Morphological characterization of Andean Passifloras (*Passiflora* spp.) from Ecuador

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Introduction

The Andean passion fruits (*Passiflora* spp.) are subject to strong changes in their distribution and in the way they are cultivated and commercialized. This is resulting in rapid genetic erosion. To support the conservation of these resources the project 'Diversity, conservation and sustainable use of native fruit germplasm of Tropical America', managed through the Andean Network for Plant Genetic Resources (REDARFIT), is developing both molecular and morphological markers for the characterization of these species. The project involves researchers in Venezuela, Colombia and Ecuador. In this paper, we present the first results of the morphological characterization of Ecuadorian material of species of the subgenera *Tacsonia* and *Manicata*. Most of it is constituted of two types of cultivated banana passion fruits. One of them is *Passiflora tripartita* var. *mollissima* (Kunth) H-N.&Jorg., sometimes called 'tacso de Castilla' (A.A.A. 1992). The other, called 'tacso amarillo'(A.A.A. 1992), is common in Ecuador but its taxonomic status has not been clarified. The widely distributed wild species *P. mixta* L., *P. cumbalensis* (Karst) Harms and *P. pinnatistipula* Cav. were included in the study, as well as *P. manicata* (Juss.) Poir. of the subgenus *Manicata*. The taxonomic relationships between these species are presented in Table 1.

Table 1. Taxonomic classification of the identified species of *Passiflora*, adapted from the floras of Ecuador and Colombia (Escobar 1988; Holm-Nielsen *et al.* 1988)

Subg. *Tacsonia*	Section *Tacsonia*	*P. mixta*
	Section *Bracteogama*	*P. tripartita* var. (Kunth) H-N& Jorg. *mollissima*
		P. cumbalensis (Karst.) Harms
	Section *Poggendorfia*	*P. pinnatistipula* Cav.
Subg. *Manicata*	*P. manicata* (Juss.) Poir.	

Materials and methods

The *Passiflora* field collection of the Technical University of Ambato, Ecuador is situated at the research station of the Faculty of Agricultural Engineering in the Cantón Cevallo (18 km from Ambato), 2860 m asl.

The material studied includes 34 accessions of cultivated banana passion fruit and 11 wild accessions. The cultivated material includes 12 accessions of *P. tripartita* var. *mollissima* and 22 accessions of 'tacso amarillo'. The wild material consists of two accessions of *P. mixta*, three of *P. pinnatistipula*, one of *P. cumbalensis* and five of *P. manicata*. This germplasm had all been collected in the Cordillera Central of Ecuador.

The morphological characterization was carried out using vegetative, floral and fruit traits, based on a preliminary list of descriptors developed by CORPOICA and other participants of the regional project (Table 2). For the quantitative descriptors, the mean of five observations was calculated.

The quantitative data were subjected to a principal component analysis with normalized varimax rotation. Hierarchical cluster analyses were performed on the principal component scores of the accessions, as well as on the qualitative data, using Euclidian distance (principal component scores) or Sokal and Michener distance (qualitative data) and the UPGMA method for grouping (Sneath and Sokal 1973).

Results

Qualitative descriptors

Among the qualitative descriptors, only those included in Table 3 showed variation and were therefore the only ones included in the cluster analysis in Figure 1. When more than one accession showed the same states for all descriptors, only one accession was included in the analysis.

Table 3 and Figure 1 show that the accessions group themselves very consistently by species, demonstrating negligible intraspecific variation for qualitative traits. Cluster analysis starts by grouping the 'tacso amarillo' on one hand and *P. mixta* and *P. tripartita* var. *mollissima* on the other hand. The *P. cumbalensis* representative comes near these species, as well as the accessions of *P. pinnatistipula*. *Passiflora manicata* is clearly distinct from the taxa of the subgenus *Tacsonia*.

