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A REVIEW ON SWEET POTATO WITH SPECIAL FOCUS ON HUNGARIAN PRODUCTION I: UTILIZATION, BIOLOGY AND TRANSPLANT PRODUCTION

TAMÁS MONOSTORI, ADRIENN SZARVAS

University of Szeged, Faculty of Agriculture
H-6800 Hódmezővásárhely, Andrássy u. 15.
mt@mgk.u-szeged.hu

ABSTRACT
Sweet potato [*Ipomoea batatas* (L.) Lam.] is a root crop plant of tropical-subtropical origin which is widely produced in the temperate zone, too. Along with several European countries, it is also grown in Hungary for decades but the increase of its growing area was stimulated by the continuously increasing consumers' demand in the last couple of years. Despite the available cultivation guides and experiences, yield stability is still not fully solved, growing site- and genotype-specific recommendations are still missing. Due to the lack of severe plant health problems detected until our days, a Pathogen Tested (PT) scheme for the production of sweet potato planting material has not been organized yet. With the increase of the growing area, however, the occurrence of various diseases and even that of leaf and root pests is expected, possibly in a short period. Thus, the stabilization of sweet potato among the cultivated plants in Hungary will require the establishing of a PT scheme for the country's conditions, as far as possible, under the control of the responsible supervisory organizations.

Keywords: sweet potato, *Ipomoea batatas*, botany, ecological requirements, transplant production

INTRODUCTION

Sweet potato, also called batata, camote, boniato, kumara, nyamis, uwi, ubi, etc. [*Ipomoea batatas* (L.) Lam.] is a tropical-subtropical plant by origin, however, it has also been grown in temperate climate for centuries. It belongs to the traditional cultures in the Southern states of the US (North Carolina, Mississippi, Louisiana, California, Oklahoma, Arkansas, etc.), but it is also registered by FAO in several European countries such as Spain, Portugal, Italy and Greece (FAO, 2014). Although the rapidly increasing consumers' demand in Europe led to a considerable increase in sweet potato import from the US (PULLMANN, 2015), the interest of European farmers has also been increasing. Besides the above mentioned, sweet potato growing is also published in Hungary (HORVÁTH, 1991A,B,C; URL3,4), Croatia (NOVAK ET AL., 2007A,B; NOVAK ET AL., 2008; BUŠIĆ, DATE UNKNOWN), Slovenia (BAVEC AND BAVEC, 2006; KUNSTELJ ET AL., 2013), Serbia (URL6), Ukraina (YUKALO ET AL., 2014), Romania (RADUT, 2014; DINU AND SOARE, 2015), Poland (KROCHMAL-MARCZAK AND SAWICZKA, 2010) and the southern part of England (LUCAS, 2013; HYDE, 2015; SANDERSON, DATE UNKNOWN), among others.
Following the first attempts for growing one hundred as well as sixty years ago (SURÁNYI, 1916; PORPÁCZY, 1953), sweet potato is cultivated in Hungary for more than twentyfive years but it became well-known and popular in the last years only – thanks to media appearances and its increasing commercial availability (HORVÁTH, 1991A,B,C; URL3,4). Currently, the consumers' demands for sweet potato are so high that cannot be fulfilled even by the intensively growing producers' circle. Besides the growing area of unsatisfactory size, other reasons can be local problems in yield stability still occurring frequently, in spite of the available guides and experiences in production technology. A crucial question is to develop technological manuals based on the optimization of the technological elements in growing site- and cultivar-specific experiments. The practical

experiences can serve as starting point that can be verified or open to be modified this way. It is essential to set up experiments from the transplant growing up to the storage.
This work, as the first part of a series of reviews on sweet potato production, aims to give a complex view of the importance and usage as well as the botanical features and ecological requirements of the plant. Further goal is to discuss the various methods of the production of planting material with special focus on agro-ecological conditions in Hungary.

