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# Genetic diversity in qualitative and quantitative traits of papaya

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## ABSTRACT

**The present study was conducted for the diversity analysis of 11 dioecious genotypes of papaya based on various morphological traits. A significant range of variation was noticed for stem colour, which varied from green to greenish light grey in majority of the studied population. The genotype P-9-15-5 was observed with an extreme variation in stem colour *i.e.,* purple pink. For stem pigmentation a predominantly indiscriminate pattern was recorded in most of the genotypes whereas two genotypes namely, P-15-1 and P-9-15-5 were distinct with purple colour pigmentation on the stem of the female and male plants. Leaf petiole colour was primarily light green to green in most of the genotypes, whereas in case of genotype P-9-25, P-14-9 and P-15-2, it was noticed green with shades of purple. Petiole sinus shape varied from slightly open to strongly closed. The wild relative of papaya genotype *V. cauliflora* was distinct with other genotype with open shape of petiole sinus shape. The mature leaf teeth shape for all the genotypes of papaya was of two types *i.e.,* straight and convex type. Genotype *V. cauliflora*, RCTP-I, Pusa Dwarf, Pusa Nanha, P-15-1, P-14-6, and P-9-15-5 were with straight mature leaf teeth shape whereas convex leaf teeth shape was recorded in P-9-25, P-14-9 and P-15-2. Inflorescence stalk colour varied from light green to green for all the studied genotypes. Flower colour varied from cream, yellowish white to white in colour in both female and male sexes of the plants. The wild relative, mountain papaya (*V. cundinamarcensis*) was most distinct genotype among the dioecious population studied. In UPGMA dendrogram based on quantitative traits of dioecious papaya revealed wide distinctness between *V. cauliflora* and *V. cundinamarcensis*.**

**Key words:** *Carica papaya*, wild relative, genotype, hybrid, UPGMA.

## INTRODUCTION

Papaya (*Carica papaya* L.) is considered as one of the important fruit crops for the growers of the tropical and sub-tropical agro-climatic regions across the globe. Papaya varieties are typically classified as either dioecious or gynodioecious based on the type of flowers borne by the plant. Papaya is the only species in the genus *Carica*, with 21 species of *Vasconcellea* recently excluded from the genus *Carica* (Badillo, 1); Ming *et al*. (7); Scheldeman *et al.* (9)).

The relatively small genome of this species shows peculiarities in major gene group's involved in cell size and lignification, carbohydrate economy, photoperiodic responses, and secondary metabolites, which place the papaya in an intermediate position between herbs and tree. Reproductive precocity, high photosynthetic rate of short lived leaves, quick growth, high flowering fruiting, production of many seeds and low construction cost of the hollow stems petioles, and fruit characterize this successful fruit crops in the tropics. High phenotypic plasticity allows these plants to establish in diverse agro-ecosystems. Papaya germplasm show moderate to high phenotypic variation for the morphological traits such as leaf shape and size, types of inflorescences and flowers, fruit shape and size, and reaction to pest and diseases. The morphology of papaya inflorescences and flower varies with sex of the plant. Only a few studies have focused upon characterizing the genetic and morphological diversity of papaya growing within natural areas (Chan, 3). Within population, genetic diversity tends to be reduced relative to wild populations (Kim *et al*., 5).

There are several reasons why a desirable genotype of papaya plant needs to be identified prior to hybridization. The availability of genetic diversity is the pre-requisite for the success of any crop improvement programme. These naturally occurring populations may serve as a reservoir of genetic and morphological diversity for cultivated papaya; therefore, we planned to characterize these populations for assessing extent of morphological and genetic diversity. A significant amount of morphological diversity was observed throughout the country, especially for reproductive characters. The aim of study is to provide information about genetic diversity on phenotypic and genotypic level among the available inbred lines and few commercial varieties and hybrids available in the country. The information gained would be useful in the breeding programs aimed at the development of superior dioecious lines of the papaya. Keeping

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in view of the above the present study has been undertaken with an objective to characterize the dioecious papaya genotypes on morphological and reproductive traits.