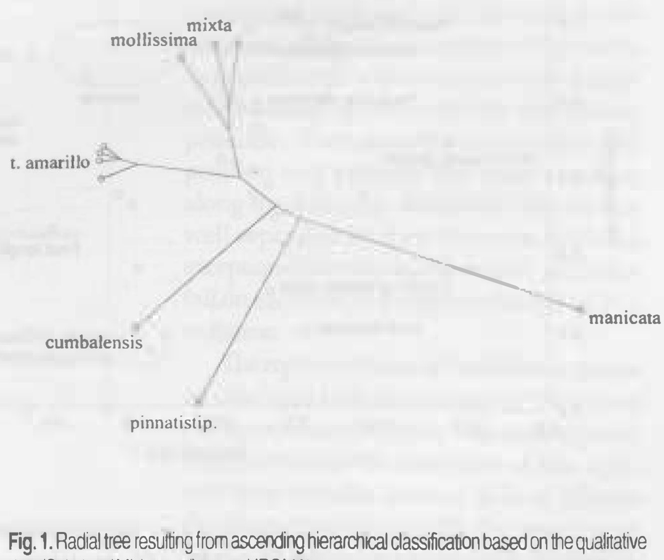

Fig. 1. Radial tree resulting from ascending hierarchical classification based on the qualitative data (Sokal and Michener distance, UPGMA).

Table 2. Descriptor list used for morphological characterization

Organ	Qualitative traits	Quantitative traits
stem	habit (liana or arborescent); shape of section; presence of anthocyans, pubescence and cork	internode length; diameter
tendrils	shape of the spiral; presence of anthocyans and pubescence	length from the base to the spiral; length and diameter of the spiral
stipules	presence, permanence, shape and colour	dimensions
leaves	colour of the petiole; number and shape of the lobules (base and apex); presence and distribution of anthocyans and of pubescence; shape of the trichomas; presence, distribution and shape of the leaf nectar glands	petiole length; number of petiolar nectar glands and position of the first one; lobule length; total width of the leaf; depth of the invagination between lobules and distance between this invagination and the petiole insertion; angle formed by the two lateral lobules
peduncle	presence of anthocyans; position, shape, margin, glands, pubescence and colour of the bracts; type of inflorescence; orientation of the flower	length and diameter; bract dimensions and length of their union; flower orientation index
flower	shape; type and colour of the corona and number of series of filaments; hypanthium/sepals ratio; anthocyans and colour of the androgynophore, presence of operculum and/or limen; union and shape of the sepals; shape of the petals; pubescence of the ovary; odour	length (to the base of the stigmas); hypanthium length
fruit	shape	length and diameter and diameter of the endocarp

Quantitative descriptors

Figure 2 presents the quantitative descriptors in the plane formed by the first two principal components. The first component accounts for 29% of the total variation and is composed principally of characteristics related to the leaves, mainly the number and position of the nectar glands on the petiole and the angle between the lateral lobules. It is also associated with the width of bracts and the length of the fruit. The number of nectar glands on the petiole and the position of the glands on the petiole, as measured by the distance from the base of the petiole, are logically placed at opposite ends of the axis.

The second component accounts for 20% of the total variation and is correlated strongly with fruit diameter and with floral traits, such as length of the flower and hypanthium, the orientation of the flower and associated traits like length and diameter of the peduncle. It is also associated with the characteristics of the tendrils. The low correlation between length and diameter of the fruit reflects the large variation in shape that exists among accessions, from the almost spherical fruits of *P. pinnatistipula* to the fusiform fruits of 'tacso amarillo'.

Petiole length, stipule size and inner diameter of the fruit contribute most strongly to the third component that accounts for 12% of the total variation. The fourth component is close behind, explaining 11% of the variation, and is particularly correlated with internode length and the size of the foliar lobules.