THE IMPORTANCE AND USAGE OF SWEET POTATO

Sweet potato is the 6th most important food crop in the world following rice, wheat, potato, maize and cassava (URL1). At the same time, sweet potato is an important fodder crop, too. Along with its cultivation history of thousands of years, its remarkable composition and nutrition physiological effects can also explain the importance of sweet potato.
Sweet potato is a high-energy food, 100 grams giving 113 cal energy compared to 75 cal of potato. Its storage roots possess a total carbohydrate content of 25-30%, 98% of which is easily digestible (VILLORDON, 2013). During storage, amylase activity is increasing in storage roots. It results in the decreasing of the initial starch content (47-74%), its metabolism into glucose and sucrose, already during the first 60 days of storage (ZHANG ET AL., 2002).
One of the most important physiological effects of sweet potato is its role in the potential improvement of blood sugar regulation thus being efficacious in the management of type 2 diabetes mellitus. It has a glycemic index (GI) ranking of medium: 63±6 (ATKINSON ET AL., 2008). However, GI (41±5 – 93±5) can depend significantly on the processing method and to a lesser extent on intravarietal differences. Samples prepared by boiling show the lowest, while those processed by baking and roasting the highest values (BAHADO-SINGH ET AL., 2011). Its antidiabetic effect is primarily related with its high fibre content and its increasing effect on blood level of adiponectin, which positively affect carbohydrate absorption and insulin level, respectively (LUDVIK ET AL., 2008).
Sweet potato (primarily the orange-fleshed cultivars) is an important source of provitamin A carotenoids, 100 grams containing 5,345 international units (IU) referring to 121% of the recommended dietary allowance (VILLORDON, 2013).
Sweet potato also is a source of vitamin C (20-30 mg/100 g), some components of the vitamin B complex (thiamine, riboflavin, niacin), potassium (204-340 mg/100 g), phosphorus (28-49 mg/100 g), calcium (21-30 mg/100 g), magnesium (10-24 mg/100 g) and iron (0.8 mg/100 g), among others (ANTONIO ET AL., 2011; VILLORDON, 2013).
Its purple-fleshed cultivars show antioxidant and anti-inflammatory effects due to their high anthocianin (peonidins, cyanidins) content. Defined genes coding for enzymes of anthocianin biosynthesis are *IbMYB1*, *IbMYB2* (MANO ET AL., 2007).
Protein content of sweet potato is low (2.5-7.5% of dry matter). Eighty percentage of its protein content is sporamine which has antioxidant effect. At the same time, sporamine has a significant trypsine-inhibitory effect which must be considered if storage roots are used as animal fodder (MATSUOKA ET AL., 1990). Proteins of sweet potato have a high lysine (higher than in rice) and low leucine content (VILLORDON, 2013).
Along with its storage roots, leaves of sweet potato are also a remarkable source of food and fodder. One hundred grams of fresh batata leaves contain, among others, 117 mg calcium, 1.8 mg iron, 3.5 mg carotene, 7.2 mg vitamin C, 1.6 mg vitamin E and 0.56 mg vitamin K, giving a quality similar to that of spinach. Besides, it contains at least 15 anthocyanin and 6 polyphenolic compounds that can contribute to antioxidant, antimutagenic, anti-inflammatory, anticarcinogenic, antibacterial and antidiabetic effects

(ISLAM, 2006, 2007). Sweet potato leaves have a crude protein content of 25.5-29.8% showing a digestability of 74-76% in pigs (AN, 2004).

Sweet potato is very important as animal fodder as well. The major producer of the world, China utilizes ca. 40% of the crop in this way. Both its storage roots (fresh or processed by boiling, drying, pelleting, milling, etc.) and its foliage (fresh, dried or ensiled) can be used for feeding pigs (primarily with roots but also with leaves), cattle (primarily with foliage) and other livestock (SCOTT, 1991; AN, 2004). Storage roots can be produced directly for feeding purposes or can be utilized as byproducts of food processing. Fresh sweet potato tubers usually show a high level of trypsin inhibitor activity (TIA): 153.5 – 628.2 mg trypsin inhibited per g protein. Depending on genotype, this level could be reduced to 12.1 – 525.2 by heat treatment (SENANAYAKE ET AL., 2013). The main factors responsible for TIA are storage proteins (primarily sporamin) giving ca. 60% of water-soluble proteins. TIA is positively correlated with the protein content of roots (TSOU ET AL., 1989). The reduction in digestibility can reach 27%. One of the most effective methods for the inactivation of trypsin inhibitors is heat treatment at 100 °C for 5 - 15 minutes (LIN, 1989; SENANAYAKE ET AL., 2013). On the other hand, digestibility of storage roots can also be improved by selecting varieties with low TIA thus making utilization without heat treatment possible (TSOU ET AL., 1989). According to OKE AND WORKNEH (2013), the opportunities for expanding the use of sweet potato are in three categories such as fresh and processed for human consumption, fresh and dried for animal feed, starches and flours for food and non-fod uses.

