Variation in Morphological and Biochemical Characters in Genotypes of Maca and Yacon

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Abstract

A set of 15 genotypes of maca (*Lepidium meyenii* Walp.) and 25 genotypes of yacon (*Smallanthus sonchifolius* (Poepp. & Endl.) H. Robins.) planted in field conditions was studied for morphological and biochemical variability. Morphological characterization of maca included evaluation of length, hypocotyl weight, shape, skin and flesh colour. In yacon we evaluated shape and colour of root tubers, character of skin, flesh colour and number of roots. Preliminary results showed that maca forms hypocotyls of small length (up to only 6 cm for genotype 168) in the Czech environmental conditions. From the viewpoint of yacon root tubers production, there were the most productive genotypes 25, 51, 75 and 85 (3.8 kg), in opposite the lowest yield was recorded in genotype 1237 (1.4 kg). Isozymes polymorphism of esterases and acid phosphatases was also used for characterization of the maca and yacon genotypes. No variation in acid phosphatase isozymes was recorded in either species. However, for esterase zymograms variation was found with three groups in maca and four groups in yacon. The biochemical analyses of dietetic features of tuberous roots are in progress.

INTRODUCTION

Maca (*Lepidium meyenii* Walp., Brassicaceae) and yacon (*Smallanthus sonchifolius* (Poepp. & Endl.) H. Robins., Asteraceae) are two crops originating in South America, have been little known and neglected in Europe. The human view on maca and yacon has been changed because of antidiabetic, nutritious and fertility-enhancing properties of both crops. The possibility of maca and yacon cultivation in the conditions of the Czech Republic was firstly proved in nineties (Frček, unpubl.; Frček et al., 1995).A limited information on the morphological and isozymes variation of maca and yacon is available in the world scale (Quirós and Cárdenas, 1997). The complex research is aimed on utilization of both Andean crops as functional food and food supplements available for broad public (Ulrichová et al., 2000; Valentová et al., 2001). The main goals of our study are improvement of the cultivation methods of maca and yacon in the field conditions of the Czech Republic and obtaining results on morphological and isozymes variation in these crops.

MATERIALS AND METHODS

Plant Material and Cultivation

A set of 15 maca genotypes originating from Peru and a set of 25 yacon genotypes secondaryly originating from New Zealand (Ecuador-primary centre of origin) have been evaluated (Table 1). The genotypes are maintained as genetic resources of perspective crops in Potato Research Institute Havlíčkův Brod, Ltd., Czech Republic. Plants were cultivated and evaluated in the field conditions of the Haná region - Olomouc (altitude 210 m, day mean temperature 16.3°C, precipitation during cultivation period 271.4 mm) from May to October 2001. Maca was cultivated on a black unwoven textile, 10 plants per genotype, planting distance 45x45 cm (this cultivation method was not optimal). Some maca genotypes were cultivated in a greenhouse (temperature by day 18-30°C, by night 12-16°C) (this type of cultivation was more suitable). Yacon was planted in furrows, 5 plants per genotype, spacing 70x70 cm.

Morphological Assessment

The shape of maca hypocotyls (Echeragay, 1999) was assessed at the time of harvest. Shape of its base and apex was evaluated according to a descriptors for *Brassica* and *Raphanus* (IBPGR, 1990). Subsequently, the weight, colour of hypocotyl and maculae (spots), length of hypocotyl and root, shape of hypocotyl in frontal view and colour of flesh were assessed. In yacon, we evaluated weight of the root tubers per plant, weight of caudexes, colour of root tubers, character of skin, colour of flesh, and shape in transversal section of root tubers. Shape of root tubers was also characterized according to morphological descriptors for yacon (Frček, 2001).

Isozymes Analyses

Young true leaves from each plant per accession were taken and a bulk sample used for analysis. Approximately 300 mg plant tissue was frozen by liquid nitrogen and were crushed and homogenized in 900 ml of 0.1 M Tris-HCl sample buffer (pH = 7.2) containing 0.1% 2-mercaptoethanol (Aung and Evans, 1987). PAGE gels were specifically stained for esterases (Est) - Fast Blue RR solution and acid phosphatases (Acp) - Fast Black K solution (Vallejos, 1983).

RESULTS AND DISCUSSION

Morphological Assessment

Preliminary results of morphological assessment of maca underground parts are summarized in Table 2. The results for yacon are shown in Table 3. The mean length of maca hypocotyls and roots is shown in the Fig. 1, the mean weight of yacon root tubers and caudexes is shown in Fig. 2.