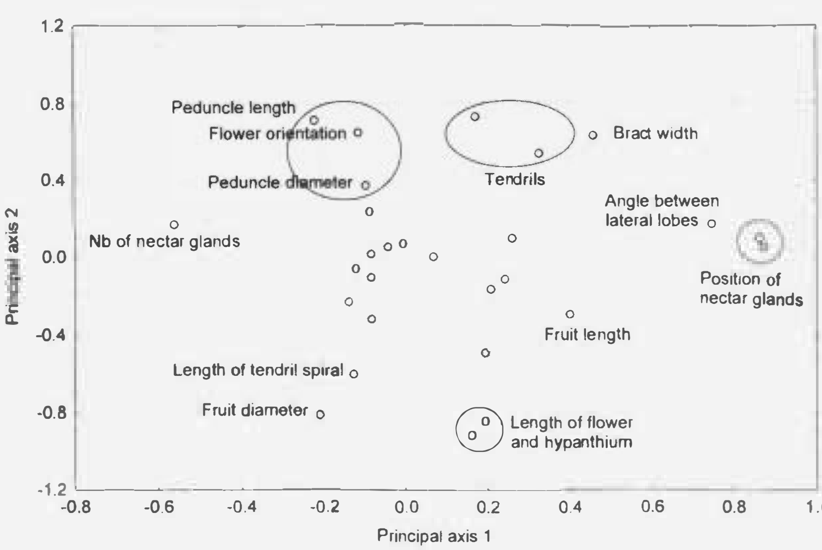

Fig. 2. Principal component analysis on quantitative data. Representation of the original variables in the principal plane.

Figure 3 shows the position of the accessions in the plane formed by the first two principal components. The only accession of *P. cumbalensis* is situated in an extreme position along the first axis, indicating its strong contribution to the formation of this axis. This contribution is obviously due to the wide angle between the lateral lobules of the leaves in this species. The fact that the first axis is strongly associated with a characteristic of the species, rather than of that particular accession, confirms the stability of this axis. The three accessions of *P. pinnatistipula* are found at the opposite end of the axis due to the narrower angle between lobules in this species.

Table 3. Variation for qualitative traits (number of individuals in parentheses)

Organ	*P.t. mollissima* (12)	tacso amarillo (22)	*P. pinnatistipula* (3)	*P. mixta* (2)	*P. cumbalensis* (1)	*P. manicata* (5)
Stem						
anthocyanin	yes	yes/no (1)	yes	yes/no (1)	yes	yes
Stipules						
permanence	perm/dec (1)	deciduous	permanent	permanent	permanent	permanent
shape	reniform aristate	aristate	pinnatisect	reniform aristate	subreniform	reniform aristate
trichomas	yes	yes	yes	no	no	no
Leaf						
petiole trichomes	yes	yes	yes	yes	no	no
petiole anthocyans	moderate	moderate	moderate	moderate	very dense	moderate
base	cordate	cordate	cordate	cordate	cuneate	cordate
length/width	equivalent	equivalent	equivalent	equivalent	inferior	equivalent
margin	serrate	serrate	serrate	serrate	serrate	dentate
pubescence	both sides	beneath	both sides	beneath or both	beneath	beneath
Bracts						
union	united	united	free	united	united	united
position	peduncle	peduncle	hypanthium base	hypanthium base	peduncle	peduncle
shape	oblong	lanceolate	ovate	oblong	lanceolate	ovate
Flower						
orientation	pendent	pendent	pendent	horizontal	pendent	erect
corona rows	one	one	two	one	one	five
corona type	tubercules	tubercules	filaments	tubercules	tubercules	filaments
corona colour	white	white	purple	white	white	purple
hypanthium/sepals	much longer	much longer	slightly longer	much longer	much longer	shorter
androgynophore	white	white+green/white (2)	white	white	mottled	white
petal colour	reddish pink	pink/red(1)/white(1)	pink	red /pink(1)	pink	red
hypanthium	external	no	external	external	external	no
pubescence	yes	yes	yes	yes	no	no
ovary pubescence						
flower odour	yes	yes	yes	yes	no	no
	no					
Fruit						
shape	oblong	oblong	round	oblong/ovoid(1)	oblong	ovoid