Industrial utilization of sweet potato is relatively less important in our days; however, it can be found in several fields. In the region of China, Japan and South Korea 30-63% of sweet potato production is used for starch extraction (FUGLIE ET AL., 2006). Due to its high starch/carbohydrate content, sweet potato can be an important raw material for ethanol production, 100 kg fresh roots yielding 14.5 l ethanol compared to 11.4 l for potato, 11.9 l for sugar beet, 17.6 l for wheat, barley, oat, and 44.9 l for maize (VILLORDON, 2013). Under given conditions in the USA (Alabama and Maryland) calculated ethanol yields (m^3 per hectare) were 5.2-6.4 for sweet potato which was comparable with 2.0-2.8 for corn, and 4.0 for cassava, only sugar cane – the most important plant source for bioethanol – giving better result of 6.4-9.6. However, start-up costs due to hand-labor associated with planting, cultivation and harvesting make the cost of culinary sweet potatoes as bioethanol prohibitively expensive (ZISKA ET AL., 2009). Breeding and development works are underway to develop sweet potato cultivars of increased yield and high carbohydrate content that can be grown successfully by mechanically planting root pieces – thus reducing costs (GEORGE ET AL., 2015). A unique utilization possibility for sweet potato is the production of biodegradable and carbon neutral bioplastics for automotive products (e.g. at Toyota), plastic sheeting for crop propagation and for domestic refuse bags (URL9).

The majority of patents reviewed by BARNES AND SANDERS (2012) focusing on the functional use of sweet potato fall under the category of ornamental products (for landscape and/or containerized gardens) and alternative food products (e.g. fries and chips, flakes, yogurt, juices), with only a few fuel ethanol products.

BOTANY

Sweet potato is a dicotyledonous plant belonging to the order Solanales, to the morning glory family (Convolvulaceae), to the genus of Ipomoea (*Figure 1*). It is a tuberous root plant, with a vine system expanding horizontally and developing a relatively shallow

canopy. Branching pattern, internode length, overall vine length, as well as the size, petiole length, and shape of leaves show considerable variability among genotypes, the latter ones even on the same plant (URL11). Batata flowers are complete, with petals united into a trumpet-shaped corolla that is usually white with pink to purple throat. It is a short-day plant (BAVEC AND BAVEC, 2006). Seeds are borne in a capsule and have a hard seed coat. They are dark brown to black, sometimes speckled or tan, and has prolonged dormancy. They are 3-5 mm in diameter. Its 1000 grain weight is about 20 g (STATHERS ET AL., 2013). Depending on genotype and growing conditions, however, flowering can fail, or sterility occurs. Sweet potato is a hexaploid with 90 chromosomes (HUAMÁN, 1999A).

The formation of storage roots can be closed or open cluster, disperse or very disperse. The roots vary in shape and size: round, round-elliptic, elliptic, ovate, obovate, oblong, long oblong, long elliptic, and long irregular or curved. The root skin color can be whitish, cream, yellow, orange, brown-orange, pink, red-purple, and very dark purple. The flesh color can be white, cream, yellow, or orange. However, red-purple pigmentation can also occur in the flesh in various patterns (HUAMÁN, 1999B). The two main commercial types of sweet potato are

- the 'staple type' cultivars with white- to cream-colored flesh, higher dry matter, starch and protein content, as well as a chestnut-like flavor, and
- the 'dessert type' cultivars of orange flesh, higher β-carotene and simple sugar content, as well as with a flavor similar to that of baked squash or carrot.

According to AUSTIN (1988), the primary center of origin of sweet potato was between the Yucatan peninsula (Mexico) and the mouth of the Orinoco River (Venezuela). Although early sweet potato remnants dating back to 8000 BC are known from Peru (STEINGOLD, 2008), the much lower molecular diversity found in the Peru-Ecuador region suggests that this region could be considered as a secondary center of diversity (ZHANG ET AL., 1999). The 'cultigen' was most likely spread by local people to the Caribbean and South America by 2500 BC (AUSTIN, 1988).

