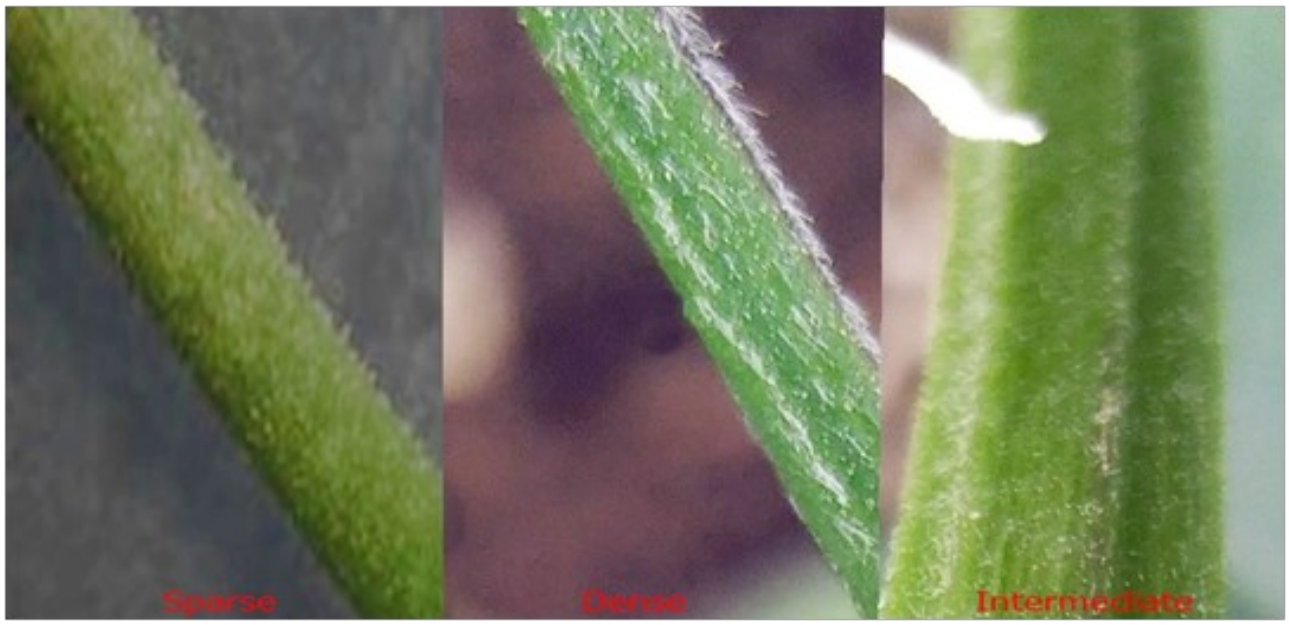

Figure 2. Hypocotyl pubescence of chilli cultivars

Figure 3. Cotyledon leaf color of chilli cultivars

Table 3. Cotyledon leaf length, cotyledon leaf width and stem length to first bifurcation in Chilli cultivars

Genotypes	Cotyledon leaf length (mm)	Cotyledon leaf width (mm)	Stem length to first bifurcation (cm)
G-3	16.66	4.33	26.23
G-4	16.33	3.64	23.73
G-5	16.00	3.33	22.50
LCA-206	15.56	3.33	23.50
LCA-235	15.66	4.00	11.00
LCA-305	16.00	3.66	23.37
LCA-353	17.00	4.00	22.50
LCA-334	16.00	4.00	18.13
LCA-424	17.00	4.00	10.80
LCA-436	16.00	4.00	10.80
LCA-620	15.66	4.33	26.33
LCA-625	15.66	4.00	19.66
LCA-960	17.33	5.00	23.73
APARNA	17.66	4.66	13.50
VAJRA	16.33	4.00	22.73
RABBI	16.33	4.33	19.23
SUPER 10	17.33	4.66	4.83
999	16.33	4.00	22.73
SURYA TEJA	16.33	3.64	23.73
MYCO TEJA	17.00	4.00	28.42

Table 4. Stem color, stem shape and stem pubescence in Chilli cultivars.

