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Morphological Heterogeneity of Wild Mango (*Mangifera indica* L.) Varieties of Hanavadi Village, Karnataka, India

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A B S T R A C T

Mango, a member of Anacardiaceae family is an important commercial fruit consumed all over India. There are about 1000 varieties of mangoes cultivated in India. However, morphological characterization and authentication of wild varieties is far done. In the present study eighteen mango varieties has been chosen from Hanavadi village, Karnataka and eighty-two parameters were employed to study the morphology. Morphology of tree, bark, leaf, inflorescence, flower, fruits and seeds were done. The results were subjected to SPSS software for statistical analysis. And the results showed wide variations among the varieties with respect to the parameters employed. Significant variations were seen in varieties namely Cnd, Nar and Ars. This study throws a light for the use of morphological parameters for differentiation of varieties and this can be useful for future germplasm conservation and mango breeding programs where selected morphological parameters are required.

***Key words*:** Germplasm, Inflorescence, *Mangifera indica* L, Morphology, Varieties, Wild tree

Mango (*Mangifera indica* L) is a tropical and subtropical fruit. It is commonly referred to as the "King of Fruits" due to its delicacy and aroma. India leads the globe in mango output, accounting for 40.4 percent of global production (Horticulture statistics, 2018). UAE, UK, Oman, Qatar, and the United States are major importers of Indian mangoes. Uttar Pradesh, Andhra Pradesh, Bihar, Gujarat, Haryana, Himachal Pradesh, Karnataka, and Madhya Pradesh are the top mango producers in India (APEDA, 2018). In Karnataka major mango growing districts include, Kolar, Ramanagara, Dharwad, Chikkaballapura and Mandya. Fruits are consumed both ripe and unripe, and is used in the preparation of various culinary. Different types of pickles are prepared from unripe mangoes. The fruits are used to prepare shakes, juices, salad, deserts, yoghurt, smoothie and jams. Apart from this, the plant is also loaded with high medicinal properties and is used as anti-diabetic, anti-inflammatory, anti-hemorrhagic, anti-allergic and anti-pyretic [1].

According to National Horticulture Board (2018), there are about 1000 varieties of mangoes cultivated in India. However, there are lot more varieties in the wild, untouched by the human intervention. The hybrid varieties conceal wild varieties by their large size and shape. The wild variants have gone ignored when size is used as a criterion. India is one of the countries where the mango originated; there is a significant chance that a large number of wild mango varieties would be present. These varieties may be added to the existing gene pool and India may become much diversified in its mango germplasm collection, when conserved. Since these are grown in the wild, they may possess some additional nutrients that can be consumed and added to our diet. One of the most significant parameters for identifying a variety is its morphology. Morphology is the foundation for later research like genetics, molecular biology, ecology, and evolution, and it is the first and foremost important stage in studying a variety [2].

Cultivation of different varieties of mango in Karnataka can be traced from Tippu Sultan's reign especially from Mandya, Mysore region. The varieties are still survived by the efforts of some local farmers who are keen in preserving the wild varieties for the future generations. There are few patch of land with wild mango varieties in Mandya district, one such is that of Hanavadi village. The source of origin of the varieties is unknown. There is a need to study and conserve these wild varieties from becoming extinct. With this background, eighteen native wild mango varieties growing in the village of Hanavadi, Malavalli taluk, Mandya district, Karnataka state, India were selected for this study.

MATERIALS AND METHODS

Collection of samples

Eighteen wild varieties of mangoes viz. Menasu mavina mara (Mns), Arasu mavina mara (Ars), Gini mavina mara (Gin), Sihi mara (Sih), Sappe mara (Spp), Kenjagada mara (Knj),

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Emme joddina mara (Emj), Onti mavina mara (Ont), Obattiunda mara (Obt), Uppinkai mara (Upp), Nara mavina mara (Nar), Raspuri (Rsp), Gund mavina mara (Gnd,variety A), Chukki mara (Chk, variety B), Bhoodh mavina mara (Bhd, variety C), Thogate mara (Tkt, variety D), Holapu mavina mara (Hlp, variety E) and Chand mavina mara (Cnd,variety F) from Hanavadi village, located at 12° 16' North latitude to 77° 01' East longitude, Malavalli Taluk, Mandya district were considered for studying the morphological characters. Samples were brought in a gunny bag. Leaves were washed with tap water and swabbed in a tissue paper. Eighty-two parameters were employed to study the morphological characters given by [3-6].

Measurement of variables
Characterization of morphological features

i. Tree and bark

Tree height and stem girth were measured using Haga altimeter. Bark morphology was done by considering a specific area on the tree. Three quadrants at different heights from each variety were chosen for the analysis. Ten morphological parameters – number of lenticels, number of bark bits, maximum length of lenticels, minimum length of lenticels, maximum width of lenticels, minimum width of lenticels, maximum length of bark bits, minimum length of bark bits, maximum width of bark bits and minimum width of bark bits, were employed to characterize it.

ii. Leaves

The forms of leaves were visually examined. Seven parameters viz., leaf length, breadth, petiole length, leaf laminar width on left and right side of the mid-rib, number of veins on either sides of the mid-rib, were calculated to characterize the varieties using leaves. Ten matured leaves from each variety were gathered. Length and breadth of the leaf, petiole length were measured using scale. Leaf lengths more than 30 cm were analyzed using thread.

iii. Inflorescence

Twenty four parameters were used to categorize inflorescence viz., length of the main axis, number of branches on it, length of the longest branch and number of branches on it, number of branches on its 3° branch, number of branches on its 4° branch, number of flowers on 4° branch, number of flowers on 3° branch and number of flowers on the longest branch; length of middle branch, number of branches on it, number of branches on its 3° branch, number of branches on its 4° branch, number of flowers on the 4° branch, number of flowers on the 3° branch and number of flowers on the middle branch; Length of the shortest branch, number of branches on it, number of branches on its 3° branch, number of branches on its 4° branch, number of flowers on the 4° branch, number of flowers on the 3° branch and number of flowers on the shortest branch. Two inflorescences from each variety were plucked randomly and studied. Length of the inflorescence was measured using thread; colour was examined visually.

iv. Flowers

Eight parameters were employed to study flowers-length and breadth of sepals and petals, length of the pedicel, length of the anther filament (staminate and bisexual flowers) and length of the style. Ten staminate and ten bisexual flowers were collected from each variety. Length and breadth of the sepals and petals were done using scale. Colour of the petals and sepals were visually examined.

v. Fruits and seeds

Eight quantitative traits namely fruit weight, length, breadth and thickness, seed weight, length, breadth and thickness and eighteen qualitative parameters namely fruit shape, fruit apex shape, attractiveness, fruit skin surface texture, depth of fruit stalk cavity, fruit stalk attachment, slope of fruit ventral shoulder, beak type, sinus type, fruit skin waxyness, ripe fruit skin colour, pulp colour of ripe fruit, pulp texture of ripe fruit, adherence of fruit skin to pulp, pulp juiciness, pulp aroma, seed shape, veins and fibres on the seeds were used to categorize fruits and seeds. Ten fruits and ten seeds were collected from each variety. Length, breadth and thickness of the fruits and seeds were measured using Vernier callipers.