The most often shape of maca hypocotyls named “Raku chupa” was recorded in 13 genotypes, shape “Aqochínchay” in 5 genotypes. The least frequent shapes “Achka chupa” and “Kimsa kucho” were observed in 1 resp. 2 genotypes (Table 2, Fig. 3). The majority of genotypes was marked with a plane shape of hypocotyl base, except for 5 genotypes with concave and 2 genotypes with convex base. The most common acute apex was observed in 11 genotypes and obtuse in 7 genotypes, while convex shape of apex was described in 2 genotypes. The violet and creme colour of hypocotyl were represented equally with exception one genotype with dark yellow hypocotyl. The creme colour of spots was confined to violet colour of hypocotyl. There were not recorded spots in creme and dark yellow hypocotyls. Shape of hypocotyl in frontal view was assessed as a circle (12 genotypes), square (8 genotypes) and oval (1genotype). Yellow, pale yellow and dark yellow colours of hypocotyl flesh were presented more or less equally (Table 2).

Five basic shapes of root tubers in yacon genotypes were recorded. The most common were shapes 14 (10 genotypes), 12 (6 genotypes), 5 (7 genotypes) and 4 (5 genotypes) (Table 3, Fig. 4). Shape 1, 7 and 8 were described only in one genotype. The root tubers were yellow (21 genotypes), violet (5 genotypes) and pale yellow (4 genotypes) in colour. No differences were recorded in character of skin, the fine skin was characteristic for all genotypes studied. The shape in transversal section was evaluated as a irregular oval (15 genotypes), oval (9 genotypes) and circle (7 genotypes). The colour of flesh was assessed as a pine colour with dark middle (12 genotypes), pine colour (6 genotypes), dark pine colour (5 genotypes) and pale pine colour (3 genotypes). Some genotypes were marked by a few amount of roots (12 genotypes), while the others possessed many and moderate number of roots (9 and 7 genotypes resp.) (Table 3).

The greatest length of hypocotyl was found in genotype 168 (6 cm), in opposite the lowest in genotype 29 (3.6 cm). From the viewpoint of yacon root tubers production, there were the most productive genotypes 25, 51, 75 and 85 (3.8 kg), in opposite the lowest yield was recorded in genotype 1237 (1.4 kg). The greatest weight of caudexes (1.2 resp. 1.3 kg) in genotypes 64 and 83 were recorded, while the genotypes 22 and 47 had the lowest weight (0.55 resp. 0.6 kg) (Fig. 2).

It is evident from the above presented data, that the large morphological variability exists among genotypes of both crops. Since the unique set of maca and yacon genotypes have not been studied yet, there is no chance to compare our preliminary results with literature.

Isozymes Analyses

A set of 15 maca genotypes and 25 genotypes of yacon was tested for variation in acid phosphatases and esterases isozymes. No polymorphism in acid phosphatases isozymes was found in either species, however three polymorphic groups of esterases were recorded in maca and four groups in yacon (Table 4). In spite of that, a large variation in morphological and yield parameters, was noted. A clear relationships between them and polymorphism of esterases was not apparent (Tables 2, 3 and 4). The esterases zymogram of genotype Unalm amarrila differed from the other two groups. This genotype was not evaluated from the morphological viewpoint because of its different life cycle (all plants were annual and they did not form hypocotyls in our conditions). However, a very low degree of esterases isozyme polymorphism was found in detailed analyses (Lebeda et al., 2003) where only the genotype 145 showed dissimilarity of type esterases spectrum. The differences in esterases zymograms given in both analyses are caused by using different methodical approaches. Thus, the polymorphism analyzed on the base of proteins, may be highly variable and the results may be heterogeneous which is in accordance with results obtained in various plant species (Soltis and Soltis, 1989; Manchenko, 1994).

Table 3 presents separation of 25 yacon genotypes grouped according to shape of root tubers (Frček, 2001). The morphological variability corresponds too little with esterases polymorphism, where we recorded four polymorphic groups (Table 4). There is 70 % of genotypes presented in the largest group A. The remaining isoforms represent 2-4 genotypes. The actual data correspond fairly well with results obtained in detailed screening of isozymes variation of both Andean crops (Lebeda et al., 2003). However, the differences of zymograms of individual groups are to small to predicate variability in complex conception.