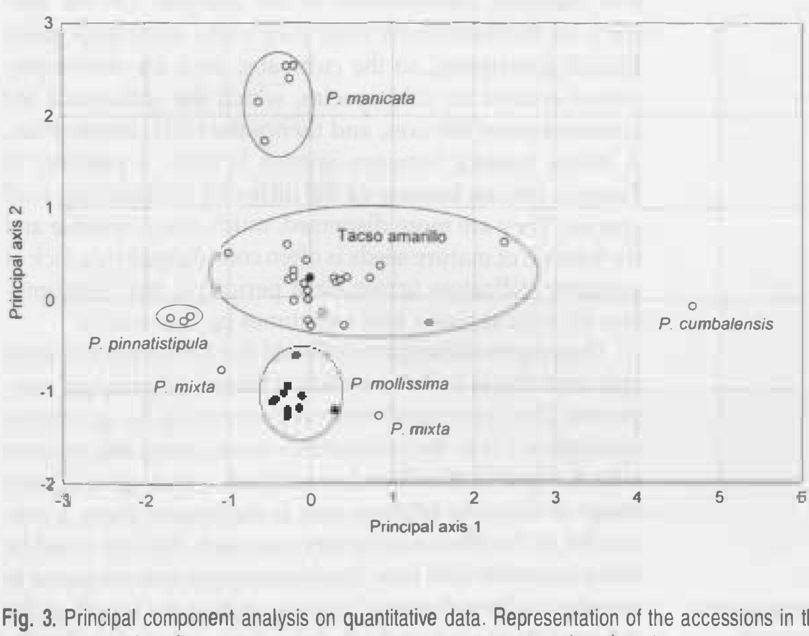

Fig. 3. Principal component analysis on quantitative data. Representation of the accessions in the principal plane. *Passiflora mollissima* accessions are represented by full black circles.

The accessions of *P. manicata* are found at one extreme along the second axis, being characterized by long and thick peduncles supporting short and erect flowers. At the other end, we find the accessions of *P. tripartita* var. *mollissima*, with wider fruits and large flowers hanging from a shorter and thinner peduncle. 'Tacso amarillo' occupies a central position and presents the most variation along the first axis. Generally the taxa are well separated by these two axes, with the exception of the two accessions of *P. mixta* that fall on each side of the group formed by *P. t. mollissima*.

The representations of the different species on axes 3 and 4 are also interesting. The former clearly separates the plants with small stipules, *P. pinnatistipula* (with scores from –1.34 to –1.44) and 'tacso amarillo' (from –1.03 to –0.25) from the others (from 0.15 to 1.92). The latter, correlated with internode length and leaf lobe size, separates the two cultivated tacsos (with all scores but one comprised between –0.25 and 1.45) from the wild species (–2.79 to –0.38).

Figure 4 presents the dendrogram obtained from a cluster analysis of the first five principal components, i.e. those with an eigenvalue of more than one. The two closest clusters are those formed by 'tacso amarillo' and 'tacso de Castilla' (*P. t. mollissima*). The smaller clusters formed by *P. manicata* and by *P. pinnatistipula* also appear homogenous. On the other hand, the two accessions of *P. mixta* each form their own group. *Passiflora cumbalensis* is placed far from all the other accessions.

Discussion

The qualitative descriptors showed little intraspecific variation, so that the analysis only allowed for the separation of distinct species. Nonetheless, they appear to structure this variation well. The classification resulting from this analysis differs little from that presented by Escobar (1988). *Passiflora t. mollissima* and *P. mixta*, which Escobar places in two distinct sections, *Bracteogama* and *Tacsonia* respectively, appear very close, while *P. cumbalensis*, included in the same section as *P. t. mollissima*, falls quite as far from *P. t. mollissima* as *P. pinnatistipula* of the section *Poggendorfia*. The 'tacso amarillo' was clearly distinct from 'tacso de Castilla' (*P. t. mollissima*) indicating that the cultivated banana passion fruits correspond to at the least two groups. As could be expected, *P. manicata* of the subgenus *Manicata* was clearly distinct from the species of the subgenus *Tacsonia*.

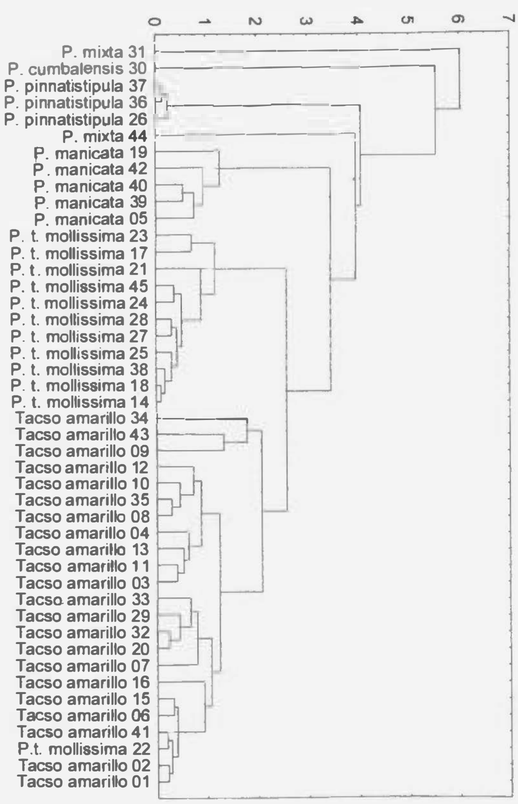

Fig. 4. Dendrogram resulting from ascendant hierarchical classification based on the coordinates for the five first principal components (UPGMA, Euclidian distances).