Statistical analysis

The results of the investigation were subjected to statistical analysis of SPSS version 21 software to find the features that best explained mango morphologically. Colour of the leaves, inflorescence, flowers and fruits were examined visually.

RESULTS AND DISCUSSION

Tree and bark

Tree height varied from 8 to 14 mts and girth from 1.05 to 4 mts (Table 1). Among the eighteen varieties, Mns, Knj and Tkt were the shortest trees (8.5 m) while Sih (14.5 m) was the tallest. Tkt (1.05 m) exhibited small stem girth while Ars (4 m) revealed a larger stem girth. Each variety was characterized by specific type of bark (Fig 1-2, Table 2). It has come to know that there is compelling variations in the bark texture among the eighteen varieties. In the company of the parameters employed to study the morphology, number of lenticels, number of bark bits, maximum width of lenticels, minimum length of lenticels and maximum length of bark bits showed significant variations among them. While maximum length of lenticels, minimum width of lenticels, maximum width of bark bits, minimum length and width of bark bits have shown little variations among them.

Table 1 Tree morphology of eighteen mango varieties of Hanavadi Village, Karnataka

Varieties	Height*	Girth*
Arasu mavina mara (Ars)	12.5	4
Emme joddina mara (Emj)	9.5	2.25
Gini mavina mara (Gin)	12.5	2.5
Kenjagada mara (Knj)	8.5	1.5
Menasu mavina mara (Mns)	8.5	2.4
Nara mavina mara (Nar)	11.5	3.55
Obattiunda mara (Obt)	11.5	2.35
Onti mavina mara (Ont)	10.5	1.25
Raspuri (Rsp)	8.5	1.45
Sihi mara (Sih)	14.5	3.15
Sappe mara (Spp)	10.5	2.5
Uppinkai mara (Upp)	11.5	2.6
Gund mavina mara (Gnd, variety A)	12.5	2.05
Chukki mara (Chk, variety B)	11.5	2.05
Bhoodh mavina mara (Bhd, variety C)	11.5	3.25
Thogate mara (Tkt, variety D)	8.5	1.05
Holapu mavina mara (Hlp, variety E)	9.55	1.9
Chand mavina mara (Cnd, variety F)	9.5	1.9

*(in meter)

Number of lenticels ranged from 7.33 to 18.67. Chk (7.333 cm) showed the presence of lower number of lenticels, but Tkt (18.666 cm) displayed a good number of lenticels.

Number of bark bits ranged from 7 to 19.333 and again Chk (7.00) revealed smaller number of barkbits and Rsp (19.333) with a substantial number of barkbits. Maximum width of lenticels ranged from 1.33 cm to 5.86 cm and it was observed that Gnd (1.333 cm) exhibited a compact width of lenticels while Ars (5.866 cm) revealed broader lenticels. Minimum length of lenticels varied from 0.466 (Emj) to 3.833 cm (Chk). Minimum width of lenticels varied from 0.133 (Spp) to 1.133 (Ars) cm. Maximum length of bark bit ranged from 6.93 to 15 cm. Tkt displayed tiny bark bits while Bhd, Hlp, Ont and Gin showed longer bark bits. Maximum width of bark bit varied from 2.566 to 5.533 cm, Gnd exhibited smaller barkbits while Spp displayed a wider bark bits. Minimum width of bark bit ranged from 0.433 cm (Spp) to 1.233 cm (Bhd).

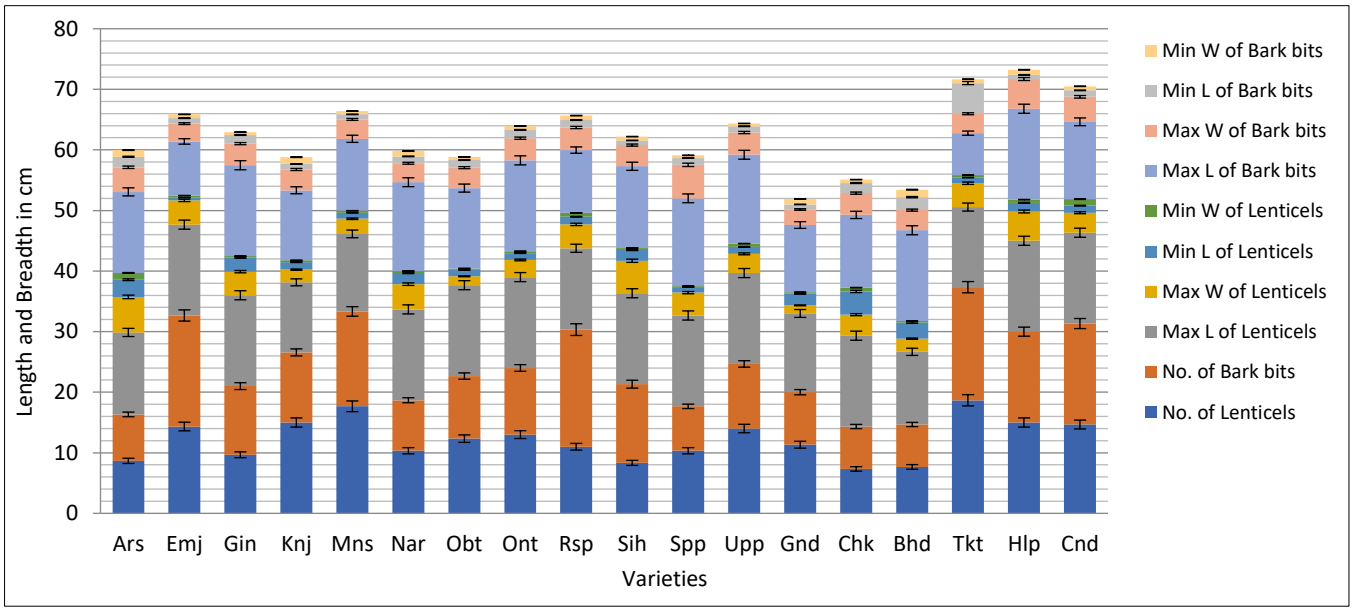

Fig 1 Bark morphology of eighteen mango varieties of Hanavadi village, Karnataka (Error bars represent standard deviation