Genotypes	Stem color	Stem shape	Stem Pubescence
G-3	Green with purple stripes	Angular	Dense
G-4	Green with purple stripes	Angular	Dense
G-5	Green with purple stripes	Angular	Dense
LCA-206	Green with purple stripes	Angular	Intermediate
LCA-235	Green with purple stripes	Angular	Intermediate
LCA-305	Green with purple stripes	Angular	Sparse
LCA-353	Green with purple stripes	Angular	Dense
LCA-334	Green with purple stripes	Angular	Intermediate
LCA-424	Green with purple stripes	Angular	Sparse
LCA-436	Green with purple stripes	Angular	Sparse
LCA-620	Green with purple stripes	Angular	Dense
LCA-625	Green with purple stripes	Angular	Dense
CA-960	Green with purple stripes	Angular	Intermediate
APARNA	Green with purple stripes	Angular	Sparse
VAJRA	Green with purple stripes	Angular	Sparse
RABBI	Green with purple stripes	Angular	Sparse
SUPER 10	Green with purple stripes	Angular	Intermediate
999	Green with purple stripes	Angular	Dense
SURYA TEJA	Green with purple stripes	Angular	Dense
MYCO TEJA	Green with purple stripes	Angular	Intermediate

Table 5. Variation in morphological features of chilli *(Capsicum annuum* L.)

Genotypes	Fruit position	Fruits per axil	Mature green fruit color
G-3	pendent	solitary	green
G-4	pendent	solitary	green
G-5	pendent	solitary	green
LCA-206	pendent	solitary	green
LCA-235	pendent	solitary	green
LCA-305	pendent	solitary	dark green
LCA-353	pendent	solitary	dark green
LCA-334	pendent	solitary	parrot green
LCA-424	pendent	solitary	dark green
LCA-436	pendent	solitary	dark green
LCA-620	pendent	solitary	dark green
LCA-625	pendent	solitary	parrot green
LCA-960	pendent	solitary	drk green
APARNA	pendent	solitary	green
VAJRA	pendent	cluster	green
RABBI	pendent	cluster	green
SUPER 10	pendent	solitary	green
999	pendent	solitary	parrot green
SURYA TEJA	pendent	solitary	green
MYCO TEJA	errect	cluster	dark green

