A REVIEW ON SWEET POTATO WITH SPECIAL FOCUS ON HUNGARIAN PRODUCTION II: AGRONOMY

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.], despite its tropical-subtropical origin, has successfully been grown for centuries also in temperate climate. Regarding the various aspects of agronomy, there are general rules that must be followed irrespective of the site of growing. These include the avoidance of forecrops promoting the accumulation of root-damaging pests and pathogens, as well as those increasing the risk of excessive N release; potassium-stressed nutrient supply; planting spacing in the 100 cm x 30 cm range; irrigation in the first 30-40 days; careful harvesting and post-harvest curing of storage roots, among others. Even these factors, however, must be adjusted to the conditions of the site of growing and, as far as possible, to the cultivars chosen. In our days in Hungary, cultivation methods based on international sweet potato literature or adapted from technologies of other crops of similar requirements are generally in use and continuously modified by individual experiences. The planning of scientifically recognized experiments for establishing site- and cultivar-specific approaches to all aspects of agronomy must consider all this information.

Keywords: sweet potato, fertilization, transplanting, plant protection, harvesting

INTRODUCTION

As described elsewhere, despite being a crop of tropical-subtropical origin, sweet potato [*Ipomoea batatas* (L.) Lam.] is also grown in several areas under temperate climate – Hungary and numbers of European countries among them (MONOSTORI AND SZARVAS, 2015). Due to its relatively recent introduction among field crops grown in Hungary, manuals on site- and cultivar-specific growing technologies are not available yet and must be prepared based on experiments performed during several crop years. Manuals based on practical experiences as well as the overview of the international practice focusing on temperate areas can be an initial step in planning a set of experiments comprising all important aspects of the production technology.

Current work, as the second part of a series of reviews on sweet potato production, aims to give a detailed discussion on the main aspects of the sweet potato production technology including crop rotation, tillage, nutrient supply, planting, plant care, plant protection, harvesting and storage. The importance and usage, botanical features, ecological requirements as well as the various methods of the production of sweet potato planting material are reviewed in the first part of this series of reviews (MONOSTORI AND SZARVAS, 2015).

THE ASPECTS OF SWEET POTATO AGRONOMY

Sweet potato growing strategies 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. In the latter case, storage facilities, and additional land for production of plants from roots are needed (CLARK, 2013).

Crop rotation

A three to five year rotation is advised to reduce the chance of problems by soil-borne diseases (Clark, 2013; Brandenberger et al., 2014), however, to control sweet potato weevil efficiently, a minimum of four years rotation is preferred (URL13). Herbicide carryover problems, especially expected after clean-tilled crops must be avoided. Fields with a history of morning glory problems should also be avoided: there is no effective control of morning glory in sweet potato, and morning glory can be a host for the sweetpotato weevil (Thompson et al., 2014).

In rotational cycles in the tropics, sweet potato is often the leading crop, except for very fertile soils, where an excessive vegetative growth at the expense of storage root formation can occur (Barker et al., 2009). Sweet potato is a common forecrop of (upland) rice, other recommended crops in the rotation are maize, sorghum, finger millet, beans, cowpeas, soybeans and sesame. On the other hand, root and tuber crops such as yams, cassava and potato should be avoided (Kapinga et al., 2009). In tropical regions with fertile topsoil (e.g. Papua New Guinea), traditional winged bean - sweet potato rotation has been replaced by peanut - sweet potato rotation or maize - peanut intercropping system (Kanua and Rangat, 1989). As sweet potato scarcely reacts to mineral fertilization during the harvest year, it is recommended to be planted in rotation with more demanding cultures (e.g. leaf vegetables) to take advantage of the residual effect of the previous fertilization (Antonio et al., 2011).

Under temperate climate in Oklahoma (USA), in organic systems sweet potato is treated as early vegetable preceded by green fallow, usually sudangrass or sorghum-sudangrass (Kuepper, 2014). In Spain, the most common forecrop is early potato, and sweet potato is followed by onion, tomato, and other field vegetables (URL6). Forecrops promoting the accumulation of root-damaging pests and pathogens (e.g. root and tuber crops, alfalfa, brake-up of grasslands), as well as those increasing the risk of excessive N release which may lead to cracks (e.g. alfalfa, clovers) should be avoided (Cowan, date unknown; URL7).

Nutrient supply

Sweet potato belongs to crops of moderate nutrient requirement. The recommended fertilizer rates for production are usually based on crop removal figures. The determined values, however, show a considerable variability at different authors, the only common feature being the stress upon potassium utilization (*Table 1*).

Table 1. Nutrient removal by sweet potato crop

N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	Remarks		References
51.6	17.2	71	10 t/ha tubers + 4 t/ha leaves		IFIA, 1992
100	90	200			DAFF, 2011
26	6	60	12 t/ha	tubers	Noguera-Ramkissoon, 2011
52	9	90		tubers+vines	
110	25	250	50 t/ha	tubers	
215	38	376		tubers+vines	
123.3	16.8	168			Brandenberger et al., 2014
24	12	48	12 t/ha tubers		URL3

In contrast, in the recommended doses to be applied, a much lower variability can be observed (*Table 2*). These doses, however, will result in high yields only if used in conjunction with yearly soil nutrient testing (and petiole sap nutrient monitoring if possible).