Table 2 Bark texture of eighteen mango varieties of Hanavadi Village, Karnataka

Varieties	Bark type
Arasu mavina mara (Ars)	Warty
Emme joddina mara (Emj)	Scaly
Gini mavina mara (Gin)	Furrowed
Kenjagada mara (Knj)	Furrowed
Menasu mavina mara (Mns)	Warty
Nara mavina mara (Nar)	Scaly
Obattiunda mara (Obt)	Fissured
Onti mavina mara (Ont)	Rough
Raspuri (Rsp)	Rough
Sihi mara (Sih)	Warty
Sappe mara (Spp)	Furrowed
Uppinkai mara (Upp)	Furrowed
Gund mavina mara (Gnd, variety A)	Warty
Chukki mara (Chk, variety B)	Fissured
Bhoodh mavina mara (Bhd, variety C)	Fissured
Thogate mara (Tkt, variety D)	Scaly
Holapu mavina mara (Hlp, variety E)	Fissured
Chand mavina mara (Cnd, variety F)	Rough

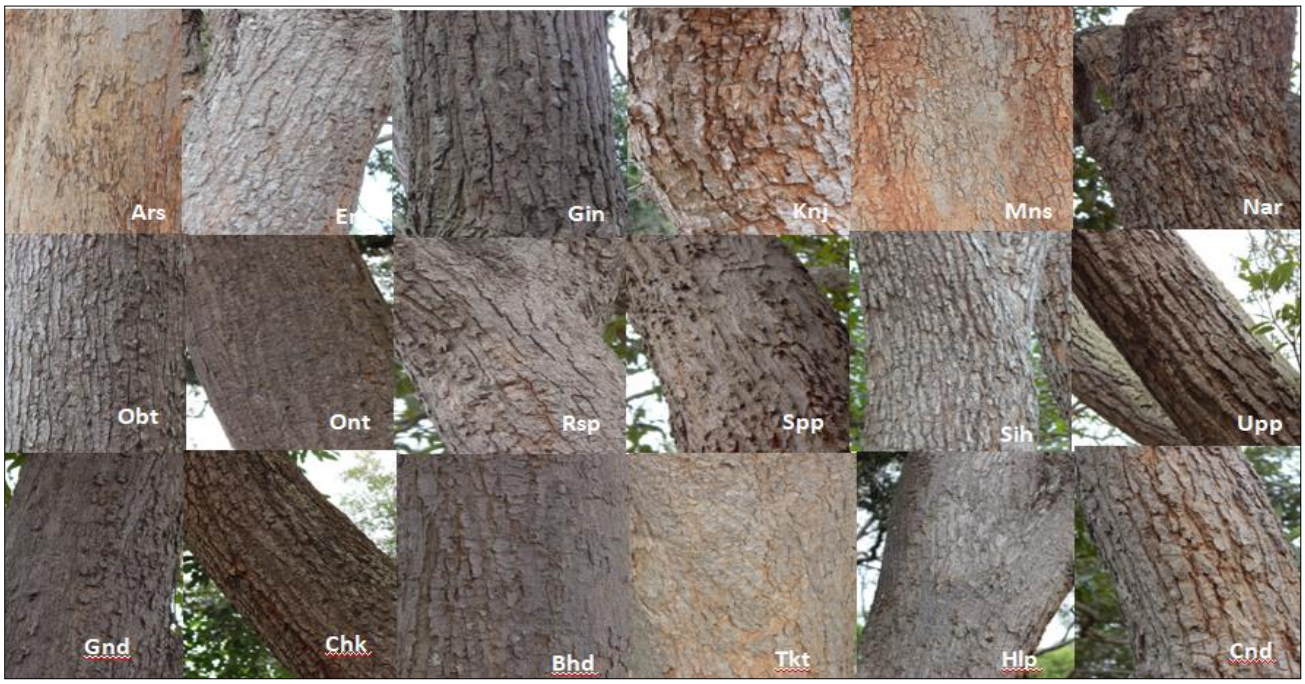

Fig 2 Bark texture of eighteen mango varieties of Hanavadi village, Karnataka

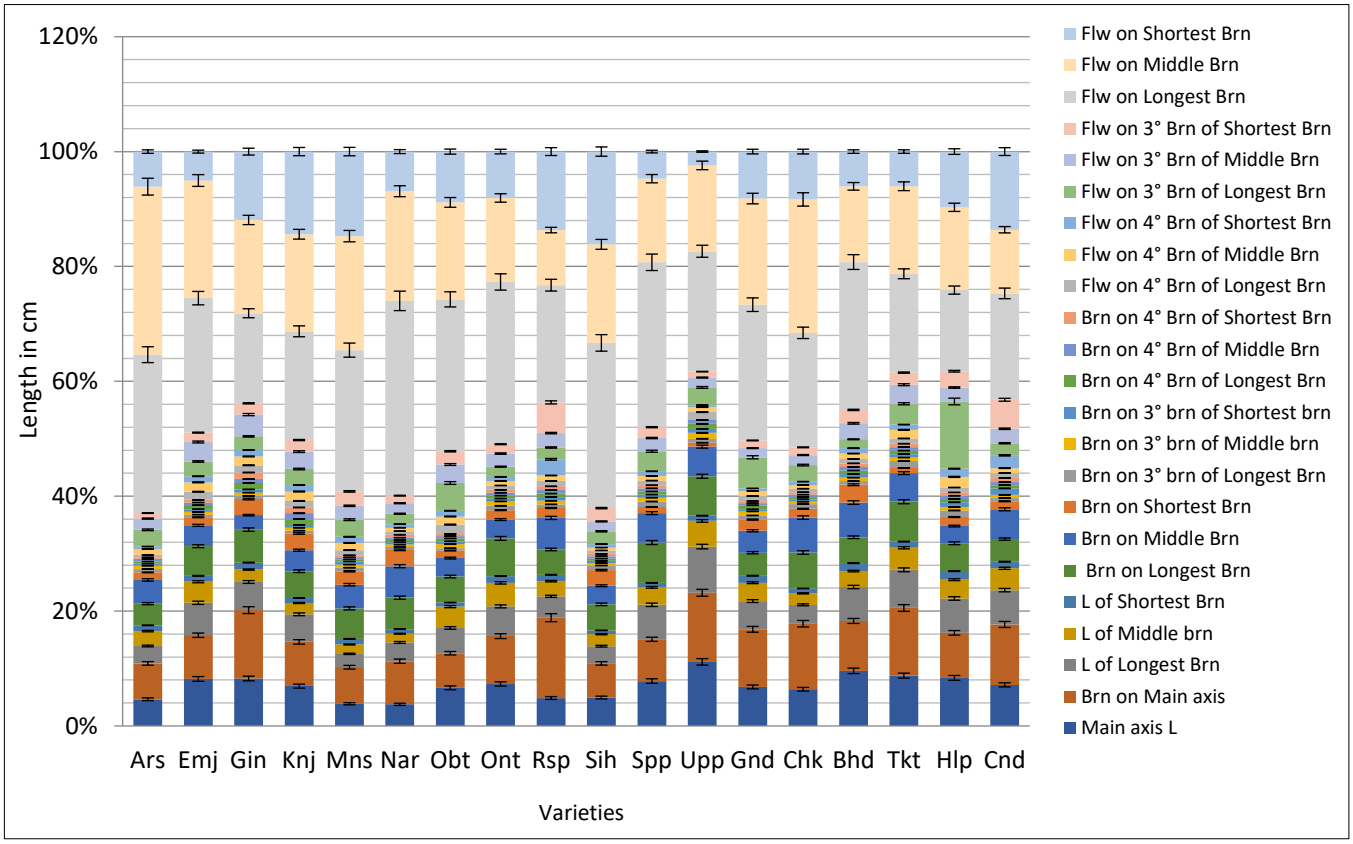

Fig 3 Inflorescence morphology of eighteen mango varieties of Hanavadi village. Karnataka (Error bars represent standard deviation)

Inflorescence

There is considerable variation in the morphology of inflorescence within the varieties collected from the same locality (Fig 3). The colour of the inflorescence branches ranged from light green to greenish pink and pink colour. Among the 18 varieties, eleven of them (Ont, Mns, Gin, Sih, Emj, Upp, Obt, Chk, Bhd and Tkt) showed green coloured branches while varieties Spp, Nar and Hlp showed greenish pink and varieties Knj, Ars, Rsp and Gnd showed pink-coloured branches. Main axis length ranged from 15.5 to 38.2 cm and branches on it from 27 to 56.5. Rsp and Spp revealed stubby and minor branches, while Gnd exhibited a lengthy and a substantial number of branches on it. Rsp (11.85), Nar (7.5) and Upp (2.65) revealed a shorter length of longest, middle and shortest branches while Gnd displayed a lengthy longest branch (27.65) and the shortest branch (6.9); Obt (18.45) showed a longer middle branch. Rsp (14) Gin (9) and Upp (2) exhibited a faint number of branches on longest, middle and shortest branch but a notable number of branches on longest (30.5) and middle branch (29.5) were reported from Chk and on shortest branch by Nar (14.00). An array of varieties viz., Emj, Knj, Gin, Rsp, Upp, Bhd and Cnd have shown a sparse number of 3° branch on longest and middle branch (2 each) and Spp (5) and Gnd (4) displayed a moderate number of branches on them.

