Potential of highland papayas (*Vasconcella* spp.) in southern Ecuador

Potencial de papayas de altura (*Vasconcella* spp.) en el sur del Ecuador

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Abstract
Southern Ecuador is considered to be a centre of biodiversity of the so-called highland papayas, Andean species of the recently rehabilitated *Vasconcella* genus, Caricaceae family. *Vasconcella* species in southern Ecuador grow mostly in the wild, above 1000 masl, and consist of *Vasconcella cundinamarcensis* V.M. Badillo, *V. stipulata* (V.M. Badillo) V.M. Badillo, *V.* × *heilbornii* (V.M. Badillo) V.M. Badillo, *V. candicans* (A. Gray) A.DC. , *V. weberbaueri* (Harms) V.M. Badillo, *V. monoica* (Desf.) V.M. Badillo, *V. microcarpa* (Jacq.) A.DC., *V. parviflora* A.DC. and the new endemic species *V. palandensis* (V.M. Badillo et al.) V.M. Badillo. At this moment only the natural hybrid *V.* × *heilbornii* 'Babaco', commercially known as babaco, is getting attention on the continuously expanding subtropical fruit market and is grown at commercial level in Ecuador. Natural hybridisation and presence of accessions of which taxonomical position (at the species level) remains unclear, combined with a limited number of botanical studies suggest that taxonomy of *Vasconcella* in southern Ecuador is still not completely explained. Nevertheless, local collections and characterization studies show that, from an agronomical point of view, these highland papayas show a big potential for the future. Organoleptic characteristics of some accessions and species are very promising, especially for use in juices and marmalades. Making use of natural or artificial hybridisation can even expand this potential. Analyses of the activity of the proteolytic enzyme complex (papain) of these local accessions and species shows that latex of unripe fruits possesses up to 15 times more proteolytic activity than papaya (*Carica papaya* L.) cultivars selected and grown for their high enzyme content. Some *Vasconcella* species, especially *V. weberbaueri* and *V. monoica*, show resistance against some important babaco root diseases as *Fusarium oxysporum* and *Meloidogyne incognita*, and could be used as a rootstock for babaco grafting. The potential of *Vasconcella* species, which needs further detailed study, is increasingly under threat as population is growing, putting pressure on fallow and forest land and concentrating on food and cash crops consequently neglecting little known native fruit crops and reducing the natural vegetation in which they occur.

Resumen

El sur del Ecuador está considerado como centro de biodiversidad de los papayas de montaña, especies andinas del recién rehabilitado género *Vasconcella*, familia Caricaceae. Especies de *Vasconcella* en el sur del Ecuador crecen, en su mayor parte en estado silvestre, sobre 1000 msnm., y se componen de *Vasconcella cundinamarcensis* V.M. Badillo, *V. stipulata* (V.M. Badillo) V.M. Badillo, *V.* × *heilbornii* (V.M. Badillo) V.M. Badillo, *V. candicans* (A. Gray) A.DC. , *V. weberbaueri* (Harms) V.M. Badillo, *V. monoica* (Desf.) V.M. Badillo, *V. microcarpa* (Jacq.) A.DC., *V. parviflora* A.DC. y la nueva especie endémica *V. palandensis* (V.M. Badillo et al.) V.M. Badillo. En este momento sólo el híbrido natural *V.* × *heilbornii* 'Babaco', comercialmente conocido bajo el nombre babaco, es cultivado al nivel comercial en Ecuador y obtiene atención del mercado internacional que está expandiéndose continuamente con nuevas frutas subtropicales. Hibridación natural y la presencia de accesiones de las cuales la posición taxonómica (al nivel de especie) permanece confusa, combinado con un numero limitado de estudios botánicos, sugiere que la taxonomía de *Vasconcella* en el Ecuador no ha sido completamente explicada. No obstante, estudios de colección y caracterización locales demuestran que estas papayas de montaña tienen alta potencial agronómica para un cultivo futuro. Las características organolépticas de algunas accesiones y especies son muy promisorias, especialmente pare su use en jugos y mermeladas. Utilizando la hibridación, natural o artificial, se puede aún ensanchar esta potencial. El análisis de la actividad del complejo de enzimas proteolíticas (papaina) de estas accesiones y especies locales demuestra que el látex de frutas verdes posee hasta 15 veces más actividad proteolítica en comparación con cultivares de papaya (*Carica papaya* L.) seleccionados y cultivados para contenido elevado de enzimas. Algunas especies de *Vasconcella*, especialmente *V. weberbaueri* y *V. monoica* de muestran resistencia contra algunas enfermedades del raíz de babaco importantes como *Fusarium oxysporum* y *Meloidogyne incognita*, y podrían ser utilizados como patrón en injertos con babaco. El potencial de las especies de *Vasconcella*, aunque necesitando más investigación detallada, está amenazado con una población creciente, incrementando la presión sobre terrenos en barbecho y bosques y concentrándose en cultivos comerciales y alimentarios, descuidando especies frutales nativas pocas conocidas y reduciendo la vegetación natural en la cual estas especies crecen.