Table 2. Recommended nutrient doses

N (kg/ha)	**P_2O_5 (kg/ha)**	**K_2O (kg/ha)**	**References**
45	90	135	URL6
60	at low P_2O_5 supply only	120	URL5
50	50-90	80-120	ROY ET AL., 2006
34-45	50-101	84-169	STATHERS ET AL., 2013B
50	100	150	BUŠIĆ, DATE UNKNOWN
30-100	20-200	50-200	O'SULLIVAN, DATE UNKNOWN
45-67	65	168-225	URL3; URL12

Nitrogen requirements can vary among cultivars, geographic locations, climates and cropping seasons (SMITH AND VILLORDON, 2009). On most soils, nitrogen application increases tuber yield, however, excess nitrogen stimulates foliage production at the expense of tubers and may lead to tuber cracking. Nitrogen application is effective only if a N:K_2O ratio of 1:1.5 to 1:2 is realised (ROY ET AL., 2006). Other authors advise an N:P:K ratio of 1:2:3 thus underlining the importance of potassium in the formation of storage roots (URL6). The response to nitrogen is usually poor if deficiencies of other nutrients (e.g. potassium) are overlooked and left untreated (O'SULLIVAN, DATE UNKNOWN).

Sweet potato is considered to be relatively tolerant of low phosphorous levels of soil. Increased rates of phosphorous fertilizers do not have significant effect neither on yield nor on storage quality (STODDARD, 2015). Residual phosphorous from previous crops seems to be sufficient to supply the needs of the sweet potato (O'SULLIVAN, DATE UNKNOWN). Mycorrhizza play an essential role in the phosphorous supply of sweet potato (O'KEEFE AND SYLVIA, 1992). Inoculation of sprouts with vesicular-arbuscular mycorrhizal (VAM) isolates increase the storage root yield (O'KEEFE AND SYLVIA, 1993). Sweet potato varieties, however, differ in the level of mycorrhizal infection and in the response to the applied phosphorous (MULONGOY ET AL., 1988).

Like other root crops, sweet potato also has a high requirement for potassium, its yield and quality responding strongly to potassium application (LU ET AL., 2001; O'SULLIVAN, DATE UNKNOWN; URL7). Appropriate levels of potassium fertilizers can contribute to more assimilates during the early and middle growth stages but also have higher sink strength of storage roots leading to higher assimilate distribution in storage roots in the later growth stages (LIU ET AL., 2013). Increased potassium doses result in higher number of tubers/plant, weight of tubers/plant and tuber yield/ha. Various cultivars, however, respond differently to potassium, the responsive ones developing longer vines, higher number of leaves and branches/plant as well as heavier vine dry weight (UWAH ET AL., 2013; DUMBUYA, 2015). Regarding the form of potassium fertilizer, potassium sulphate can result in higher tuber starch content, while potassium chloride increases fresh weight and overall starch yield (LU ET AL., 2001). According to ROY ET AL., (2006), however, potassium chloride can depress root dry-matter content, for this reason the use of potassium sulphate or a mixture of the two sources is recommended.

For the application of fertilizers, different strategies are in use. Nitrogen is usually applied pre-plant, along with phosphorus and potassium, incorporated in the soil broadcasted or in the band. If heavy leaching (>5 cm rains, especially on sandy soils) is common, a split application is advised. In this case, one half to two thirds of nitrogen are applied pre-plant with an additional application 4 to 6 weeks after planting (BRANDENBERGER ET AL., 2014; COWAN, DATE UNKNOWN). Additional fertilizers are normally applied sidedress banded, e.g. positioning a band on either side of the row for nitrogen. For phosphorus, pre-plant application in bands 7.5 cm to the side and 7.5 cm below the roots is more effective than broadcasting. For potassium, pre-plant incorporation or banded application of one half to two thirds of the dose is advised. The rest of potassium is applied with nitrogen together. If leaching occurs shortly after sidedressing, additional potassium can be necessary (COWAN, DATE UNKNOWN). A similar strategy is applying all phosphorus in the basal along with 50 kg of nitrogen and 50 kg of potassium. The remaining nitrogen and potassium, however, should be divided into two side-dressings at 4 to 6 weeks and at 10 to 12 weeks from planting (*Table*) (DAFF, 2011).

There are also recommendations on after-plant-only applications. High levels of nitrogen are not required for optimal storage root initiation (ca. 13 days after transplanting), on the other hand, maximum nitrogen uptake by storage roots is at the 23 and 40 days following transplanting (SMITH AND VILLORDON, 2009). According to these observations, in North-Carolina, the principal state in sweet potato production in the USA, nitrogen is applied 28 days after planting, phosphate at or shortly after planting, and one-fourth of potash at or near planting, while the rest at layby when vines are beginning to increase growth (URL12). A method from Hungary recommends similar applications with differences of nitrogen to be applied 14-21 days after planting, and remaining phosphorous at the start of tuberation (URL3).

If single nutrient fertilizers are applied, a technology from Spain recommends (URL6):

- ammonium sulphate (21% N): 220 kg per ha
- superphosphate (18% P_2O_5): 500 kg per ha
- potassium sulphate (50% K_2O): 280 kg per ha

Complex NPK fertilizers are also frequently applied but the recommended proportions and doses are variable, depending on the local conditions. In Spain 500 kg per ha of NPK 9-18-27, while in the USA (Alabama) 1,500 kg per ha of NPK 5-10-10 applied after-plant are recommended (URL1; URL6). Unlike those of nitrogen and phosphorous, the applied doses of potassium are still similar in these two cases.

In intensive growing of sweet potato where nutrient supply is based on fertigation, the formulas can be varied adapted to the plants' requirements in the given development stages (URL4):

- after planting NPK 15-30-15 to promote rooting;
- in July NPK 25-10-10 to promote fast growing of vines;
- from August to harvesting NPK 10-5-30 to achieve a high yield.