Figure 1. Foliage, flower and storage roots of sweet potato
Source: authors

Sweet potato is a naturally transgenic crop: it carries the *Ib*T-DNA1 és *Ib*T-DNA2 sequences of *Agrobacterium tumefaciens* and *A. rhizogenes* origin. Homologies between open reading frames (ORFs) of the foreign sequences and genes of defined role (e.g. tryptophan-2-monooxygenase - *iaaM*, indole-3-acetamide hydrolase - *iaaH*, C-protein - *C-prot*, agrocinopine synthase – *Acs*) were detected but their actual physiological role is still to be determined. As at least one of the T-DNAs is present in all the 291 tested cultivated

clones, but not in the closely related wild relatives, it is therefore conceivable that the transferred genes contributed to the expression of a trait that was subsequently selected for during domestication (KYNDT ET AL., 2015).

SWEET POTATO PRODUCTION

Sweet potato production quantities by continent are shown in *Table 1*. In the order of countries, China is the first one with a total production of 70,963,630 tons, giving 68% of the world's sweet potato yield. On the 2nd to 10th places China is followed by Nigeria, United Republic of Tanzania, Ethiopia, Indonesia, Angola, Uganda, Vietnam, United States of America, and Mozambique with productions at a lower order of magnitude (between 3,478,270 and 1,313,380 tons) (FAO, 2014). In Europe, sweet potato production is registered by FAO in Portugal (22,440 t), Spain (21,800 t), Italy (6,723 t) and Greece (5,150 t) only, but it is cultivated in numbers of other countries, too (see above).

Table 1. Total production (tons) of sweet potato in the world and by continents (FAO 2014)

World	**104,453,966**
Asia	**78,615,157**
Africa	**21,110,486**
Americas	**3,879,431**
South America	1,364,385
Northern America	1,342,070
Caribbean	1,122,937
Central America	50,038
Oceania	**792,780**
Australia	43,690
Europe	**56,113**

ECOLOGICAL REQUIREMENTS

Sweet potato is considered the most widely adapted of the agriculturally important root crops native to the humid tropic and subtropic regions, and is successfully grown in many temperate regions.

Climate

The zone of sweet potato cultivation is in latitudes between about 40° N and 40° S and from sea level to about 2000 m elevation in tropical highland zones. It requires a minimum frost-free period of 120-150 days. Thrives if minimum is above 24 °C, and does not grow well below 10°C. It prefers plenty of sunlight and warm nights, does not tolerate shadow (HUAMAN, 1999B; CLARK, 2013; URL3; URL8; URL10). Short days promote fleshy root development and flowering, while long days promote top growth (URL5).

It needs 500 mm of rainfall while growing, but 750-1000 mm of rain for the whole year. A dry period 50 days after planting is unfavorable because the storage roots are forming. After roots initiated, sweet potato withstands drought, but it does well with 2-2.5 cm per week rain or irrigation. When the crop is close to be harvested, little or no rain is preferred (CLARK, 2013; THOMPSON ET AL., 2014; URL10). Water stress during the tuber initiation

and tuber maturity phases adversely affect tuber development and yield, compared to the stress during the tuber development phase (NAIR ET AL., 1989).

Soil

For the development of more and better quality roots, a well-drained, light, sandy loam, or silt loam soil is needed. On rich, heavy soils sweet potatoes produce high yields of low-quality roots, while on extremely poor, light sandy soils low yields of high-quality roots. Both surface and internal drainage are important, because poor surface drainage may cause wet spots reducing yields, and poor internal drainage also reduces yields. Soils of poor internal drainage have a high moisture content and poor aeration that cause batata roots to be large, misshapen, cracked and rough skinned (CLARK, 2013; URL5). Areas just broken from sod or pasture, as well as excessive amounts of organic matter should be avoided (THOMPSON ET AL., 2014). Sweet potato tolerates soil pH between 5.5 and 6.8, the optimum being 5.8 to 6.0 (CLARK, 2013).

THE PRODUCTION OF PLANTING MATERIAL

Cultivation strategies of sweet potato vary according to the region: in the tropics, plants are produced and maintained on the field whole year, while in temperate regions roots are stored during winter to serve as initial material for sprout production for the subsequent crop (CLARK, 2013).