Another batch of varieties viz., Mns, Obt, Ont, Rsp, Sih, Spp, Chk, Bhd, Tkt, Hlp and Cnd displayed sparse number of branches on 4° branch of longest, middle and shortest branch (2 each). While Gin, Gnd and Knj on longest branch, Knj on middle branch and Gin and Knj on shortest branch (4 each) displayed a fine number of branches on 4° branch. Upp variety revealed a small number of flowers on 4° branch of middle (2.5) and shortest (1) branch and Bhd (2) on longest branch. A good number of flowers were reported from Obt (8) on longest, Ars, Emj, Mns and Obt (7) on middle and Rsp (9) on shortest branch. Again, Upp exhibited a faint number of flowers on 3° branch of middle (5) and shortest branch (3) and Bhd on longest branch (5). Gnd on longest (30.5), Obt (16) on middle and Cnd (18) on shortest branch revealed a considerable number of flowers on 3° branches. Ars has exhibited a very good number of flowers on middle (201.5) and longest branch (190) and Mns has showed fine number of flowers on shortest branch.

Flowers

Like inflorescence, flowers also varied among the varieties (Fig 4-5). It is observed that there are compelling differences among the varieties. Sepal colour remained the same (green) but petal colour varied from cream to creamish pink and pink colour. Except petal length, rest all parameters for flowers have shown significant variations among them. Bisexual flowers were larger in size in terms of pedicel, sepal, petal and anther filament lengths. Varieties Hlp (1.75 mm) and Mns (2mm) exhibited tiny pedicel length on staminate and hermaphrodite flowers respectively while Bhd revealed longer pedicel (4.3mm and 4.55mm) on both the kinds of flowers. Stubby sepal length was reported from Obt (1.49 mm) on staminate flower and Nar (1.8 mm) on hermaphrodite flowers but Spp showed longer sepals (2.86 and 3.28) on both the flowers.

Obt showed compact sepal width on both the kinds of flowers (0.83mm and 0.86mm) but Tkt and Cnd (1.35 and 1.5mm) exhibited longer sepal length on both staminate (2.86mm) and hermaphrodite (3.28mm) flowers. Smaller petals were reported from Ont (2.65mm) and Gnd (2.9 mm) while longer petals were exhibited by Cnd (3.65mm) and Spp (4.02mm) on staminate and hermaphrodite flowers respectively. Gin (1.4mm) and Ont (3 mm) produced larger sepal width on staminate and hermaphrodite flowers. A squat anther filament was reported from Tkt (1.45mm) and Chk (1.6mm) while Sih (2.2) and Spp (2.25) revealed longer filaments on staminate and hermaphrodite flowers respectively. Style length was very tiny in Ars (0.91mm) but slightly longer in Chk (1.45mm).