In any nutrient supply strategy, however, the genotype-specific nutrient requirements such as the low nitrogen requirement of the cultivar 'Beauregard' must be considered (TUCKEY, 2001; PHILLIPS ET AL., 2005; URL12).

To adjust soil pH, calcium can be supplied by lime or dolomite, any additional calcium may be applied in the basal as gypsum (DAFF, 2011). Sweet potato can suffer from magnesium and sulphur deficiency, hence they may be applied in fertilization protocol (O'SULLIVAN, DATE UNKNOWN). Trace element (e.g. zinc, copper, manganese, iron, boron) deficiency can be detected by regular petiole testing, but two foliar applications around the time of side-dressing should maintain adequate levels (DAFF, 2011). Boron (1-4 kg/ha) is usually added to prevent a surface defect known as blister, either in soil (Borax) or as foliar application (Solubor)(ROY ET AL., 2006; O'SULLIVAN, DATE UNKNOWN; URL3; URL5). In Brasil, application of 2 kg/ha boron increased yield but neither the boron sources nor the application form had significant effects (ECHER AND CRESTE, 2011). In California, US, boron application did not have any significant impact neither on yield nor on storage quality (STODDARD, 2015).

Organic fertilizers are frequently applied in sweet potato. In general, sweet potato responds better to composts of plant materials containing high potassium relative to nitrogen than to animal manures being lower in potassium (O'SULLIVAN, DATE UNKNOWN). Usually, grass clippings or another biodegradable mulch are mixed into soil, however farmyard manure is not recommended (URL1; URL3). Application of cow dung alone or in combination with NPK fertilizers resulted in lower yield compared to NPK alone (HALIRU ET AL., 2015). As exception, however, in Brasil cattle manure gave better results than biofertilizer (OLIVEIRA ET AL., 2010).

Tillage

Sweet potato is grown in rows prepared as level or raised beds, the raised being preferred in most areas to improve drainage (CLARK, 2013). The soil is ploughed 15-20 to 40 cm deep to loosen topsoil, to incorporate limestone and other fertilizers if needed (THOMPSON ET AL., 2014). According to PORPÁCZY (1953), tillage need not be deeper than 20-30 cm because in loose soil layers storage roots become longer while reaching a compact soil layer forces the formation of tubers. Beds should be at least 20 cm high and as wide as equipments allow. Narrow beds can dry quickly, reducing yield, while high beds aid in preventing excess water damage (THOMPSON ET AL., 2014). Wide ridges of 25-30 cm height without turn rows are recommended for North-Carolina (URL11).

In tropical Africa (e.g. Uganda), sweet potato is grown on mounds (100 m wide, 60 cm high) on flat areas, or in the case of mole and root rot problems. On hilly or slopy regions ridges (100 cm apart, 60 cm high) are preferred to prevent erosion (KAPINGA ET AL., 2009).

In Australia, planting on the flat is not frequently used because of the poor drainage despite making the soil loose. Other method is planting on ridges or moulded beds that are prepared by ploughs, or occasionally by hand. Planting on mounds is considered to be the best method of planting. Mounds are made by hand, or they are formed from ridges made by a plough first. Mounds may be ca. 25 to 90 cm wide across the top and 15 to 40 cm high. Plant materials are usually incorporated in the mound to make it very loose providing good drainage, as well as to make the soil warm (URL8).

In Northern areas of the USA, the covering of flat soils or the raised beds with black plastic or black fabric mulch about 3 weeks prior to planting is recommended to warm up soil (URL1; URL13). Similarly, if drip irrigation is applied, polyethylene foils are necessary to cover soil. In Croatia, black foils are recommended for the continental, while white ones for the mediterranean regions. On sloping fields low balks (like for cucumber production) are prepared and foils of 120 cm width, on flat areas high balks (like for strawberry) and foils of 140-150 cm width are necessary (BUŠIĆ, DATE UNKNOWN).

In Hungary, primarily on loose soils, cultivation on the flat is used with great efficiency, especially in less intensive cultures (L. HORVÁTH, T. VÁRALJAI, PERSONAL COMMUNICATION). Ridges prepared 70-80 cm apart prior to or at transplanting, as well as ridges and beds originally prepared for horticultural crops (e.g. strawberry) are also used, primarily for intensive growing (HORVÁTH, 1991a).

Transplanting

Field planting can be started when frosts are passed, and soil temperature reaches at least 18 °C at a 10 cm depth for 4 consecutive days. Plants set out too early may be injured by frost, roots of the transplants do not grow, vines develop a purple color, vigor is reduced, root yield is low, furthermore, roots are round or chunky rather than oblong (THOMPSON ET

AL., 2014; URL11). Under Hungarian conditions, planting should be performed in the third decade of May (HORVÁTH, DATE UNKNOWN). Practical experiences, however, show that planting started after the first decade of May and finished one, or even two months later can result in an acceptable yield (T. VÁRALJAI, PERSONAL COMMUNICATION).

Slips are transplanted at a depth of 7.5 cm with a minimum of two plant nodes in the ground and at least two leaves or more above the ground. Transplants are planted into soil manually with a notched stick, or by drag as well as precision transplanters with set distances (URL11). The usage of rootless transplants, or trimming roots to some millimeters helps to avoid the development of deformed storage roots if transplants' roots are far too long (URL2).