In sweet potato growing, 'slips' – sprouts grown from mature storage roots – are used as planting material. The application of seed tubers like in potato growing is considered to be useless here (HORVÁTH, 1991C), although according to some authors, it can be useful if the availability of slips is not sufficient (URL7). Early Hungarian cultivation trials showed the benefits of using slips instead of seed roots: the storage root yield was 25% higher in the former case (SURÁNYI, 1916; PORPÁCZY, 1953). The techniques for deriving slips (also called 'draws') of proper quality show some variability – primarily according to the growing region. Well-organized Pathogen Tested (PT) schemes providing the highest quality of planting material are in use in several countries, however, they are lacking in most of the tropical-subtropical regions (for review, see HENDERSON, 2015).

Transplant production in tropical and sub-tropical regions

In most of the tropical regions, sweet potatoes are grown throughout the year, thus traditionally; propagation is performed using field cuttings from vines. In the two basic systems used, vine cuttings (slips) derive from nursery beds, or from commercial fields (KAPINGA ET AL., 2009; STATHERS ET AL., 2013). When planting material is collected from vines, the top (apical) portion of three nodes ca. 20-30 cm in length must be cut for various reasons. This part recovers from shocks by cutting and planting most easily, and establishes faster than the lower parts of the vine. The tip of the vine is more likely free of sweet potato weevil pupae, larvae or eggs, or stemborer eggs. From longer vines several cuttings can be taken, however a vine portion of at least 15 cm must remain on the plant. In the case of slips deriving from starter roots, the selection is performed as described later in this paper (STATHERS ET AL., 2013).

The so-called rapid multiplication technique is also widely used in the tropics. This case, nursery beds are established by planting 'mini cuttings' derived from the upper 25-30 cm part of the vine cut into short pieces of 2 or 3 nodes, and one leaf at the top part left. Longer cuttings (at least 3 nodes, ca. 20 cm) perform better than the shorter (ca. 10 cm) ones. Donor plants that are free of diseases, pests and drought effects should be preferably

2-3 months old. Cuttings are planted upright or at a slant at a spacing of 10 cm x 20 cm, with at least two of the nodes buried under the soil (KAPINGA ET AL., 2009; STATHERS ET AL., 2013). The first harvest of vine cuttings is possible after 6 to 8 weeks, and can be repeated ('rattooning') up to 3 times (STATHERS ET AL., 2013).

In PT systems, to obtain large numbers of stem cuttings in a short period of time, a sequence of rapid multiplication techniques is applied. These include the propagation from *in vitro* plantlets free of viruses, the use of microcuttings with 1-2 nodes, the production of mini-storage roots, and the sprouting of storage roots (HUAMÁN ET AL., 1999; STATHERS ET AL., 2013). In Israel, plantlets of *in vitro* origin are raised in insect-proof greenhouse. Slips taken from these stock plants are transplanted into nursery beds. Slips containing the apical four nodes are collected here and used in the commercial fields (Z. DAR, PERSONAL COMMUNICATION). Nursery beds are usually fertilized with complex fertilizers of high nitrogen content (*Table 1*).

Transplant production in temperate regions

In areas where the cold seasons or other sanitary reasons do not allow a continuous multiplication via collecting stem cuttings, sprouting of storage roots is the common method for the multiplication of transplants (HUAMÁN ET AL., 1999). It was experimentally revealed that transplants derived from transplanting young slips into the seed bed give better yield of marketable roots compared to those obtained directly from dormant sweet potato root sprouts (NOVAK ET AL., 2007B).

Transplants are usually produced in plant beds from seed stock the choice of which influences the success of the sweet potato crop. Roots selected for seed stock from the previous year's crop must be true to varietal type, free from disease or insect damage, must have firm flesh, bright skin color, and free from veins. They must be harvested before any danger of frost. Hills producing at least four No. 1 potatoes must be chosen, and all damaged roots or those less than 3.8-4 cm in diameter must be discarded (BRANDENBERGER ET AL., 2014; THOMPSON ET AL., 2014). In the USA, the usage of smaller roots not reaching the marketable grade is usual (SMITH ET AL., 2009), otherwise the medium size is recommended (HUAMÁN ET AL., 1999).