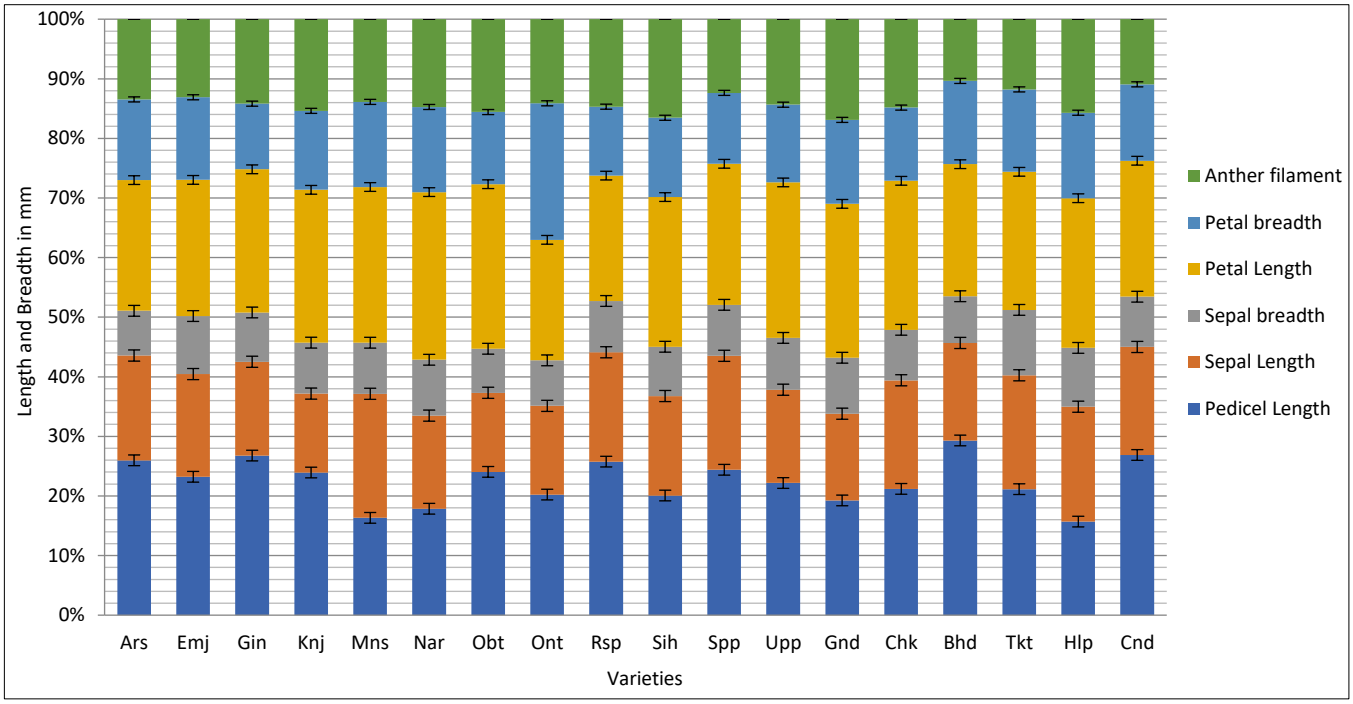

Fig 4 Flower morphology (male) of eighteen mango varieties of Hanavadi village, Karnataka (Error bars represent standard deviation)

Fruit and seeds

The main morphological characters that characterize a mango variety, is the fruit form, size, colour, beak type and slope on ventral shoulder, which have revealed a significant variation among the varieties (Fig 6-7). Fruit shape varied from oval to oblong, round and ellipsoid. Fruit skin colour ranged from green, yellow, orange and red; and pulp colour from orange to yellow, and yellowish orange (Fig 8-9). Pointed beak was more prevalent among the varieties, however prominent and perceptible beak types were also observed in Gin and Knj; Sih, Nar, Mns and Cnd respectively. From the study it has come to know that there are significant variations among the chosen varieties. Eight qualitative characters of fruits has revealed that among the eighteen varieties, Rsp was the sizeable, soaring fruit with longer length (7.74cm) width (6.09cm,) thickness (5.64cm) and massive weight (128.85gm) while Obt (4.93 gm), Gnd (4.15 cm) Gin (3.72 cm) and Spp (46.34 gm) exhibited smaller length, breadth, thickness and low weighted fruits. Obt revealed smaller seed length (3.40 cm) and breadth (2.58 cm) while Mns exhibited high seed weight (17.95 gm) and thickness (2.06 cm). Chk (7.16 gm) and Ont (1.62 gm) showed low weighted and thin seeds while Spp (6.09 cm) and Cnd (3.50 cm) showed longer and wider seeds.