The preliminary results obtained in this study showed a very low variation of isozyme polymorphism in contrast to a large variability of morphological characters. The question remains, how will the morphological variability correspond with variability of some important nutritious components (Daňková et al., 2001; Valentová et al., 2001). This topic as well as an establishment of variation in DNA content (by flow cytometry) in genotypes of both crops are in progress (Lebeda et al., unpubl. results).

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Tables

Table 1. Survey of maca and yacon genotypes used in the study of morphological and isozymes variability.

	Number of genotype
Maca (*Lepidium meyenii* Walp.)	13,29,136,144,145,146,151,153,168,265,280,290,310, 314, Unalm amarylla
Yacon (*Smallanthus sonchifolius* (Poepp. & Endl.) H. Robins.)	5,6,17,18,20,22,25,28,31,47,48,51,57,60,64,68,74,75, 83,84, 85,88,90,92,1237

Table 2. Hypocotyl variation in maca genotypes.

Gen. no.	Hypocotyl Shape	Shape of base	Shape of apex	Colour	Colour of spots	Shape in frontal view	Colour of flesh
13	2, 8	convex, plane, concave	obtuse, convex	creme	without spots	circle	yellow
29	8	plane	acute, obtuse	creme	without spots	circle, square	pale yellow
136	8, 9	plane	acute, obtuse	violet	creme	circle, square	dark yellow
145	8, 9, 11	plane, concave	acute, obtuse	violet	creme	circle, oval, square	pale, dark yellow
146	2, 8	concave, plane	acute	violet	creme	square	yellow
151	8	concave, plane	acute	violet	creme	circle, square	pale, dark yellow
153	8	convex	obtuse	violet	creme	circle	yellow
168	8, 9	plane	acute, obtuse	violet	creme	circle, square	yellow
265	8	plane	acute	creme	without spots	circle	pale yellow
280	8	plane	acute	creme	without spots	circle, square	yellow
290	8, 9	plane, concave	acute, obtuse	creme	without spots	circle, square	pale, dark yellow
310	8	plane	acute	dark yellow	without spots	circle	not evaluated
314	8, 9	plane	convex, acute	creme	without spots	circle	yellow

Table 3.Variation of underground parts in yacon genotypes.

Gen. no.	Root tubers Shape	Colour	Character of skin	Shape in transversal section	Colour of flesh	Amount of roots
5	5	yellow, violet	fine	circle	pine colour	many
6	14	pale yellow	fine	oval	pine colour with dark middle	moderate
17	14	yellow	fine	oval	dark pine colour	few
18	12,14	yellow	fine	irregular oval	pine colour with dark middle	few
20	14	yellow	fine	irregular oval	pine colour with dark middle	few, moderate
22	12, 14	yellow	fine	oval	pine colour	many
25	7	pale yellow	fine	irregular oval	pine colour with dark middle	moderate
28	4	yellow	fine	circle	pine colour with dark middle	few
31	5	yellow	fine	irregular oval	dark and pale pine colour	few
47	4	yellow	fine	circle, oval, irregular oval	pale pine colour	many
48	14	yellow	fine	oval	dark pine colour	few, many
51	4	yellow	fine	irregular oval	pine colour with dark middle	few
57	12	yellow, violet	fine	irregular oval	pine colour with dark middle	few
60	5	yellow	fine	irregular oval	pale pine colour	few
64	14	yellow, violet	fine	circle	pine colour	many
68	14	pale yellow	fine	irregular oval	pine colour with dark middle	many
74	5	yellow	fine	circle, irregular oval	pine colour with dark middle	few
75	12	yellow	fine	irregular oval	pine colour with dark middle	few
83	5, 8,14	yellow, violet	fine	circle, oval	pine colour	many
84	1,14	yellow	fine	oval, irregular oval	pine colour with dark middle	moderate
85	5	yellow, violet	fine	irregular oval	pine colour with dark middle	many
88	4, 12	yellow	fine	irregular oval	pine colour	few, moderate
90	12	pale yellow	fine	oval	dark pine colour	moderate
92	5	yellow	fine	oval	dark pine colour	moderate
1237	4	yellow	fine	circle, irregular oval	pine colour	many

Table 4. Polymorphism of esterases in maca (*Lepidium meyenii*) and yacon (*Smallanthus sonchifolius*) genotypes.