Virus-free planting materials have a crucial importance in maximising sweet potato slipschemes (for review, see HENDERSON, 2015). In countries where viral diseases are a regular problem, subsequent generations of virus-free nuclear stock roots/plants, foundation plants, generation zero (G0), G1 and G2 plants are produced under strict pathogen (virus) control. Foundation seed should be obtained every 4 years to maintain uniformity and high quality (THOMPSON ET AL., 2014). To build a foundation stock of roots to be used to grow seed stock next year, well-shaped roots free from insects and diseases and true to variety must be chosen, off-types (mutants) must be discarded. Seed stock is produced from vine cuttings taken from foundation stock. Seed stock potatoes must be handled very carefully with cotton gloves. They must be harvested before frost, and must not stay in the field unprotected from the sun after digging (DAFF, 2011).

Seed stock produced from vine cuttings is less likely to transmit diseases from seed beds to the commercial fields, compared to those derived from pulling slips. Cuttings are derived by cutting vines 2.5 cm (in USA) up to 10 cm (in China) above the soil surface, and held 24-48 hours in an upright position to promote rooting before transplanting (ZHANG ET AL., 2009; THOMPSON ET AL., 2014).

The most efficient way for producing virus-free plants is *in vitro* micropropagation the detailed discussion of which is not aimed in the current paper (LIZARRAGA ET AL., 1992; DENNIEN ET AL, 2013; THOMPSON ET AL., 2014). Furthermore, instead of cycles of bedding root-based propagation, micropropagation along with nodal cultures is recommended to

reduce the opportunity of genetic drift (VILLORDON AND LABONTE, 1996; DOLIŃSKI AND OLEK, 2013; UBALUA AND OKOROAFOR, 2013).

Maximum sprout production can be achieved if roots are presprouted at (21)25-30 °C and 90% relative humidity for 2-4 weeks prior to bedding (HUAMÁN ET AL., 1999; SMITH ET AL., 2009; CLARK, 2013; BRANDENBERGER ET AL., 2014). Presprouting lasts until most roots have sprouts of ca. 6 mm in length (THOMPSON ET AL., 2014). In regions where the sprout growing season is cold, sprouts are available 4-6 weeks after bedding in heated beds, while in 7-8 weeks in cold frames, that period can be decreased by one week if roots have been pre-sprouted (BRANDENBERGER ET AL., 2014).

The average number of sprouts per bedding root is between 0.7 and 10.0 (HORVÁTH AND SZENTKIRÁLYI, 1995). To plant one hectare sweet potato, 750-900 kg (SMITH ET AL., 2009), or even up to 800-1,500 kg (CLARK, 2013) bedding roots are required to generate enough transplants. They are expected to produce around 150-250 (THOMPSON ET AL., 2014), or even up to 1500 sprouts per m^2 of plant bed (URL7). Slips must be hardened a few days before cutting by reducing the amount of water, but avoiding plants to wilt (THOMPSON ET AL., 2014).

In our days, the Australian sweet potato commercial system is considered one of the most intensive and highest yielding plant bed type systems in the world (HENDERSON, 2015). Virus-free plants are grown *in vitro* from meristems, deflasked plants are grown in insect-proof tent ('igloo'), and 30-45 cm long tip cuttings are taken from plants in igloo followed by planting in field. Storage roots are harvested after 120-150 days and cured in shed for 4-5 days. Washed roots are clipped in fungicide then packed and sent to growers. Growers are supplied with bedding roots, and produce planting material on-farm (DENNIEN ET AL., 2013). Small, oversized and misshapen roots are excluded from production. Depending on the season and/or genotype, bedding roots may be pre-sprouted at 25-30 °C. Planting in raised beds around 1 m wide, with roots hand-placed (not touching) and covered with 20-30 mm of soil are advised. Complex fertilizers (*Table 1*) and light irrigation are applied. Early season beds are warmed using plastic covers, however aeration is supplied to prevent over-heating, CO_2 toxicity, or excessive humidity (HENDERSON, 2015). Roots placed in the beds can be covered with five-centimeter mesh chicken wire to prevent roots from being pulled up when slips are pulled from the beds. Roots are covered by five centimeters of clean sand or sandy soil (BRANDENBERGER ET AL., 2014). Besides the method described above, a wide range of PT and non-PT transplant growing strategies are in use in the temperate regions (for review, see HENDERSON, 2015).