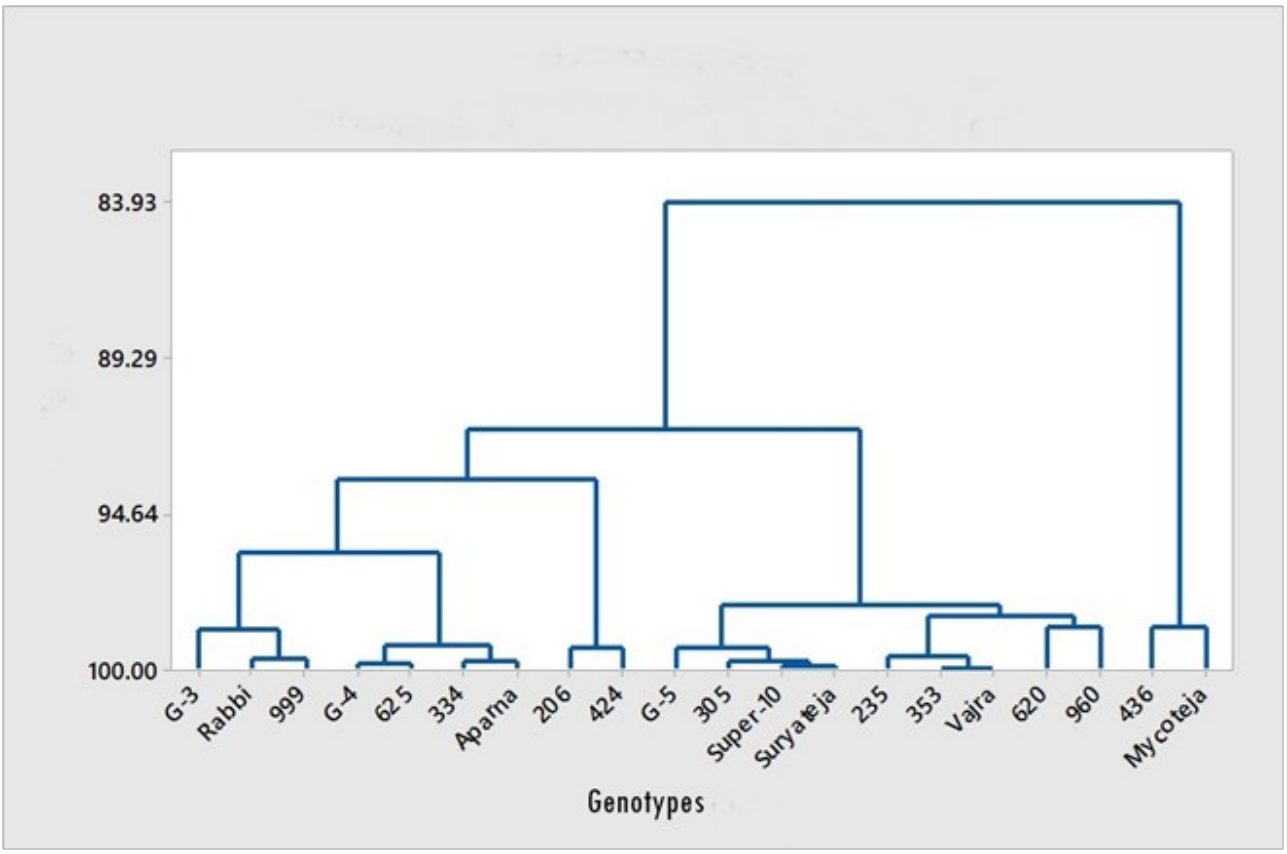

Figure 4. Dendrogram showing mean performance of various quantitative characters in chilli (*Capsicum annuum* L.) genotypes

Table 6. Mean performance of various quantitative characters in chilli (*Capsicum annuum* L.) genotypes, Bold values indicate maximum and minimum mean performance.

Genotype	Plant Height (cm)(PH)	Number of Primary Branches per Plant (NPBP)	Days to 50 per cent Flowering (DFF)	Fruit Set Per cent (FSP)	Number of Fruits per Plant (NFP)	Fruit Diameter (cm) (FD)	Fruit Length (cm) (FL)	Average Dry Fruit Weight (g), (ADFW)	Number of Seeds per Fruit, (NSF)	Yield perPlant(g), (YP)
G-3	87.30	2.75	32.00	**18.00**	116.70	1.33	7.62	0.88	58.60	97.55
G-4	114.60	2.80	31.40	46.50	227.00	1.15	7.80	0.85	61.50	195.81
G-5	63.87	2.90	34.60	31.00	136.40	1.99	4.42	1.49	69.18	144.91
LCA-206	70.40	4.90	31.00	57.00	184.00	1.22	9.92	0.72	59.00	148.22
LCA-235	66.80	3.80	38.00	32.00	185.60	0.82	8.60	0.89	52.50	100.39
LCA-305	**48.90**	2.95	36.00	48.00	159.80	1.32	7.80	1.09	48.50	131.81
LCA-315	80.40	2.90	30.50	55.00	140.80	1.52	9.25	1.21	57.50	153.46
LCA-353	88.55	3.95	29.60	76.00	279.60	1.00	9.55	0.90	51.00	168.82
LCA-334	85.50	3.20	29.20	64.00	195.80	1.22	12.90	0.96	66.90	201.80
LCA-424	82.50	3.90	32.00	44.00	269.50	1.60	9.88	0.91	50.88	164.50
LCA-436	65.20	3.30	33.00	78.00	145.70	1.42	8.47	1.49	59.50	162.88
LCA-620	83.55	4.20	31.50	58.00	288.00	1.49	9.60	1.10	88.90	251.90
LCA-625	95.60	3.50	30.00	80.00	345.40	2.0	8.70	1.53	78.40	**305.50**
LCA-960	74.90	2.90	25.55	35.00	88.80	1.99	8.82	1.52	80.40	96.30
LCA-334	93.80	3.55	28.00	67.00	210.00	0.99	8.44	0.91	72.00	178.25
APARNA	96.70	3.50	36.00	38.00	129.20	1.49	8.52	0.96	59.50	109.60
VAJRA	92.50	3.60	31.55	59.00	133.40	1.41	10.53	1.19	60.00	149.60
RABBI	105.31	3.10	25.60	45.00	**389.50**	1.28	5.99	0.72	96.50	210.88
SUPER 10	112.50	3.80	29.80	29.00	77.50	1.52	8.61	1.46	55.80	**85.99**
999	86.50	**3.70**	29.00	52.00	78.50	2.55	7.40	1.65	75.80	125.43
SURYA TEJA	75.88	2.91	35.00	58.00	201.40	1.60	**6.78**	0.75	48.80	108.75
MYCO TEJA	81.50	3.50	31.00	48.00	179.60	1.45	8.55	0.73	45.90	102.8
Mean	**88.18**	**3.60**	**31.40**	**51.40**	**179.55**	**1.32**	**9.50**	**1.10**	**72.88**	**159.51**
C.V.	6.55	15.00	8.39	11.50	18.66	4.00	6.70	18.40	12.70	17.90
F ratio	13.90	5.20	5.50	11.40	16.20	27.88	29.42	12.22	6.87	6.60
S.D.	0.44	0.29	1.94	0.33	12.88	0.05	0.45	0.10	5.55	18.80
C.D. 5%	12.11	0.91	2.99	13.85	62.60	0.01	0.95	0.39	11.77	55.64