Group	*Lepidium meyenii* genotypes
A	29, 136, 168, 153, 265, 290, 314
B	145, 146, 151, 280, 310
C	Unalm amarilla

Group	*Smallanthus sonchifolius* genotypes
A	17, 18, 20, 22, 25, 28, 51, 57, 64, 75, 83, 84, 85, 90, 1237
B	5, 48, 88, 92
C	6, 60, 68
D	47, 74

Figures

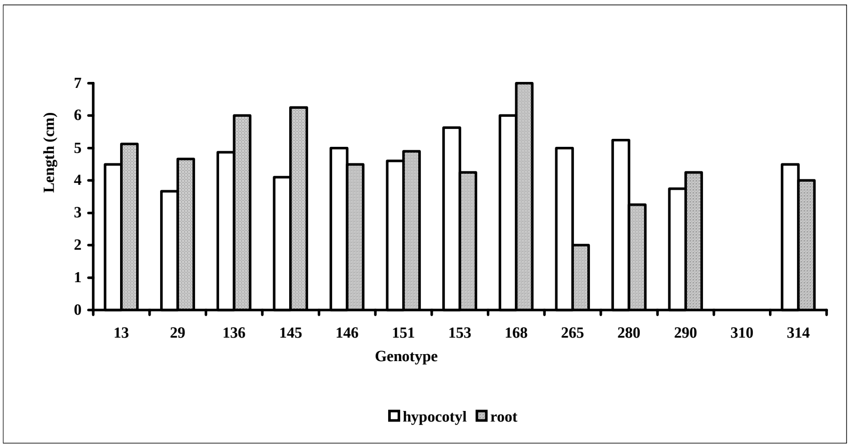


Fig. 1. Mean length of hypocotyls and roots in maca genotypes in 2001.

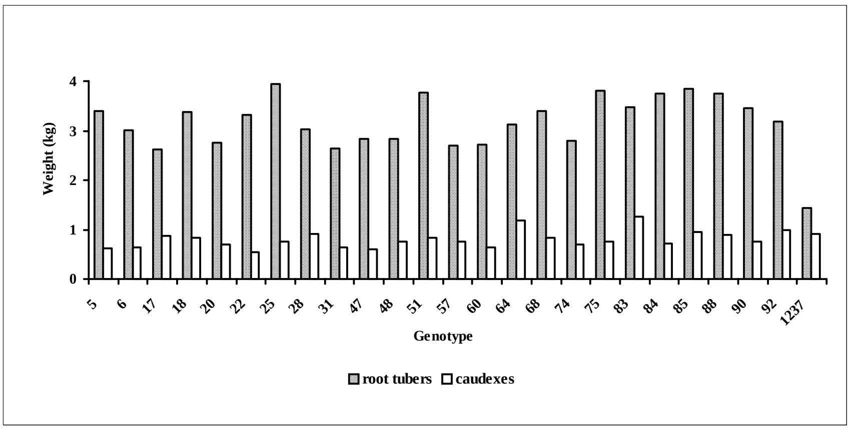
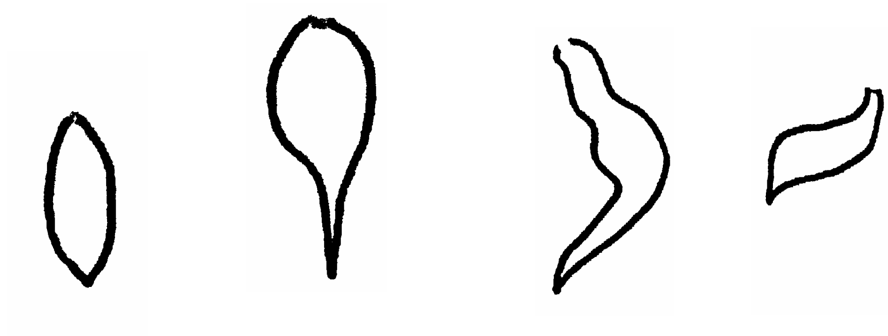


Fig. 2. Mean weight of root tubers and caudexes in yacon genotypes in 2001.

Raku chupa Aqochínchay Achka chupa Kimsa kucho

Fig. 3. Basic shapes of hypocotyl recorded in maca (according to Echegaray, 1999).



4 5 12 14

Fig. 4. Basic shapes of root tubers recorded in yacon (according to Frček, 2001).