In Hungary, transplants are produced by various methods, and without an official PT scheme. If produced in one step, in the 1st week of April, selected roots are densely distributed on the surface of a bed prepared directly on soil, or in racks filled with a soil or sand layer of 8-10 cm depth. Roots are covered with a soil/sand layer of 1.5-3 cm. Soil must be kept wet continuously. Shoots appear at 24-30 °C after 2-3 weeks and grow quick but at higher temperature weak slips will develop. Shadowing must be avoided. Slips are harvested by tearing off the shoots. To reduce the number of stock roots, slips can be harvested two times. This case, the growing process starts 1-2 weeks earlier, and transplants from the first harvest are stored in wet sand at 15-18 °C in dim light for 5-10 days. Efficiency of transplant growing can be increased if (1) roots are pretreated at 43 °C for 26 hours, or (2) presprouted at 24-26 °C for two weeks, or (3) cut into 3-5 pieces to finish apical dominance. If transplants are grown in two or more steps, mother plants are raised early spring under the conditions described above. Developing vines are cut into pieces of two nodules in the middle of April, and the slips are cultivated in flower soil or fertilizer blocks at 25-30 °C, under foil cover until the appearance of the first axillary shoots (HORVÁTH, 1991C).

To achieve a good sprouting and a high yield of transplants, nutrient supply of plant beds is applied in most areas (*Table 1*). Unlike in the nutrient supply for storage root production where potassium supply is dominating, here an even proportion of nutrients or the dominance of nitrogen is preferred. The only exception is the advice of SMITH AND VILLORDON (2009) for Louisiana conditions stating that the plants use more bed-applied nitrogen when field-applied nitrogen is applied split or sidedress after planting.

Table 1. Recommended complex fertilizer doses for transplant growing

Dose (kg/ha)	NPK fertilizer	Additional information		Region	References
5,000	8-8-8	raked into tops of bed	+60-180 kg/ha N after sprout cutting or leaching rain	USA	SMITH ET AL., 2009; URL8
4,000		incorporated pre-bedding			
976	10-10-10 or 12-12-12			USA	BRANDENBERGER ET AL., 2014
336-561	8-24-24 or 7-21-21			USA	SMITH AND VILLORDON, 2009
50	20-20-20			n/a	HUAMÁN ET AL., 1999
250	25-5-5		optionally, +130 kg/ha urea	Kenya, Tanzania	STATHERS ET AL., 2013
420	23-21-0	+4S			
1,000	5-6-5	+30-40 kg/ha N		Australia	LOVATT, 2013

By Hungarian experts, NPK supply of 0.03 kg each per m^2 is recommended with an additional 0.03-0.05 kg per m^2 nitrogen after the first cutting of slips (HORVÁTH, 1991c). Along with irrigation, after each pulling or cutting an additional 11 kg per m^2 $NaNO_3$ top-dressed is advised (URL8).

Roots continue to produce sprouts for several weeks, depending on cultivar, root size and the vigor of the bedded seedstock, however a genotype-dependent capacity of shoot production can be observed during the whole bedding season (KUEPPER, 2014; URL8).

For the conservation of germplasm, both field and *in vitro* genebanks are used world-wide – both having advantages and disadvantages. Sweet potato genotypes can be stored *in vitro* in three ways: as test tube plantlets (currently being the most common form), as artificial seed, or by cryopreservation for long-term storage (GUO ET AL., 2001).

CONCLUSIONS

The production of planting material for sweet potato, one of the most important food crops with high importance also in animal nutrition and in several industrial fields, is a crucial step in determining a profitable yield and high quality of storage roots. For this purpose, well-organized Pathogen Tested (PT) schemes are needed to provide virus-free and genetically certified transplants. Systems of this type are usually based on initial planting materials of *in vitro* tissue culture origin and are established in prominent sweet potato growing countries under temperate climate (for review, see HENDERSON, 2015).

Due to the lack of severe plant health problems detected until our days, and due to the consumers' and growers' interest increasing only recently, a PT system for the production

of sweet potato planting material has not been organized in Hungary yet. Transplants are produced by some growers and distributed via commercial channels (URL2,3), and genotype samples are available from the gene bank of the Research Centre for Agrobiodiversity (URL10). Currently, the planting material is produced by traditional methods but successful *in vitro* micropropagation experiments are under way (J. PAUK, PERSONAL COMMUNICATION). With the increase of the growing area, however, the occurrence of various diseases and even that of leaf and root pests is expected, possibly in a short period. Thus, the stabilization of sweet potato among the cultivated plants in Hungary will require the establishing of a PT scheme for the country's conditions, possibly under the control of the responsible supervisory authorities.

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