The row distance generally applied in sweet potato production is between 70 and 107 cm, the most preferred being 100 cm. The usual plant-to-plant distance is 17 to 30 cm, the 30 cm being most widely used (BAVEC AND BAVEC, 2006; CLARK, 2013; URL2; URL5; URL11). In North Carolina, 15 cm plant-to-plant distance at a 107 cm row distance resulted in the highest number of No. 1 roots and the greatest investment return in experiments with two cultivars (BARKLEY ET AL., 2015B). In Croatia, looser plant spacing (120 cm x 30-40 cm) is recommended (BUŠIĆ, DATE UNKNOWN). Like in the tropics, ridges or mounds 70-80 cm apart are recommended for temperate zone, too. The plant density is 3-4 per m^2 in good, and 4-5 per m^2 in bad growing conditions. On the top of each mould, 2-3 slips must be planted (HORVÁTH, 1991A; URL13). Spacing plants evenly is important to produce high yields of No. 1 fresh market grade, otherwise genotype-specific requirements must be considered to improve yield (URL11). For 'Beauregard', for example, 15 cm or 23 cm spacing would be recommended depending on the anticipated harvest being early or late, respectively (SCHULTHEIS ET AL., 1999).

In general, slips cut about 20 cm from the tip of the vines with all the leaves trimmed off except for the two youngest emerging leaves are usually used. Cuttings can be also made from stem pieces of 5 nodes: the bottom 3 nodes are buried, 2 of them are above ground (URL14). Cutting with less than five nodes were not found to give high yields while cuttings with more than five nodes do not result in higher yield thus constituting a waste of planting material (AMOAH, 1997). The preferred size of transplants, however, is variable in the different countries, according to the traditions based on experiences, the growth type of the cultivars, the method of transplant production and the usual way of planting. In the USA, slips of 25 to 30 cm in length with a stem diameter of 0.6 cm or greater are desired to increase the number of nodes that can be placed below the soil surface. Increasing slip planting depth increases yields with a maximum at a depth of 13 cm. The reasons for this feautere can be: more nodes underground increase the potential number of storage roots to be produced, while deeper planting provides the slip with a less variable environment compared to the conditions nearer the soil surface (MEYERS, 2013). 'Marginal' transplants of 13-18 cm length can also be used but weak transplants of less than 8 leaves and slender stem, are not expected to survive in the field. On the other hand, plant cuttings longer than 30 cm can create a problem if a precision-type transplanter is used, and they will be difficult to cultivate even if transplanted successfully (URL10). Australian growers prefer 35-45 cm sprouts, depending on the planting process, but sprouts in the range of 20-50 cm are considered acceptable (for review, see HENDERSON, 2015). In Hungary, slips of 15-25 cm with at least 3-5 leaves are preferred, those longer than 30 cm are hard to transplant manually (HORVÁTH, 1991C; HORVÁTH, DATE UNKNOWN). It is also recommended to remove and dispose the bottom 2.5 cm from each slip of 15-23 cm, as that part sometimes harbors disease organisms (URL13).

Several methods of planting are kown. Cuttings can be planted in vertical position; at an angle of 30 or 60 to soil surface; or the bottom part buried horizontally and the top part bent upwards (URL14).

Slips should be transplanted as soon as possible after removal from the bed (URL10), however transplants shipped by supplyers to growers can survive several days if packed in wet paper tissue. After arrival, they can be stored in wet soil-peat mixture until transplanting (URL2). Transplants, however, must not be dipped in water thus avoiding the spreading of pathogens causing bacterial soft rot, pox, fusarium root, stem rot and other diseases (URL10).

After transplanting, watering with 0.04 to 0.06 l (URL10) or 0.12 to 0.24 l (THOMPSON ET AL., 2014) is necessary.

Adventitious roots start growing in 24 hours after transplanting. The number of roots becoming storage roots is determined in the first two weeks after transplanting. Under ideal conditions, adventitious roots become storage roots. If the conditions are unfavorable or the root is damaged, they become fibrous roots. When the initially favorable conditions become adverse later, long, slightly thickened 'pencil' roots develop (MEYERS, 2013).

Plant care

Irrigation

Soil moisture appears to be the most limiting factor in determining storage root-number during the critical early developmental stages of one to 30 days after transplanting (SMITH AND VILLORDON, 2009). Sweet potato is thought to be an - at least moderately – drought-tolerant crop responding very well to irrigation even if water is naturally available (RASHID, 1989; DAF, 2011; THOMPSON, 2014). Drought stress reduces nitrogenous compounds and root yield, while it increases root dry matter, the latter one serving as the best indicator and selection criterion for drought resistance (EKANAYAKE AND COLLINS, 2004). If irrigated at transplanting and in the first 40 days on demand, the plants are expected to survive later water stress. In fact, however, irregular watering, too little or too much water cause reductions in yield and quality: uneven water availability causes growth cracks, and drought may reduce yields. Excess water in extremely wet soils cause problem due to the lack of oxygen. In saturated soils, lenticels expand, and if rainy conditions persist, roots sour and rot (URL5; URL11). Irrigation of sweet potato beyond 60% field capacity was found non-economic (NAIR ET AL., 1989).