## MATERIALS AND METHODS

The experiment was carried out at the Experimental Orchard of the Division of Fruits and Horticultural Technology, ICAR-IARI, New Delhi. Total of 11 dioecious genotypes, RCTP-1, Pusa Nanha, Pusa Dwarf, *Vasconcellea. cauliflora, Vasconcellea cundinamarcensis,* P-15-1, P-9-25, P-14-6, P-14-9, P-9-15-3 and P-15-2 were selected as treatment with 4 replication for the study. The 6 week old seedlings were planted with a spacing of 1.5 m × 1.5 m in the net house and observations were recorded on the traits given in Table 1. Morphological traits were considered from the papaya descriptors of IBPGR (4).

Morphological data from each genotype were compiled and divided into quantitative and qualitative traits. Qualitative character were tabulated and presented as such for characterization. Quantitative traits were subjected to analysis in Power Core 3.0 software. Data from female, hermaphrodite and male plants were grouped according to dioecious and gynodioecious genotype to assess the vegetative traits, while the nine female reproductive traits were assessed independently of the three male reproductive traits. The results from the discriminant analysis and the cluster analysis were compared to assess overall trends.

## RESULTS AND DISCUSSION

Diversity among the genetic resources is the base for any genetic improvement in crop plants. Genotypic diversity is worthless unless it is promptly conserved and efficiently utilized in crop improvement programme. The efficient exploitation and conservation depends on the information available about plant genetic diversity (Bekele *et al*., 2). In the present investigation, the characterization and genetic diversity of papaya genotypes developed and collected from across the country was evaluated using morphological traits.

The commercial papaya genotypes exhibits moderate to high phenotypic divergence for the morphological parameters namely leaf shape, leaf length, leaf width, type of inflorescence and flowers, fruit shape, fruit length, fruit diameter. The most diverse and economically desirable phenotypic traits of papaya genotypes are related to flower and fruit characteristics. The morphology of papaya inflorescence and flower varies with sex of plant. A significant range of variation was noticed for morphological qualitative traits of the 11 dioecious genotypes of papaya (Table 2). Stem colour varied from greenish light grey to grey among the studied population whereas it was purple pink colour in case of genotype P-9-15-5. A predominantly indiscriminate pattern was recorded for stem pigmentation in most of the genotypes whereas two genotypes namely P-15-1 and P-9-15-5 were distinct with purple colour pigmentation on the stem of the female and male

**Table 1.** List of the qualitative and quantitative morphological traits of the papaya.

| Vegetative | Reproductive | | |
|---|---|---|---|
| | Female | Male | Hermaphrodite |
| Stem colour[a] | Flower colour[a] | Flower size[a] | Flower colour[a] |
| Stem pigmentation[a] | Flower size[a] | Inflorescence size[a] | Flower size[a] |
| Mature petiole Length (Female)[b] | Inflorescence size[a] | Colour corolla lobes[a] | Inflorescence size[a] |
| Length of mature petiole (Hermaphrodite)[b] | Fruit diameter[b] | | Fruit diameter[b] |
| Length of mature petiole (Male)[b] | Length of fruit[b] | Colour of corolla tube[a] | Length of fruit[b] |
| Length of mature leaf (Female)[b] | Fruit shape[a] | | Fruit shape[a] |
| Length of mature leaf (Hermaphrodite)[b] | Fruit skin colour[a] | | Fruit skin colour[a] |
| Length of mature leaf (Male)[b] | Fruit central cavity shape[a] | | Fruit central cavity shape[a] |
| Width of mature leaf (Female)[b] | Fruit central cavity index[b] | | Fruit central cavity index[b] |
| Width of mature leaf (Hermaphrodite)[b] | Fruit weight | | Fruit weight[b] |
| Width of mature leaf (Male)[b] | Fruit stalk end shape[a] | | Fruit stalk end shape[a] |
| Leaf shape[a] | Seed colour[a] | | Seed colour[a] |
| Leaf petiole colour[a] | Seed surface lustre[a] | | Seed shape[a] |
| Petiole sinus shape[a] | | | |
| Mature leaf teeth shape[a] | | | |
| Sex form[a] | | | |
| Inflorescence stalk colour[a] | | | |