Contrary to the qualitative descriptors, the quantitative descriptors clearly demonstrated intra- as well as interspecific variation. Leaf descriptors gave the clearest indications in this respect. The different taxa appear well grouped in the dendrogram derived from the principal components, with the exception of one of the accessions of *P. t. mollissima* which is found among the 'tacso amarillo' and that of *P. mixta*, whose two accessions are included in two distant clusters. The quantitative descriptors confirmed the existence of two groups of cultivated banana passion fruit. The greater diversity found in 'tacso amarillo' compared with 'tacso de Castilla' may be a result of biased sampling, since the former is more common in the Central Cordillera of Ecuador. Similarly, the little diversity found in *P. pinnatistipula* may be due to a sampling effect. The distance between the two accessions of *P. mixta* may be related to the high degree of polymorphism reported in this species (Killip 1938).

The classification derived from the quantitative descriptors does not agree with the one derived from the qualitative data, or with current taxonomy, not even in the division between subgenera. While *P. mixta* appears closer to *P. t. mollissima* than the 'tacso amarillo' in the dendrogram derived from qualitative traits, the analysis of the quantitative descriptors shows more similarity of 'tacso amarillo' to *P. t. mollissima* than to the other species of the subgenus *Tacsonia*. *Passiflora manicata* appears closer to the cultivated tacsos than *P. pinnatistipula*, and the more typical species of *Tacsonia*, *P. cumbalensis* and *P. mixta* are rejected even further from the cultivated tacsos. This divergence between the two dendrograms may be explained by differences in (i) the balance between species in the data set, (ii) the balance between vegetative and floral traits, and (iii) the probably stronger effect of artificial selection on quantitative vegetative characters in the domestication process.

As qualitative descriptors showed very limited intraspecific variability, each taxon is represented by one or very few character combinations in the analysis. On the contrary, all the individuals were used in the analysis of quantitative descriptors, so the cultivated taxa are over-represented relative to wild species, which has influenced the construction of the axes, and thence the final classification. A better balance between species is often a problem in *Tacsonia* studies because of the difficulty in collecting wild species. They are more dispersed, much less accessible and the harvest of mature seeds is often complicated by a lack of maturity indicators (green hard pericarp), fruit consumption by wild animals, and sometimes by seasonality.

Quantitative descriptors included few floral traits and these only contributed to the formation of the second principal component. They were much better represented in the qualitative descriptors. Given their importance in taxonomy, this explains why the classification based on qualitative traits gave a better image of distances between taxa. In the present study, a general list of *Passiflora* descriptors was used. This list could be complemented with new floral descriptors that are easier to measure in the subgenus *Tacsonia*, such as the length of the different floral parts. Indeed, this subgenus is defined by the relative size of hypanthium and sepals, while the corona is generally reduced to one series of tubercules, which strongly limits the possible variation in number and size of corona filaments.

The differential distribution of wild and cultivated taxa along the fourth component of quantitative variation suggests that domestication favoured lianas with longer internodes and larger leaf blades. In any case, this distribution contributed to the closer similarity observed between the accessions of 'tacso de Castilla' (*P. t. mollissima*) and 'tacso amarillo'.

Conclusion

Qualitative descriptors showed very limited intraspecific variation. However their analysis gave an interesting image of the interspecific variation. *Passiflora t. mollissima* and *P. mixta* appear much more similar than indicated by taxonomy of the subgenus *Tacsonia*. 'Tacso amarillo' forms a distinct cluster, close to these two species. *Passiflora cumbalensis* falls quite as far from these three groups as *P. pinnatistipula*. The latter is logically intermediate between all the other species of the subgenus *Tacsonia* and *P. manicata* (of the subgenus *Manicata*).