Recommendations for irrigation regime are variable. Irrigation is recommended when 40 to 50% of the field-capacity moisture has been depleted (URL5). Under dry conditions, 2.5 cm of water should be provided weekly until 2 weeks before harvesting (URL13). According to HORVÁTH (DATE UNKNOWN), the most critical are the first 5-6 weeks and the periods affected by drought, however, between the 40th and 60th days irrigation should not be applied. Similarly, suspension of irrigation for 5 days in the last week of July is recommended to promote storage root development by drought stress (URL4). Too much water should not be applied at once to avoid cracking of tubers, and in the last 1-1.5 months prior to harvesting irrigation must be quit (URL2; URL5). According to Clemson (URL5), on the other hand, a constant water supply, especially during the tuber formation stage at 7 to 9 weeks is considered to be important.

In Spain, three or four irrigations were found to be sufficient during the whole growing season. Under extremely dry conditions, however, eight to nine irrigations every fifteen days are recommended (URL6). Generally, 18 to 20 mm water per week can be applied early in the season, and 40 to 45 mm per week during the middle part of the season when storage roots are enlarging rapidly and a reduction to about 20 mm late in the season (DAFF, 2011).

In sweet potato, various irrigation systems can be efficiently applied, depending on the current climatic and soil conditions, as well as on genotype, among others. Overhead (pivot or linear systems, pipe and risers or a side-roll system), drip, and furrow irrigation are the systems used the most frequently (BRANDENBERGER ET AL., 2014). Drip irrigation was found to be more water-conserving compared to sprinklers (TRAYNOR ET AL., DATE UNKNOWN; KUEPPER, 2014). On the other hand, it resulted higher yield compared to blocked furrow systems, although showing a higher water use efficiency (ÖNDER ET AL., 2015).

Mechanical weed control, vine lifting and vine harvesting

Interrow tillage by cultivators or by hand hoeing should be applied to control weeds (see below) until rapidly growing vines cover the inter-row space (BRANDENBERGER ET AL., 2014).

Specialists have different opinion about the necessity of lifting vines to prevent the formation of under-developed secondary storage roots at the points where shoots nodes touch the soil surface. Some authors feel it necessary to force the plants to develop storage roots under the main vine only (URL2; URL14) but others not (HORVÁTH, DATE UNKNOWN). The effect of vine lifting on yield can depend on the variety: if it is bushy and its vines do not root, vine lifting has no effect, but if the variety is creeping with a lot of lateral roots, then vine lifting may have a positive effect on yield (ANONYMOUS, 1989; AMANTE AND O'SULLIVAN, DATE UNKNOWN). An important aspect in performing it is not to turn the lifted vines over to avoid the rot of the leaves (STATHERS ET AL., 2013B). In the tropics, lifting is usually performed once or twice during the wet season only. Vine lifting is advised not to be a routine practice, but to be undertaken only after root growth on stem nodes has been observed (AMANTE AND O'SULLIVAN, DATE UNKNOWN).

Under tropical and subtropical conditions, growers harvest vines to be used as fodder for livestock. Vine harvesting can be performed several times during the second half of the growing season, beginning at 30-45 days after planting (the beds are covered by vines), and repeating every 10-15 days. Two to four of the longest vines per plant are cut, leaving about 15 cm length. Harvesting of vines, however, can reduce the storage root yield to some extent (AMANTE AND O'SULLIVAN, DATE UNKNOWN).

Plant protection

In countries with centuries-long tradition of sweet potato cultivation, the growers must face several plant protection problems in the fields or during storage. Where sweet potato has been grown only for some decades, such as Hungary, plant protection does not need the application of pesticides at the moment, the plant can be cultivated by manual or mechanical control of pests similarly like in ecological farming systems.

Weed control

Weed control is necessary in the first four to six weeks only, because later most sweet potato crops cover the ground completely and effectively shade out weeds (HORVÁTH, 1991A; STATHERS ET AL., 2013B). In conventional production, herbicides can be used to provide weed control during the early period. For the herbicides and active ingredients effective in and recommended for sweet potato, current information must be collected. In organic production, cultivation by cultivators or by hand hoeing are ways of weed control (BRANDENBERGER ET AL., 2014). In the tropics, mulching and intercropping can also contribute to the decrease of weed growth (STATHERS ET AL., 2013B). Positive effect of black plastic mulch on sweet potato yield was revealed in the temperate zone, too (NOVAK, 2007A,B; BUŠIĆ, DATE UNKNOWN). To prevent damage to developing roots, weeds must be cultivated with implements that does not scrape or remove soil from the bed, e.g. disc hillers, rolling cultivators, or other equipment. These throw soil to the bed, avoid root damage, and increase the bed height. To achieve less damage to vines, rows must be cultivated in the same direction each time. Hand hoeing, as well as mulching (plastic films or organic mulches) can also be used to reduce weed competition (HORVÁTH; 1991A; BRANDENBERGER ET AL., 2014).

Against perennial weeds, Glyphosate can be applied at least two weeks before planting (LIU ET AL., 2014). Herbicides with atrazine and S-metolachlor active ingredients were found to be effective for use in sweet potato 1 to 2 days after planting. In special cases (e.g. against *Imperata cylindrica*), a mixture of Glyphosate+Prometryn/S-metolachlor can be used at 4, 8, and 12 weeks after planting (STATHERS ET AL., 2013B).

Herbicide active ingredients registered for application in sweet potato in North Carolina, USA are clomazone, DCPA, flumioxazin, glyphosate, S-metolachlor, napropamide, carfentrazone-ethyl, clethodim, fluazifop, and sethoxydim (BARKLEY ET AL. 2015A). In Hungary, diphenamid and chloramben herbicides are recommended (HORVÁTH, 1991A).