Note :a =qualitative traits, b= quantitative traits

**Table 2.** Morphological qualitative traits of dioecious genotypes of papaya at vegetative and reproductive stage.

| Genotypes/ Qualitative traits | [a]V.clf | RCTP-I | Pusa Dwarf | Pusa Nanha | [b]V. cdm | P-15-1 | P-9-25 | P-14-6 | P-14-9 | P-9-15-5 | P-15-2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Stem colour | Green | Greenish grey | Green and light grey | Green and light grey | Light grey | Greenish grey | Light grey | Grey | Green | Purple pink | Green |
| Stem pigmentation | Green | Indiscrimate | Indiscrimnate | Indiscrimnate | Indiscrimnate | Purple | Indiscrimnate | Indiscrimate | Indiscrimate | Purple | Indiscrimnate |
| Leaf shape | 1 | 10 | 1 | 1 | 3 | 16 | 4 | 10 | 2 | 3 | 2 |
| Leaf petiole colour | Light green | Light green | Green purple | Light green | Light Green | Light green | Green with shades of purple | Light green | Green with shades of purple | Light green | Green with purple shade |
| Petiole sinus shape | Open | Strongly closed | Strongly closed | Strongly closed | Strongly closed | Slightly open | Strongly closed | Strongly closed | Slightly closed | Slightly open | Slightly closed |
| Mature leaf teeth shape | Straight | Straight | Straight | Straight | Slightly closed | Straight | Convex | Straight | Convex | Straight | Convex |
| Inflorescence stalk colour | Light green | Green | Green | Light green | Light green | Green | Green | Green | Green | Green | Green |
| Flower colour (female) | White | Cream | Yellowish white | Yellowish white | Cream | Cream | White yellow | Cream | Cream | Cream | Yellowish white |
| Colour of corolla lobes male | White | Cream | White yellow | Cream | Whitish | Cream | White yellow | Cream | White yellow | Cream | Cream |
| Colour of corolla tubes male | White | Greenish yellow | Greenish yellow | Yellowish white | Cream | Greenish yellow | Greenish yellow | Green | Greenish yellow | Greenish yellow | Greenish yellow |
| Flower size male | Small | Small | Small | Small | Small | Small | Small | Medium | Medium | Small | Medium |
| Flower size (female) | Medium | Medium | Medium | Medium | Small | Medium | Large | Large | Large | Medium | Medium |

[a]V.clf =*V. cauliflora*, [b]V. cdm =*V. cundinamarcensis*

plants. Total six type of leaf shape was observed for the 11 dioecious genotypes. Among the six types, type 1 leaf shape was frequently noticed followed by type 10 and 2 in the dioecious population. A light green colour of leaf petiole was primarily observed for most of the genotypes whereas it was noticed green with shades of purple in case of genotypes P-9-25, P-14-9 and P-15-2. Petiole sinus shape also varied from slightly opens to strongly close. However, most of the papaya genotypes were recorded with strongly closed petiole sinus shape whereas genotype *V. cauliflora* was recorded with open shape of petiole sinus. The mature leaf teeth shape was of straight and convex type in the studied dioecious genotypes. Genotypes *V. cauliflora*, RCTP-I, Pusa Dwarf, Pusa Nanha, P-15-1, P-14-6, and P-9-15-5 were observed with straight mature leaf teeth shape whereas convex leaf teeth shape was recorded in P-9-25, P-14-9 and P-15-2 genotypes. Inflorescence stalk colour varied from light green to green among all studied dioecious genotypes. Flower colour variation was also observed among the studied genotype which varied from cream, yellowish white to white in colour in both female and male sexes of the plants. There was not much influence of the type of sex on flower colour of the plants. Colour of corolla lobes of male flowers varied from white to greenish yellow and in case of corolla tubes of male flowers the variation in colour ranged from white to greenish yellow. Flower size was also recorded in a scale of large, medium and small in both female and male plants. The flower size was mostly medium sized in female plants of most of the genotypes, whereas the genotypes such as P-9-25, P-14-6 and P-9-15-5 were observed with large size of flowers. The smallest female flower size was recorded in *V. cundinamarcensis* followed by *V. cauliflora,* whereas the genotypes P-9-25, P-14-6 and P-14-9 was noticed with large female flowers. The significant amount of variation observed was based type of sex on inflorescence size of the dioecious genotypes. Data presented in Table 3 revealed that the inflorescence in male plant was large across the genotype whereas it was of small size in female plants. A significant variation was observed in case of fruit shape of female plants of the 11 dioecious genotypes of papaya. It was predominantly oblong shape in most of the genotype whereas elliptic fruit shape was observed in Pusa Dwarf, P-14-6 and P-15-2. There was not much distinction noticed among fruit skin colour in female fruits across the dioecious genotypes. The yellow colour was predominant at the ripening stage in most of the genotype. Fruit central cavity also varied from round, angular to slightly star shaped among the female fruits of dioecious genotypes. The angular shape was observed in RCTP-1, Pusa Dwarf, P-9-25 and P-9-15-5 papaya genotypes. The genotypes such as, P-15-1, P-14-9 and P-15-2 was observed with slightly star shaped fruit central cavity. Fruit stalk end shape was predominantly flattened in majority of studied dioecious female genotypes followed by depressed stalk end in RCTP-1, Pusa Dwarf, P-14-6 and P-9-15-5 genotypes. Sudha *et al.* (10) reported widest morphological diversity in terms of fruit weight, fruit length, fruit girth among genotypes collected from different parts of South and Little Andaman Islands. The seed colour variation was also recorded across the population, it varied from black, brownish black to grey in colour but the variation was largely dependent on the type of genotype plants. There was narrow variation among the genotypes for seed surface luster and seed shape. The seed surface was predominantly dull in most of the genotypes. Seed shape greatly varied in two wild genotypes *V. cundinamarcensis* and *V. cauliflora* and in one commercial genotype *i.e.,* Pusa Dwarf, in a range of spherical and completely distinct from other genotypes of the population. Similar physical characteristics of the papaya seeds were also reported by Mengarda *et al*. (6).