Introducción

Highland or mountain papayas consist of a group of under-exploited *Vasconcella* species that can be found in the subtropical Andean mountain climates of South America, particularly Colombia and Ecuador (National Research Council 1989). Compared to their well-known tropical cousin, the papaya (*Carica papaya* L.), they tend to be smaller, less succulent, and quite different, but often very pleasant, in taste.

Badillo (1971, 1993) presented a total of 20 species within the *Vasconcella* subgenus of the *Carica* genus, and recently added (Badillo et al. 2000) a new endemic species found in Southern Ecuador, resulting in a total of 21 species. Recently subgenus *Vasconcella* was rehabilitated as a genus, changing most of the nomenclature and making *Vasconcella* the biggest genus within the Caricaceae (Badillo 2000). Ecuador holds 15 of these 21 species (Badillo 1983, 1997, 1999) and must unquestionable be considered as one of the "hot spots" for *Vasconcella*. Southern Ecuador alone, covering only 39987 km^2 or 15 % of the Ecuadorian land area, comprises nine species (Badillo 1983, 1999; Van den Eynden et al. 1999) and is generally acknowledged to be an important centre for *Vasconcella* research (Soria 1991). The native *Vasconcella* species found in southern Ecuador generally occur over 1000 m above sea level (masl). They are *V. candicans* (A. Gray) A.DC., *V. cundinamarcensis* V.M. Badillo, *V. microcarpa* (Jacq.) A.DC., *V. monoica* (Desf.) V.M. Badillo, *V. parviflora* A.DC, *V. stipulata* (V.M. Badillo) V.M. Badillo, , *V. weberbaueri* (Harms) V.M. Badillo, *V.* × *heilbornii* (V.M. Badillo) V.M. Badillo, a natural hybrid, and the recently described endemic *V. palandensis* (V.M. Badillo et al.) V.M. Badillo.

The National Research Council (1989) classifies the potential of these *Vasconcella* species at three levels: (1) direct use of the tasty, high quality fruits; (2) use of genetic variability as "raw" material for the creation of new *Vasconcella* fruits; and finally (3) use in breeding programmes for papaya improvement in order to extend cultivation range, by using genetic endowment for cold adaptability, and improve papaya production, by using resistance genes from highland papayas.

Direct use of highland papayas is common in the Andes where fruits are eaten fresh, roasted, in juices, in marmalades or in preserves (Van den Eynden et al. 1999). Only babaco, *V.* × *heilbornii* 'Babaco', is already commercially developed. It was introduced as a crop in New Zealand in 1973 (Harman 1983) from where it spread in the eighties to Australia (Cossio 1988), Italy (Cossio 1989; Ferrara et al. 1993), Spain (Merino Merino 1989), France (CTIFL 1992), South Africa (Wiid 1994) and even Switzerland (Evéquoz 1990), Canada (Kempler et al. 1996) and the Netherlands (Heij 1989) where greenhouse trials have been initiated. The hybrid character of babaco implies vegetative propagation, giving rise to typical phytopathology problems. Solution of a number of propagation problems lies in the use of *in-vitro* propagation (Jordan & Velozo 1996; Vega de Rojas & Kitto 1991).

Use of highland papaya genes in papaya breeding is especially useful in programmes that focus on the incorporation of resistance against papaya ringspot virus. *V. candicans*, *V. cundinamarcensis*, *V. stipulata* and *V.* × *heilbornii* are Ecuadorian *Vasconcella* species that have been reported as being resistant against papaya ringspot virus (Manshardt & Wenslaff 1989). Interspecific gene flow between *Carica papaya* and *Vasconcella* species shows considerable postzygotic barriers making the use of embryo rescue indispensable (Mekako & Nakasone 1975; Drew et al. 1997).