Pathogens

In Hungary and neighbouring countries, sweet potato is considered to be relatively less susceptible to diseases compared to countries with a centuries long tradition of its cultivation. Regarding the dominance of soil-borne, polyphagous pathogens attacking storage roots, the pathogen control of sweet potato is a complex activity. The occurrence of diseases can be prevented by the application of resistant genotypes, by proper selection of the site for growing, by crop rotation, by avoiding mechanical damages of storage roots during harvesting, carrying and storage, as well as by applying healthy propagating materials (HORVÁTH, 1991B; RUBATZKY AND YAMAGUCHI, 1997). There are numbers of reference papers reviewing the most common diseases and pests of sweet potato (CLARK AND MOYER, 1988; AMES ET AL., 1997; CLARK ET AL., 2009; EKMAN AND LOVATT, 2015).

Over 30 viruses belonging to 9 families have been identified, half of them from the families Geminiviridae and Caulimoviridae. Most of these viruses can be associated with symptomless infections (CLARK ET AL., 2012). On the other hand, however, virus diseases can contribute even up to 40% to yield losses, and the usage of virus-tested planting material can result in the increase of yields up to 7 times and more (LOEBENSTEIN ET AL., 2009).

In plant beds, the most destructive diseases are southern blight, Rhizoctonia stem canker and slime molds (CLARK AND MOYER, 1988). Most important root-borne diseases being important if storage roots are used to initiate propagation material are black rot, scurf, foot rot, as well as viral diseases. In the control, crop rotation, the use of disease-free and/or fungicide-treated roots for seed, cutting slips at least 2-3 cm above ground can play a decisive role (CLARK ET AL., 2009). Soil-borne diseases such as soil rot (pox), Fusarium wilt, Fusarium root rot and stem canker, circular spot and bacterial wilt can be responsible for severe losses of yield. On the other hand, foliar diseases - the most important being stem and leaf scab, Alternaria stem and petiole blight, white rust and chlorotic leaf destruction - usually have little effect on production. Storage root and post-harvest diseases include, among others, Rhizopus soft rot, bacterial root and stem rot, Java black rot, foot rot and charcoal rot. These diseases usually develop after harvest or after packaging for long-distance transport (CLARK ET AL., 2009; AMES ET AL., 1997).

Table 3 gives a list of major pathogens of sweet potato from various parts of the world (AMES, 1997; CLARK ET AL., 2009; LOEBENSTEIN ET AL., 2009; SORENSEN, 2009; FIUME, 2015).

Review on Agriculture and Rural Development 2015 vol. 4 (1-2) ISSN 2063-4803

In Hungary, detailed description of diseases has not been prepared yet. Regarding the presence of the pathogens in the region, however, infections by *Alternaria*, *Erwinia*, *Fusarium*, *Rhizopus* and others can be expected. *Rhizoctonia* sp. has already been detected in sweet potato plantlets showing symptoms of damping-off (G. BESE, PERSONAL COMMUNICATION).

Table 3. The most important pathogens of sweet potato

Species	Damage		
	Root	Stem	Foliage
Viral diseases			
Sweet potato feathery mottle virus (SPFMV)	X*		X
Sweet potato chlorotic stunt virus (SPCSV)/S. p. sunken vein virus (SPSVV)			X
Sweet potato virus disease (SPVD): SPFMV and SPCSV/SPSVV interaction			X
Sweet potato mild mottle virus (SPMMV)			X
Bacterial diseases			
Bacterial stem and root rot – *Erwinia chrysanthemi*	X	X	
Bacterial wilt (*Ralstonia*/*Pseudomonas solanacearum*)	X	X	X
Soil rot/Pox (*Streptomyces ipomoea*)	X	X	X
Phytoplasma			
Little leaf (proliferation disease)/Witches' broom	X	X	X
Fungal diseases			
Alternaria leaf spot and stem blight (*Alternaria* spp.)		X	X
Alternaria storage rot (*Alternaria* spp.)	X		
Alternaria stem and petiole blight (*Alternaria* spp.)			X
Anthracnose (*Colletotrichum coccodes*)			
Black rot (*Ceratocystis fimbriata*)	X		
Cercospora leaf spot (*Cercospora* spp.)			X
Charcoal rot (*Macrophomina phaseolina*)	X		
Chlorotic leaf distortion (*Fusarium denticulatum*)			X
Circular spot (*Sclerotium rolfsii*)	X		
Foot rot (*Plenodomus destruens*)	X		
Fusarium root rot and stem canker (*Fusarium solani*)	X	X	
Fusarium wilt (stem rot) (*Fusarium oxysporum f.sp. batatas*)		X	X
Java black rot (*Lasiodiplodia theobromae*)	X		
Mottle necrosis (*Pythium ultimum*)	X		
Phyllosticta leaf blight (*Phomopsis ipomeae-batatas*/*Phyllosticta batatas*)			X
Rhizoctonia stem canker (sprout rot) (*Rhizoctonia solani*)		X	
Rhizopus soft rot (*Rhizopus spp.Rhizopus stolonifer*)	X		
Rootlet rot (*Pythium ultimum, Rhizoctonia solani*)	X		
Rust, red (*Coleosporium ipomoeae*)			X
Rust, white (*Albugo ipomoeae-panduratae*)			X
Scab, leaf and stem (*Sphaceloma batatas*)		X	X
Southern/Sclerotial blight (*Sclerotium rolfsii*)	X		X
Scurf (*Monilochaetes infuscans*)	X		
Septoria leaf spot (*Septoria bataticola*)			X
Violet root rot (*Helicobasidium mompa*)	X		X