Table 7. performance of various quantitative characters in chilli (*Capsicum annuum* L.) genotypes

Genotypes	Days to 50 per cent flowering	Days to first fruit maturity	Plant height (cm)	Fruits/ Plant	Fruit length (cm)	Fruit width (cm)	100 seed weight (g)	Green fruit yield plant^{-1} (g)	Red fruit yield Plant^{-1} (g)
G-3.	80	121.5	92.5	128.52	12.75	1.5	0.374	217.13	196.63
G-4	86	129	105.5	73.29	11.75	1.1	0.776	153.02	222
G-5	81.5	130.5	90	54.56	9.25	1.2	0.533	187.63	128.32
L.C.A-206	79	121	81	96.56	10.75	1.1	0.558	301.29	272.77
L.C.A-235	83	124	83	74.09	8.75	1.4	0.706	172.53	163.13
L.C.A-305	81	118	85.5	75.07	9	1.1	0.546	165.13	113.46
L.C.A-334	79.5	132.5	73.5	81.25	7.75	0.9	0.942	161.27	253.46
L.C.A-353	84.5	129	86.5	57.12	10	1.3	0.754	190.55	169.88
L.C.A-424	78.5	133.5	64	44.9	8.25	1.3	0.64	317.62	307.13
L.C.A-436	80.5	122.5	61	74.09	7.15	1.3	0.459	245.13	131.79
L.C.A-620	83.5	128.5	91	30.48	6.75	0.95	0.58	166.25	138.29
L.C.A-625	82	130	97.5	71.55	9.75	1	0.615	170.79	234.46
L.C.A-960	81.5	133.5	79.5	64.83	8	1.1	0.624	139.53	142.63
APARNA	86	118.5	72.5	75.07	8.25	1.3	0.64	162.61	253.46
VAJRA	84.5	119.5	90	51.94	8.25	1.1	0.56	187.63	128.32
RABBI	82	119	103	101.24	11.75	1.1	0.776	153.02	222
SUPER-10	83.5	118	107	80.63	10	1.3	0.754	190.55	169.88
999	86	120.5	105.5	98.25	10.5	1.1	0.721	178.38	68.96
SURYA TEJA	81	119	96.5	74.26	9.25	1.2	0.533	187.63	128.32
MYCO TEJA	80.5	121	88	77.58	11	1.1	0.384	391.63	147.63
Mean	82.2	124.45	87.65	74.26	9.44	1.1	0.623	201.96	179.62
std	2.33621	5.658	13.191	21.646	1.6226	0.151	0.14108	64.524	62.44
cv	0.028	0.045	0.150	0.291	0.171	0.129	0.226	0.319	0.347

Based on plant height, the cultivars were characterized into four groups, are short, medium, tall and very tall plants. Of the five cultivars which belonged to medium plant height (LCA-206), two cultivars *viz.*, Super-10 and Suryateja were categorized as short plants which was grouped into tall plants. Such difference in plant height was also noticed in chilli (Adetula and Olakojo, 2006; Manju and Sreelathakumary 2002; Bozokalfa and Turhan 2009; Kashinath 2003). Hence, both plant height and plant spread characters may not be suitable for clear cut characterization, however they can be used to distinguish cultivars that belong to either end of the scale.

Based on qualitative fruit characters like fruit color at intermediate stage and at mature stage, neck at the base of fruit, fruit shape at the pedicel and blossom end, fruit cross sectional corrugation, fruit surface and ripe fruit persistence, it was possible to make distinction between the varieties to a larger magnitude. But, the keys developed using these qualitative fruit characters was found to be grossly inadequate to distinguish many varieties from each other and they were found to be grouped under a single category. However, use of some prominent quantitative characters like fruit length and width to supplement these qualitative characters would certainly aid in further resolution of varieties from each other as these are very apparent in the field and the difference between the varieties for these two characters is also very large among the varieties. Henceforth, supplementing qualitative with some very apparent quantitative characters would serve better to develop more efficient keys for identification of dissimilar varieties.

CONCLUSION

From the results, it was concluded that all the 20 genotypes deliberated are significantly different from one another showing that there is quantifiable variability among the genotypes of (*Capsicum annuum* L.) considered. Cultivars with superior seed size had sophisticated values for germination, seedling length, seedling dry weight and seedling potency than that of cultivars with lesser seeds. Hence, these characters which seem to mimic the characters of seed size, weight might be of some use for broad grouping of the cultivars. Midst seedling morphological traits, hypocotyl color, pubescence, between stem characters and stem color were found to be useful for identification of cultivar.

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