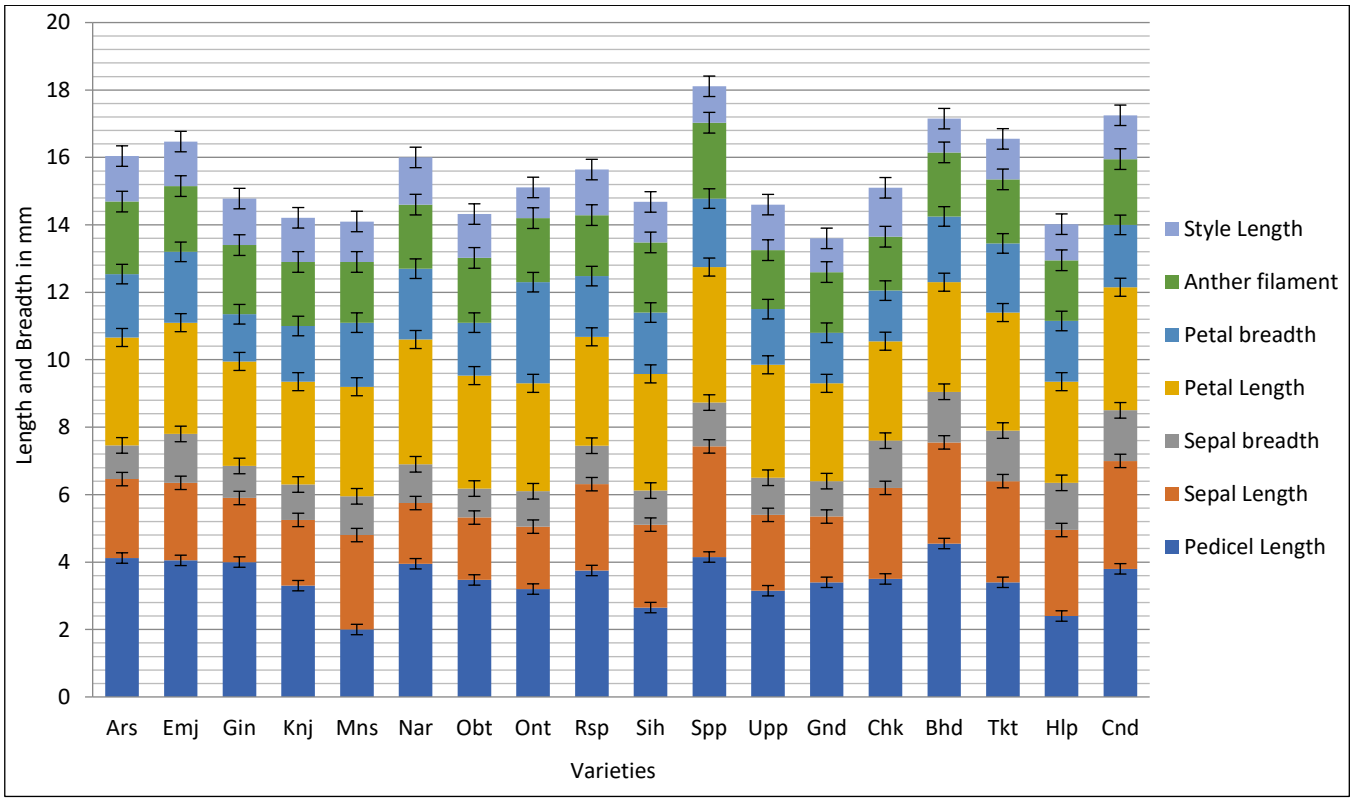

Fig 5 Flower morphology (Bisexual) of eighteen mango varieties of Hanavadi village, Karnataka (Error bars represent standard deviation)

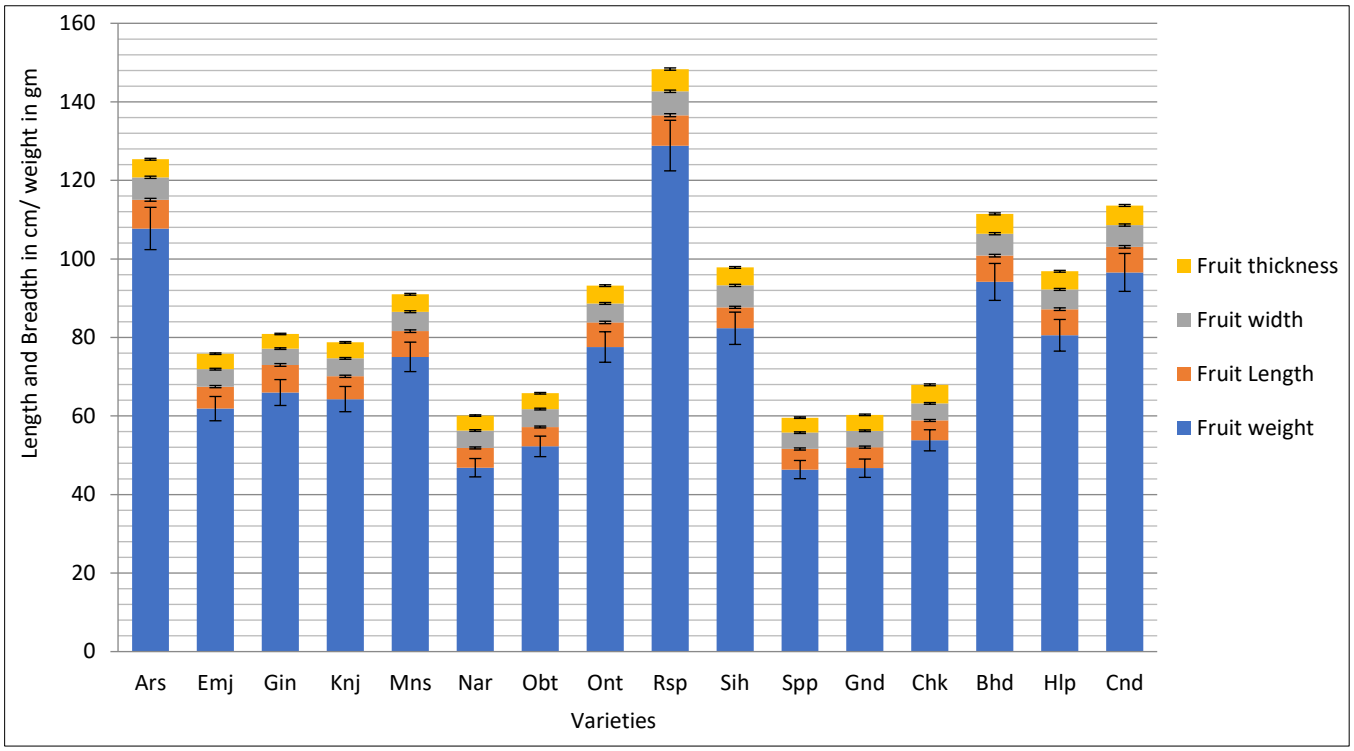

Fig 6 Fruit morphology of sixteen mango varieties of Hanavadi village, Karnataka (Error bars represent standard deviation)