* depending on SPFMV strain and sweet potato variety

Pests

Worldwide, the sweet potato weevil is the most important insect pest both in the field and storage, the second one being vine borer (LEBOT, 2009; SORENSEN, 2009). Since most sweet potatoes are produced in low-input agricultural systems, insect losses reach 60–100% (SORENSEN, 2009). Weevils can be controlled by numbers of pest managment practices: hilling up, field sanitation, using uninfested planting material, crop rotation, timely harvesting to avoid soil cracking in dry season (in tropical regions), plot separation, natural enemies (entomopathogenic nematodes, bacteria and fungi, e.g. *Beauveria bassiana* preparates), sterile insect technique, barrier crops, mulching, flooding (after harvesting), chemical control (difficult due to the characteristics of the insect's life cycle, and the limited availability of approved products), resistant varieties, pheromone traps (SORENSEN, 2009; STATHERS ET AL., 2013B; HUE AND LOW, 2015). Wine borer can be controlled by insecticides and parasitoids, as well as proper selection of cultivars (SORENSEN, 2009). In general, soil-borne insects can be controlled by insecticides applied pre-plant or at planting (BRANDENBERGER ET AL., 2014).

Table 4. The most important pests of sweet potato

Species	Damage		
	Root	Stem	Foliage
Arthropods			
Sweet potato weevil (*Cylas formicarius*, *C. brunneus*, *C. puncticollis*)	X	X	X
West Indian sweet potato weevil (*Euscepes postfasciatus*)	X		
Rough sweet potato weevil (*Blosyrus* spp.)	X		X
Clearwing moth (*Synanthedon* spp.)	X	X	
Peloropus weevil (*Peloropus batatae*)	X	X	
White grubs (*Plectris aliena*, *Phyllophaga ephilada*, *Polyphylla fullo*, *Anomala vitis*, *Melolontha melolontha*, etc.)	X		
Mole cricket (*Gryllotalpa gryllotalpa*)	X		
Wireworms (*Agriotes ustulatus*, *Conoderes amplicollis*, etc.)	X		
Sweet potato stemborer (*Omphisa anastomasilis*)		X	
Striped sweet potato weevil (*Alcidodes* spp.)		X	
Mites (*Aceria* spp., *Eriophyes gastrotrichus*, *Tetranychus urticae*)		X	X
Sweet potato butterfly (*Acraea acerata*)			X
Tortoiseshell beetles (*Aspidomorpha* spp.)			X
Armyworms (*Spodoptera* spp.)			X
Sweet potato hornworm (*Agrius cingulata*)			X
Leaf folders (*Brachmia convolvuli*, *Herpetogramma hipponalis*)			X
Strobiderus beetle (*Strobiderus aequatorialis*)			X
Flea beetles (*Chaetocnema confinis*)			X
Cucumber beetles (*Diabrotica* spp.)			X
Southern green stink bug (*Nezara viridula*)			X
Aphids (*Aphis gossypii*, *Myzus persicae*, etc.)			X
Whiteflies (*Bemisia tabaci*)			X
Nematodes			
Brown ring of roots (bulb and stem nematode) (*Ditylenchus dipsaci*, *D. destructor*)	X		
Lesion (*Pratylenchus brachyurus*, *P. coffeae*)	X	X	X
Reniform (*Rotylenchulus reniformis*)	X		X
Root-knot (*Meloidogyne* spp.)	X	X	X

Table 4 gives a list of major pests of sweet potato from various parts of the world (Ames, 1997; Lebot, 2009; Sorensen, 2009; Fiume, 2015). Recent publications list ca. 270 insect and mite pests for sweet potato (Liu et al., 2014).

Based on unpublished observations, under the temperate climate and soil conditions of Hungary, soil-borne pests such as white grubs (*Polyphylla fullo*, *Anomala vitis*, *Melolontha melolontha*, etc.), mole cricket (*Gryllotalpa gryllotalpa*), wireworms and cutworm of turnip moth (*Agrotis segetum*) cause serious damages in storage roots (Monostori, unpublished). Damages by arthropodal pests such as spider mite, Southern green stink bug, green peach aphid, silverleaf whitefly, as well as caterpillars of various butterflies and moths can be expected or has already been detected on plant parts above ground but they rarely contributed to serious losses in leaf surface and yield.

Some species of plant-parasitic nematodes can be responsible for considerable damages of sweet potato, causing production losses up to 10%. Resistant cultivars, non-host crops in rotation with sweet potato, as well as nematicides can be means of nematode control (Overstreet, 2009).

Disorders

Table 5 summarizes the disorders caused by nutritional deficiencies and by adverse environmental effects on the storage roots and/or above-ground parts of the sweet potato plants (Clark and Moyer, 1988; Ames et al., 1997; Ekman and Lovatt, 2015). Unlike infectious diseases, non-infectious disorders are not progressive, however their symptoms can occasionally be confused with those of some infectious ones (Clark and Moyer, 1988). Depending on the given macro- or microelement, deficiency symptoms can be observed as stunted growth, discolouring (yellow, pale, etc.), distortion, wilting of leaves, holes, spots on leaves, brittle, distorted stems, lesions, discolouring of storage roots, etc. (Ekman and Lovatt, 2015).