The project "*Conocimientos y Prácticas Culturales sobre los Recursos Fitogenéticos Nativos en el Austro Ecuatoriano*" aimed at extending and conserving the knowledge on local native fruit species in Southern Ecuador. The highland papaya complex was one of the target fruit species that on the one hand shows a lot of potential but on the other hand is under an increasing threat of genetic erosion.

Material and Methods

The taxonomical situation of highland papayas in southern Ecuador, and its difficulties, was studied using existing taxonomical identification keys (Badillo 1971, 1983, 1993) during an ethnobotanical field survey from 1994 - 1997 and during *Vasconcella* germplasm collection trips (1997 – 1999). The phenotypical and morphological study was carried out on the 211 accessions that were collected in Loja Province during germplasm collection. A descriptor for highland papayas was elaborated, based on the IPGRI descriptor for *Carica papaya* (IPGRI 1988), and plants, leaves, flowers, inflorescences and especially fruits were characterised in detail. Accessions most suitable for use in traditional recipes and their optimised processing parameters were determined, resulting in different processed products.

Phytopathological studies focused on natural resistance of some *Vasconcella* species against the root fungus *Fusarium oxysporum* and the nematode *Meloidogyne incognita*, two important problems in commercial babaco (*V.* × *heilbornii* 'Babaco') cultivation in Ecuador. Greenhouse plants were inoculated with *F. oxysporum* (10^6 conidia per plant) and the typical *F. oxysporum* symptoms which were described against an established scale (Ochoa et al. 1999) whereas *M. incognita* infection was determined by counting the final nematode population after an initial inoculation (10^3 juveniles J_3 per plant).

Preliminary phytochemical enzymatic analysis of green *Vasconcella* fruits was performed after experiencing severe irritation symptoms during collections, indicating high papain content. Analysis of papain activity was carried out by Blue Star Chemicals, a Belgian papain importing and processing company. Latex was extracted on green fully grown fruits through 2 mm deep cuts. Latex was dried at 55 °C for 24 h. Proteolytic activity was determined using BAPA method, measuring the amount of N-α-benzoyl-DL-arginine-p-nitroanilide hydrochloride (DL-BAPA) that was hydrolysed by papain enzymes (Heyens 2000).

Results

During the ethnobotanical study a new *Vasconcella* species (*V. palandensis* (V.M. Badillo et al.) V.M. Badillo) was described. The specific *Vasconcella* germplasm collection revealed big problems in identifying some collected *Vasconcella* accessions with the existing identification tables. The Venezuelan Caricaceae specialist Victor M. Badillo (1993) mentions in his latest Caricaceae revision that numerous nothomorphs or varieties of the natural hybrid *V.* × *heilbornii* in especially southern Ecuador still remain undescribed. The high rate of natural interspecific hybridisation and presumably backcrossing that take place in southern Ecuador complicate a consistent taxonomical classification. Preliminary classification based on AFLP analysis revealed an inconsistency in the classification of *V. cundinamarcensis*, *V. stipulata* and *V.* × *heilbornii* and a huge genetic variability in the latter two species (Van Droogenbroeck et al. 2000).

The phenotypical or morphological characterisation evidences this variability by describing the expression of the genetic variability. A huge variability in pomological characteristics of a number of highland papaya accessions has been documented for Loja Province (Table 1). This huge variability, that makes correct taxonomical classification very difficult, is a big advantage in the selection of adequate accessions (species) for use as fresh or processed fruit. Apart from the typical characteristics of babaco, that during the last decennia has received more and more attention worldwide, a lot of other interesting pomological characteristics can be found in other unknown highland papaya accessions. Optimisation of the processing parameters of traditional recipes combined with the selection of the most adequate highland papaya type resulted in very promising processed products. Regionally, juices, marmalades and liquid preserves of highland

papayas have always been of local importance. These products, up till now mostly based on babaco fruits, have only recently been successfully introduced on the national markets and the first export attempts have been documented. The very aromatic *V. stipulata* looks very promising for the preparation of marmalade (at 62 ° Brix, without addition of pectin) whereas preliminary studies on the use as dehydrates for infusions confirm this potential.