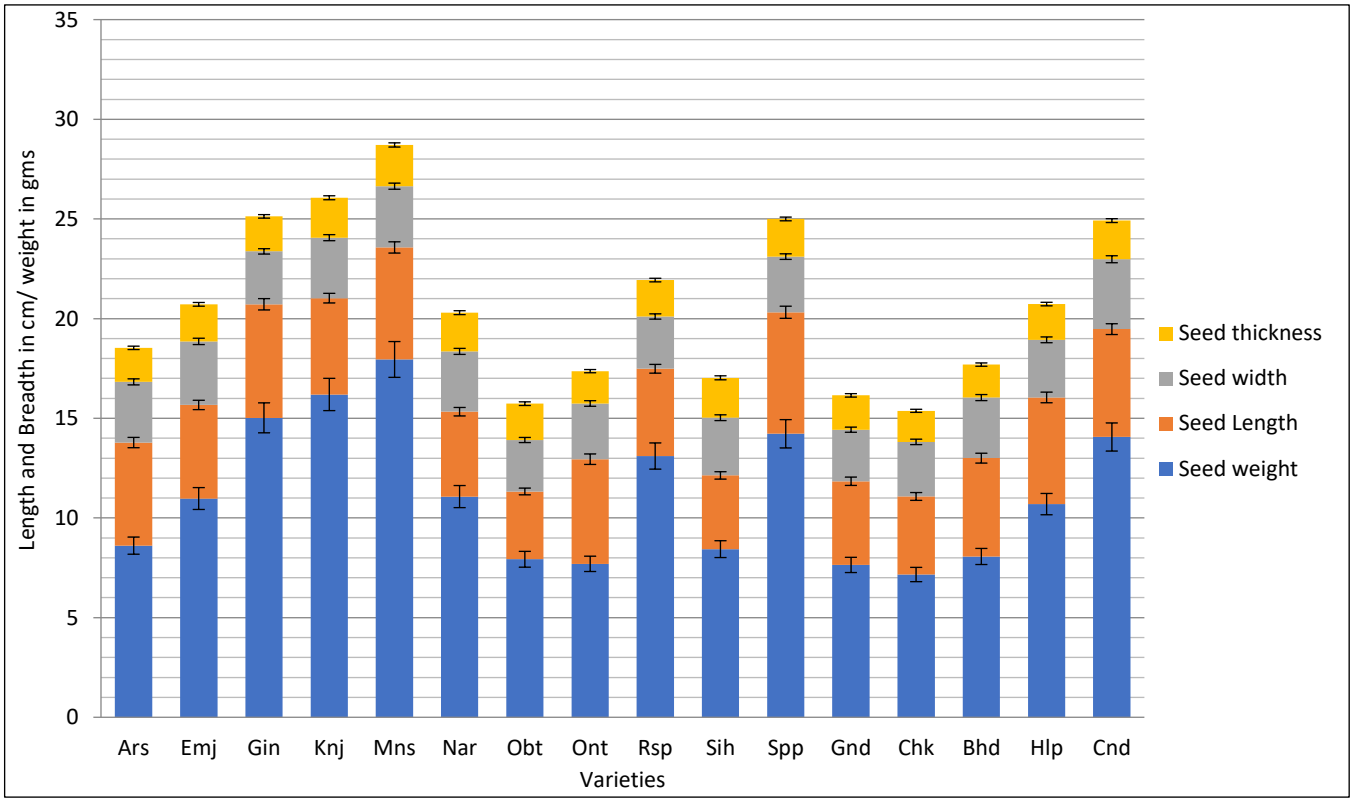

Fig 7 Seed morphology of sixteen mango varieties of Hanavadi village, Karnataka (Error bars represent standard deviation)

Hanavadi is a small village in Malavalli taluk, Mandya district. Mango orchards are common to this district because of Tippu's regime in this area. He was patron of orchards and supported the farmers to raise the mango orchards. He even granted some land and distributed seeds for their propagation (Deccan Herald, dated June 7, 2010). In the aftermath of Tippu's era, mango cultivation and propagation was not stopped thereafter but was continued by some enthusiastic farmers who were keen in preserving and propagating these varieties. One such orchard is maintained in the village Hanavadi. These are more than 100 years old, as one of the old ladies from the village says that she had been seeing these trees from her childhood. My study on some of these varieties has revealed a wide diversity among them. Morphology is the primary tool taken during the study of identification of cultivars. The parameters which have been employed have proven to distinguish the mango varieties reasonably.

Present work closely relates to that of [7] with tree height more than 10 m but few are less than 10 m. According to [7], tree height and girth of non-cultivated varieties were more than 10m in height and 92.62 inches in circumference. The tree height of grafted varieties ranged from 2 mts to 5 mts [5] while [8] suggest that the grafted varieties are tall to medium sized, upright and spreading.

Mango leaves are also a varying factor where leaf length, breadth, petiole length are few qualitative characters that differ from one another. While leaf shape, colour, margin type, tip, texture shows some similarities among the varieties. Petiole length varied between 2 to 8.25 cm [3], [5], [7], [9-10]. It was observed that the present study shows a short petiole length ranging from 1 cm to 4.55 cm and not exceeding 5 cm. This result is in close relation with that of [5] who has worked on grafted varieties. Leaf length is in close relation with that of [3] viz., 16 to 23 cm. Leaf width of the present study matches with the results of [3], [7] viz., 3 to 5.5 cm. Measuring the breadth of right and left lamina of the mid-rib, number of veins on either sides of the mid-rib has been done for the first time and it has come to know that the number of veins and laminar width on either sides of mid-rib is not the same.

Fig 8 Fruits of sixteen mango varieties of Hanavadi village, Karnataka

Lanceolate leaf shape is very commonly seen among the varieties irrespective of their origin. However oblong, ovate, oblanceolate, elliptic leaf shapes have also been reported [3], [7], [8], [11-12]. Leaves are shades of green in hue. Leaf tip is acuminate to acute [11-13] Leaf margin is entire or wavy. Coriaceous texture of the leaf in the present study is in accordance with that of [11]. The leaves had very strong aroma.

Inflorescence is diversified in their colour, length, branches and flowers. It was observed that Ont, Mns, Cnd, Gin, Sih, Emj, Upp, Obt are green in colour, Spp, Nar and Hlp are greenish pink while Knj, Rsp, Ars and Gnd are pink in colour which are closely related to [11], [14-15]. Panicle length ranged from18cm to 38cm which resembles the panicle length of [15]. Branching on the main axis, on the longest branch, middle

branch and shortest branch; counting the number of branches on it were done for the first time. This shows the degree of branching and the flower density in each type of branches.

Flowers are complete, pentamerous, hermaphrodite and staminate. Calyx and corolla are five in number anthers are also five but only one is fertile and rest sterile. Length and breadth of sepal, petal and anther filaments of hermaphrodite flowers were much larger than the staminate flowers. And anther filament length was longer than the style length. This observation indicates that the observed varieties were self-compatible and were less projected for cross pollination. There by the indigenous qualities of the fruits are retained by the plants itself. This trait can be applied for conserving the distinct characters of the fruit. The observation is contrary to that of [14]. Pedicel length of the observed data Hlp, Cnd, Mns and Bhd are in close relation with the pedicel length of *Mangifera zeylanica* and *Mangifera rubropatela*. Sepal length of Obt, Cnd, Nar and Spp resembled with *Mangifera rubrapatela* and *Mangifera lalijiwa*; sepal width of Obt, Tkt, Obt (bisexual) and Bhd resembled with *Mangifera zeylanica* and *Mangifera lalijiwa*. Petal length, breadth and anther filament length of the observed varieties were much smaller compared to the work of [16] while style length of Chk was quite closer to M. tenom.