Quantitative descriptors clearly demonstrated intra- as well as interspecific variation, particularly for leaf traits. However, the resulting classification cannot be relied upon, because of data limitations. More quantitative floral descriptors should be included in the list and efforts should be made to reach a better representation of the different species.

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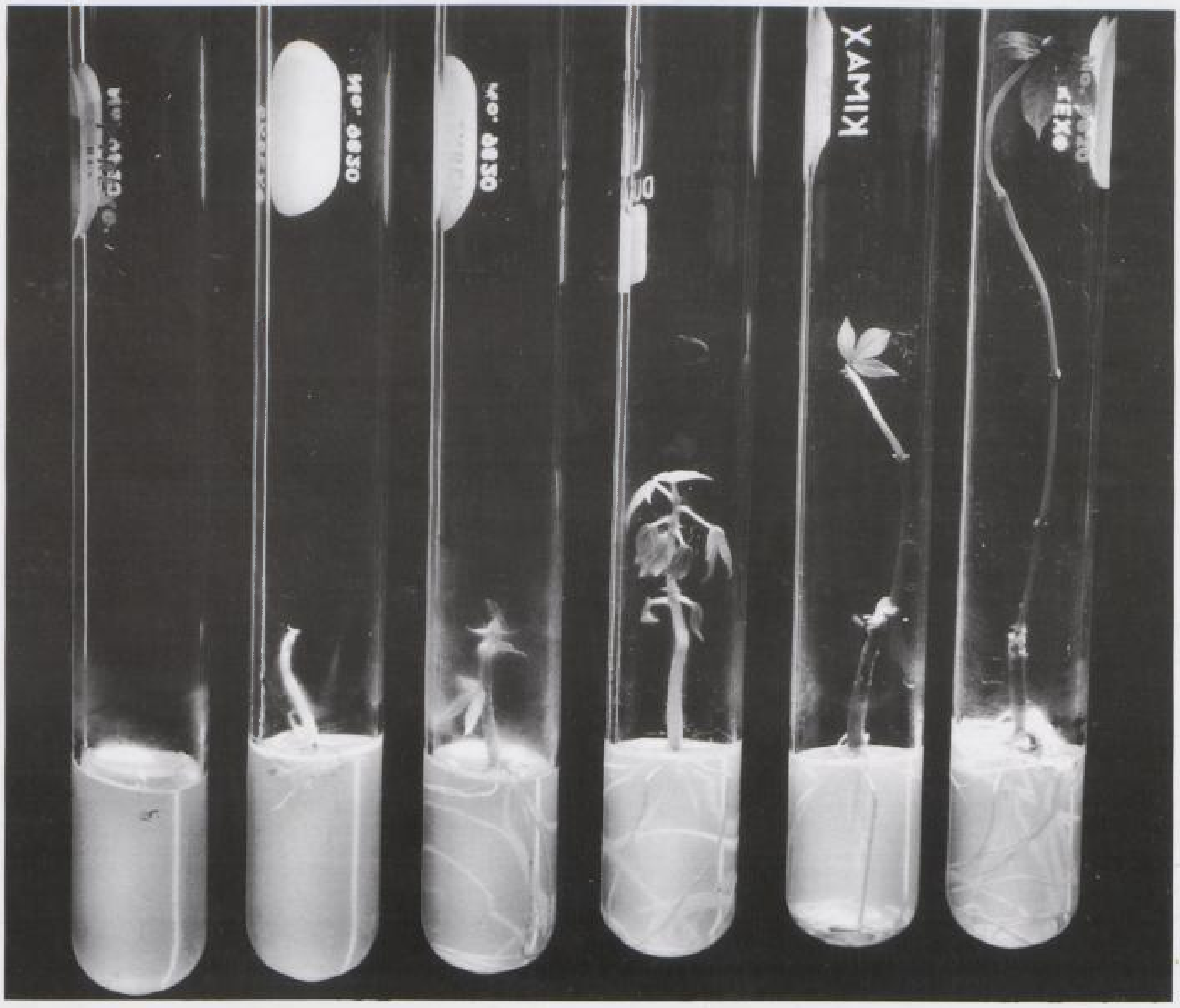

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