Paired dissimilarity matrix presented in Table 4 shows wide range of dissimilarity ranging from 1.7 to 8.8 among the 11 dioecious genotype of papaya based on the 12 morphological quantitative distances. The largest distinction (8.8) was observed between genotype P-14-9 and *V. cundinamarcensis* followed by (7.7) P-15-2 and *V. cundinamarcensis* based on Euclidean distance. The similar distinctness was also observed between P-9-15-5 and *Vasconcellea cundinamarcensis* (7.6), *V. cundinamarcensis* and *V. cauliflora* (7.5), P-9-25 and P-14-9 (7.5) and Pusa Dwarf and *V. cundinamarcensis* (7.4). However, maximum closeness (1.2) was observed between Pusa Nanha and P-14-6 followed by Pusa Nanha and P-15-2 (1.6); Pusa Nanha and P-15-1 (1.7); Pusa Nanha and Pusa Dwarf (1.7).

Data illustrated in Fig. 1 indicate a wide range of variation among the dioecious genotype of papaya. The clustering was carried out based on Euclidean coefficient in a range of 2.16 to 7.39. Total 3 clusters were observed among the 11 studied dioecious papaya genotypes. The two wild species of papaya namely *V. cundinamarcensis* and *V. cauliflora* were observed in same cluster no. 'I'. The closeness were recorded in RCTP-I and P-9-15-5 followed by Pusa Nanha and P-14-6 based on morphological quantitative traits. The analysis of the dendrogram on dioecious genotypes indicates a significant influence of type of sex on the quantitative traits.

The principle component based analysis was carried out of morphological quantitative traits of

**Table 3.** Morphological qualitative characters of dioecious genotypes of papaya.

| Genotypes / Qualitative traits | [a]V.clf | RCTP-I | Pusa Dwarf | Pusa Nanha | [b]V. cdm | P-15-1 | P-9-25 | P-14-6 | P-14-9 | P-9-15-5 | P-15-2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Inflorescence size (male) | Medium | Large | Large | Large | Medium | Medium | Large | Large | Medium | Large | Large |
| Inflorescence size (female) | Small | Medium | Small | Small | Small | Medium | Medium | Medium | Large | Medium | Large |
| Fruit shape (female) | Oblong | Oblong | Elliptic | Oval | Pear shaped | High round | Round | Elliptic | Oblong | Oblong | Elliptic |
| Fruit skin colour (female) | Yellow | Yellow | Yellowish | Greenish yellow | Yellow | Yellow | Light yellow | Yellow | Yellow | Yellow | Greenish Yellow |
| Fruit central cavity shape (female) | Round to angular | Angular | Angular | Round | Round | Slightly star shaped | Angular | Round | Slightly star shaped | Angular | Slightly star shaped |
| Fruit stalk end shape (female) | Flattened | Depressed | Depressed | Flattened | Flattened | Flattened | Flattened | Depressed | Flattened | Depressed | Flattened |
| Seed colour (female) | Grey | Brownish black | Grey | Black | Brown | Brownish black | Grey | Black | Grey | Brownish black | Grey |
| Seed surface luster (female) | Intermediate | Dull | Glossy | Intermediate | Dull | Glossy | Dull | Dull | Dull | Dull | Dull |
| Seed shape (female) | Spherical | Ovoid | Spherical | Ovoid | Spherical | Ovoid | Ovoid | Ovoid | Ovoid | Ovoid | Round |