Table 1. Pomological variability within 211 highland papaya accessions

	V. cundinamarcensis	*V. stipulata*	*V.* × *heilbornii* s.l.
Seed Index*	54.9 – 137.8	33.6 – 113.9	0 – 38.4
Fruit Weight (g)	61.6 – 216.3	52.8 – 179.6	46.2 – 1269.5
Percentage Pulp (%)	65.3 – 79.7	58.7 – 89.3	65.5 – 97.7
Soluble Solids (° Brix)	2.6 – 8.2	3.7 – 10.1	3.6 – 9.7

* Number of seeds / 100 g fruit

Babaco (*V.* × *heilbornii* 'Babaco') is still the only highland papaya that is cultivated at a commercial level in Ecuador, but its production is seriously threatened, especially in greenhouses, by the root fungus *Fusarium oxysporum* and the nematode *Meloidogyne incognita.* As adequate chemical treatments are lacking at the moment (Ochoa et al. 2000) the use of resistant *Vasconcella* rootstocks in babaco cultivation could become another promising use of some highland papayas. The presumed progenitors of babaco, *V. cundinamarcensis* and *V. stipulata*, combine *F. oxysporum* resistance with high *M. incognita* susceptibility, which precludes their use as rootstock. On the other hand, *V. monoica* and especially *V. weberbaueri* show resistance against *F. oxysporum* and very low *M. incognita* susceptibility (Table 2). Evaluation of grafting techniques using different species combinations showed good compatibility with success rates ranging 50 - 100 %.

Table 2. *Fusarium oxysporum* and *Meloidogyne incognita* susceptibility of highland papayas

Species	Days to reach final *Fusarium oxysporum* infection phase	Final *Meloidogyne incognita* population*
V. × *heilbornii*	71	821
V. stipulata	151	3,477
V. cundinamarcensis	149	2,835
V. monoica	No Symptoms	107
V. weberbaueri	No Symptoms	15

* initial population : 10^3 J_3 juveniles per plant

Highland papayas are generally acknowledged to have high papain activities (National Research Council 1989), although concrete data are scarce. Preliminary papain analysis of some Ecuadorian *Vasconcella* species indeed revealed a very high proteolytic activity (Table 3), especially when compared to *Carica papaya*, currently used for papain extraction. Particularly some varieties of *V.* × *heilbornii* and *V. stipulata* show promising papain activity levels. Nevertheless, caution is warranted as no results about exact enzymatic composition nor actual yields are currently available.

Table 3. Papain activity in Ecuadorian *Vasconcella* species

Species	Papain Activity (mU BAPA/mg dried latex)
Carica papaya (reference)	10.4
V. × *heilbornii* 'Babaco'	38.1
V. × *heilbornii* var. *chrysopetala*	127.6
V. stipulata	129.4
V. cundinamarcensis	57.0
V. monoica	55.1

List of special symbols: **α** : Greek lower case alpha × : multiplication symbol (hybrid)

Discussion

The huge intra- and interspecific diversity of highland papayas in southern Ecuador considerably complicates their taxonomical classification. A complete *Vasconcella* collection combined with a thorough revision at taxonomic and genetic level is advised in order to solve these problems. Nevertheless, this diversity at *Vasconcella* species level offers a wide range of possibilities that have only recently received scientific attention. Germplasm can be used in *Vasconcella* or papaya breeding programmes geared at developing high quality fruits, which can be used as fresh fruits and in processing as well. Genetic resistance of some species against important pests or diseases can also be used in the development of better varieties. Finally, the phytochemical properties of highland papayas, especially their proteolytic enzymes, prove to be promising. As research on highland papayas is in its preliminary stage a lot of fundamental research still needs to be done.

In spite of the wide array of possibilities that highland papayas offer, their present distribution in one of the hot spots of diversity is under increasing threat. As human population increases, so does pressure on land, resulting in deforestation and loss of wild *Vasconcella* stands. The shift of cultivation system towards cash and food crops results in a neglect of native fruit crops, which do not show big economic advantages, and results in a reduction in highland papayas cultivation. Overall, it must be concluded that the threat, or presence, of genetic erosion in highland papayas in southern Ecuador is considerable.

In order to take full advantage of the possibilities that highland papayas offer, it is obvious that there is an urgent need for conservation actions. The international community must be prepared to help broaden the knowledge on highland papayas in order to convince local organisations and farmers of the potential that exists in southern Ecuador and the surrounding areas. Local awareness is the only way to safeguard the present *Vasconcella* populations from further losses. The establishment of multilocation field collections is one of the first steps that have to be taken. These gardens would protect important *Vasconcella* accessions and can serve at the same time as field laboratories for future research programmes.

More information and photographs of the different highland papayas can be found at the URL http://allserv.rug.ac.be/~xschelde/start.htm.

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