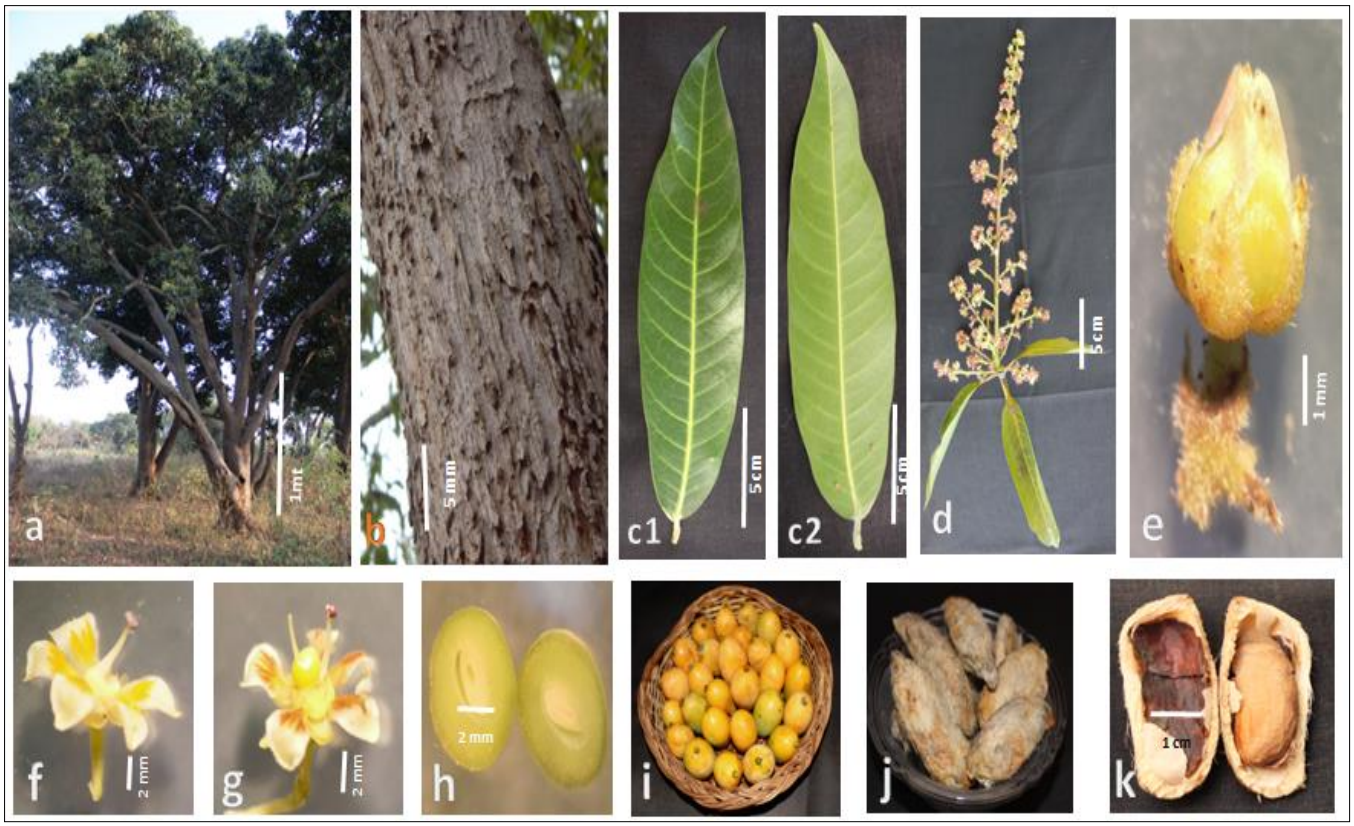

Fig 9 A view of a. Tree, b. Bark, c1. Leaf (dorsal side), c2. Leaf (ventral side), d. Inflorescence, e. Flower bud, f. Male flower, g. Bisexual flower, h. Ovary section, i. Fruits, j. Seeds and k. Embryo of Spp Mango variety of Hanavadi village, Karnataka

Fruits are the determining factor for the identification of varieties. They differ in many ways in their shape, depth of fruit stalk cavity, colour, beak type, sinus type, slope of fruit ventral shoulder, texture, pulp colour, juiciness, attractiveness, etc. The observed varieties were unique in their characters such as fruit length, breadth, thickness and aroma. Fruits of the present study were very unique in their characters such as the fruit skin colour, pulp colour, fibre contents, sweetness, and sourness of fruits. Fruit skin colour of Sih and Obt turns to very light yellow colour when it is ripened but Chk variety remain green colour even after ripening. The pulp colour of the varieties are light orange (Sih and Obt) to orange colour (Chk) fruits. Fibre content of the fruits delimits it from varietal selection. But one should be aware that fibre acts as roughage and aids digestion. Since the varieties of the present study viz., Nar, Spp, Emj, Gin and Mns have exhibited dense fibres in it they can be utilized for breeding that assists indigestion.

The presence of low sugar content in Spp variety becomes best suited variety for diabetic patients. Less sourness of Sih variety (unripe fruit) is a good variety for patients with acidity. As these varieties are mono-embryonic in nature they are well suited for further hybridization. These are unique characters not present in other varieties. Fruit length of the observed varieties, were from 3.75 to 7.95 cm, width from 3.5 to 6.85cm and thickness from 3.13 to 6.32 cm. These results were solitary in their way which is different from the data of other authors [3-5], [9-10], [17-18]. Seeds of some varieties were densely covered by fibres and few were characterized by lines on it either raised or parallel to the surface. As to the characteristic of wild varieties, fibre was dense to medium. Even the seeds of some varieties were fully covered by fibres.

CONCLUSION

This study of morphology of wild varieties of mango has revealed distinctive traits not present in any hybrid varieties. These wild varieties are ignored by the cultivars due to the small size of the fruits. But if we consider the medicinal value of these fruits, it should be kept in mind that these varieties should not be missed out from cultivation and must be preserved for future generations also. So, there is a need to conserve the wild varieties from becoming extinct. A few varieties from Hanavadi village have been studied here, like such if more work is done on wild varieties of other regions, India would become much more diversified in its germplasm collection.

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