[a]V.clf =*V. cauliflora*, [b]V. cdm =*V. cundinamarcensis*

**Table 4.** Paired dissimilarity matrix based on Euclidean distance of 12 quantitative traits of 11 dioecious papaya genotypes.

| Genotype | [a]V.clf. | RCTP-I | Pusa Dwarf | Pusa Nanha | [b]V.cdm. | P-15-1 | P-9-25 | P-14-6 | P-14-9 | P-9-15-5 | P-15-2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [a]V.clf. | 0 | | | | | | | | | | |
| RCTP-I | 4.6 | 0 | | | | | | | | | |
| Pusa Dwarf | 2.9 | 2.9 | 0 | | | | | | | | |
| Pusa Nanha | 3.5 | 1.8 | 1.7 | 0 | | | | | | | |
| [b]V.cdm. | 7.5 | 7.6 | 7.4 | 6.8 | 0 | | | | | | |
| P-15-1 | 3.9 | 2.4 | 2.5 | 1.7 | 6.3 | 0 | | | | | |
| P-9-25 | 6.6 | 4.9 | 5.2 | 4.6 | 4.8 | 4 | 0 | | | | |
| P-14-6 | 3.7 | 2.2 | 2.5 | 1.2 | 6.4 | 2.3 | 5 | 0 | | | |
| P-14-9 | 3.6 | 4.2 | 3.2 | 3.2 | 8.8 | 4.6 | 7.5 | 3.1 | 0 | | |
| P-9-15-5 | 4.5 | 3.5 | 2.9 | 1.8 | 7.6 | 2.4 | 4.9 | 2.2 | 4.1 | 0 | |
| P-15-2 | 3.8 | 2.7 | 2.4 | 1.6 | 7.7 | 3 | 5.9 | 1.8 | 2.2 | 2.7 | 0 |

[a]V.clf =*V. cauliflora*, [b]V. cdm =*V. cundinamarcensis*

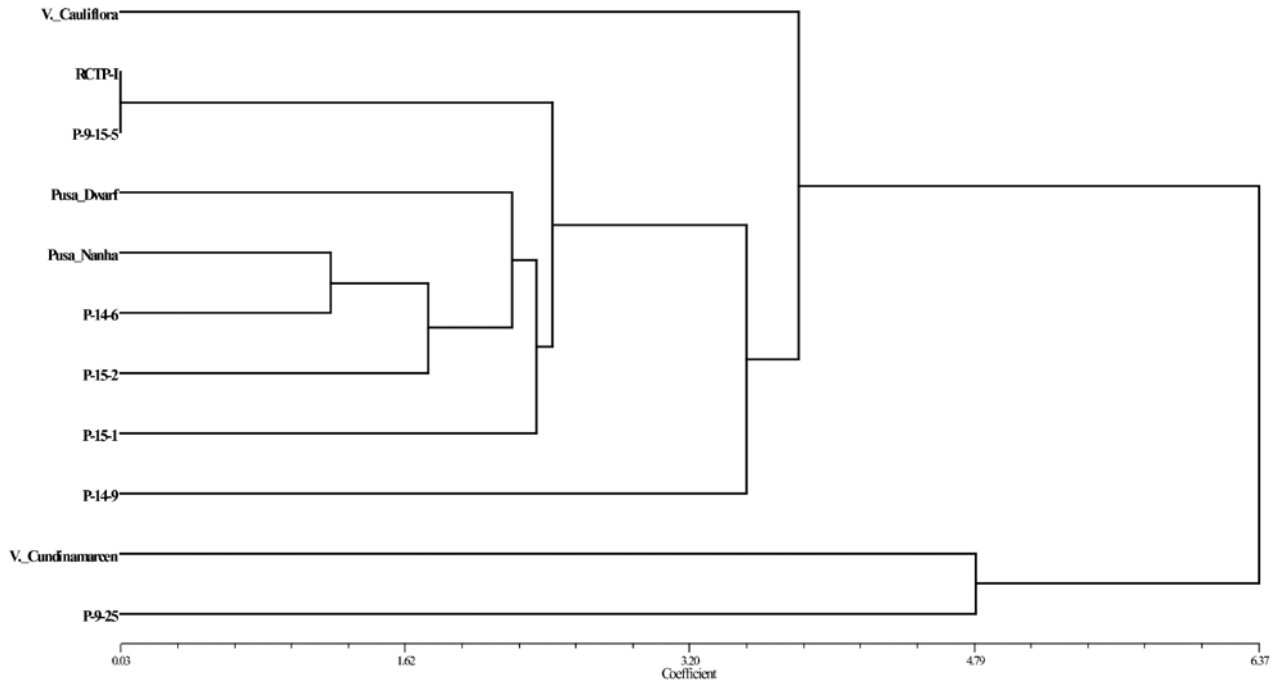


**Fig. 1.** Dendrogram showing clustering of 11 dioecious genotypes on quantitative traits.

papaya. The range of component 1 was -0.8 to 0.7 based on Euclidean distance. The values presented in Table 5 indicate that P-14-9, RCTP-I, P-15-5, P-15-2 and Pusa Dwarf are the larger contributor of the variation based on morphological quantitative traits whereas *V. cundinamarcensis* is among the lower contributor for the variation in component "I'. However, genotype P-15-1 was among the lower contributor across the four components. Data presented in Table 5 further revealed in component 2 that *V. cauliflora* is a largest contributor of the variation with a value of 0.8 but same genotype contribution value was 0 in component 3. In component 4 the variation level was reduced compare to component 1, 2 and 3 across the 11 dioecious genotypes. The Principle component analysis of dioecuious genotypes of papaya gives a description when a lot of traits were accounted concurrently expressing a significant variation in the morphological qualitative and quantitative parameter and other important economical traits. However, cluster analysis of dioecious genotypes indicated a clear and informative unveil of the relative positions of the inbred lines and varieties. The similar findings have been published earlier in case of papaya (Ocampo *et al.,* 8).

Many genotypes of papaya both inbred lines and varieties were grown and possess significantly higher divergence in both qualitative and quantitative traits morphological and traits of gynodioecious and dioecious genotype and it can be utilized further in the selection, conservation and development of improved varieties of papaya. A significant level of variation was observed on qualitative traits of papaya particularly with two wild species V. *cauliflora* and *V. cundinamarcensis*. *Carica papaya*, highland papayas are generally smaller and have distinct texture, taste and aroma (Scheldeman *et al*., 9). The wild species of papaya V. *cauliflora* and *V. cundinamarcensis* required special attention of researches particularly breeders to exploit the genetic resistance source inongoing and future breeding programs of papaya.

**Table 5.** Principle component based analysis of 11 quantitative traits of dioecious papaya genotypes.

| Genotype | C1 | C2 | C3 | C4 |
|---|---|---|---|---|
| *V. cauliflora* | 0.1 | 0.8 | 0 | 0.3 |
| RCTP-I | 0.5 | -0.2 | 0.3 | 0.1 |
| Pusa Dwarf | 0.3 | 0.4 | -0.2 | -0.2 |
| Pusa_Nanha | 0.2 | -0.1 | 0 | -0.1 |
| *V. cundinamarcensis* | -2 | -0.2 | 0 | 0.2 |
| P-15-1 | 0 | 0.1 | 0.3 | -0.3 |
| P-9-25 | -0.8 | 0.1 | -0.1 | -0.3 |
| P-14-6 | 0.1 | -0.3 | 0 | 0.1 |
| P-14-9 | 0.7 | -0.2 | -0.3 | 0.1 |
| P-9-15-5 | 0.5 | -0.2 | 0.3 | 0.1 |
| P-15-2 | 0.5 | -0.3 | -0.2 | -0.1 |

A significant amount of morphological diversity was observed among the studied genotypes of papaya, especially for stem and petiole colour, petiole length, flower size, fruit length and diameter, fruit central cavity index and seed surface luster. The wild relative mountain papaya (*V. cundinamarcensis)* was most distinct genotype among the dioecious population.

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