Table 5. Disorders caused by adverse environmental effects

Disorder	Cause
Nutrient deficiency symptomps N, P, K, Ca, Mg, B, Cu, Zn, Mn, Fe	lack or restricted availability of the given nutrient
acid soil and aluminium toxicity	low soil pH causing increased Al solubility
alligator skin	hot, wet conditions; pH; nutrition
cold damage	<15 °C - on leaves and shoots; <13 °C on storage roots
corky skin	in excessively wet soils
growth cracks	fluctuating growth: changes of dry and wet periods
herbicide damage	inappropriate herbicide, leaking spray tank; overspray
salinity	>25 µM (EC=5.6 dS/m) NaCl in irrigation water (200 µM: lethal)
sunburn, sunscald	insufficient soil coverage (due to erosion, hard underground pan)
veins on roots	secondary root growth under skin
water stress, water blisters	insufficient or excess water
souring	soil saturated with water before harvesting
intumescence	reduced transpiration + high humidity and low light intensity
skinning	crude handling at harvest, packing, shipping
lightning damages	lightning
fasciation (flat stems)	unknown (unaffected growth)
distal end rot	unknown (developing during curing or storage)
subcutaneous roots	unknown (extended storage?)
false broomrape	unknown (bacteria?)

Harvesting and storage

Sweet potato is a perennial plant grown as annual under the temperate climate. Thus, storage roots are not biologically mature at harvest - unlike the tubers of potato. Storage roots can be harvested any time after reaching marketable size in a sufficient number (BRANDENBERGER ET AL., 2014). The screening of the cut surface of tubers can help to determine maturity: if it is getting black, the tubers are still not ready for being harvested (HORVÁTH, 1991B). Harvesting too early or too late can result in low yields due to tubers not reaching their maximum size in the first case and roots becoming fibrous, being attacked by weevils or root rots in the second (STATHERS ET AL., 2013A). Furthermore, too early harvesting can worsen storage quality (HORVÁTH AND PROKSZA, 2005). Harvesting is usually started when the leaves lose their dark green colour and begin to turn yellow, as well as the soil begins to crack (LIU ET AL., 2014; FIUME, 2015). Sweet potato can be injured below 13 °C, especially below 7 °C. Depending on the utilization purposes, however, harvesting can be prolonged up to the first frosts due to the temperature still being in the safe range near the roots (SUMNER, 1984; FIUME, 2015). Regarding the growth period of 4-6 months, under the general weather conditions of Hungary, it is recommended to finish harvesting between 5th and 10th of October (HORVÁTH AND PROKSZA, 2005).

Foliage is usually cut 2-4 to 15 days prior to harvesting (STATHERS ET AL., 2013A; URL6). Pre-harvest removal of canopy (e.g. with a rotary mower or modified flail chopper) has a ‘curing’ effect: skinning damage was reduced by 62, 53 and 26% if canopy was mowed 10, 8 and 4 days earlier, respectively (LA BONTE AND WRIGHT, 1993).

To prevent the thin and delicate skin of sweet potato from bruising and abrasions, harvesting and handling must be performed with much care. In small fields, storage roots are digged out manually with a spade fork, hoe, pickax or other suitable tools (BRANDENBERGER ET AL., 2014; LIU ET AL., 2014). For mechanical harvest on small fields a modified disk, a moldboard plough (with the tip of the wing cut off) or a middle buster (with a notched coulter), on larger areas a three-point hitch chain-digger, a low, flat-bed potato digger, rod link chain conveyors, or a combine can be used (SUMNER, 1984; STATHERS ET AL., 2013A; BRANDENBERGER ET AL., 2014). Depending on the harvesting method, roots moved to soil surface are collected as far as possible by hand. Sweet potatoes are removed from vines, excess dirt is shaken off, and excess root length is broken off (SUMNER, 1984; FIUME, 2015). Harvested roots may be scalded by the sun if left in the sun for more than 30 min at temperatures above 32 °C. Scalded areas turn purplish-brown and become more susceptible to storage rots (STATHERS ET AL., 2013A; URL8).

Sweet potatoes sold soon after harvest (“green”) are less sweet than those that have not been cured. If storage for an extended period is planned, sweet potato must be cured to promote the formation of a second skin over scratches and bruises. Benefits of curing can be summarized as enhancing culinary characteristics (eating quality, e.g. increased sugar content and flavour), aiding in wound healing (suberization), increasing shelf life by reducing respiration and losses due to shrinkage and diseases, setting the skin (EDMUNDS ET AL., 2008; LEBOT, 2009). In the course of curing, the roots are stored in a warm place (27-30 °C) at high humidity (85-90%) for 5-8 days (HORVÁTH AND PROKSZA, 2005; URL9). The duration depends on the difference between the root pulp temperature and 29 °C – at higher pulp temperature being even as low as 3-5 days. Curing must be started some hours after harvest. A delay of as few as 12 hours has been shown to be detrimental to successful curing (EDMUNDS ET AL., 2008).

Sweet potatoes must be stored at a temperature of at least 13 °C, the ideal range being 13 to 16 °C (DAFF, 2011; FIUME, 2015). Storage below 10 °C or above 20 °C must be avoided (HORVÁTH AND PROKSZA, 2005). Improper storage conditions can be responsible for several problems such as dry matter loss and pithiness, sprouting in storage, chilling injury, excessive shrinkage, disease development in storage (EDMUNDS ET AL., 2008).

CONCLUSIONS

Despite its tropical-subtropical origin, sweet potato has successfully been grown for centuries also in temperate climate. Regarding the various aspects of agronomy, there are general rules that must be followed irrespective of the site of growing. These include the avoidance of forecrops promoting the accumulation of root-damaging pests and pathogens, as well as those increasing the risk of excessive N release; potassium-stressed nutrient supply; planting spacing in the 100 cm x 30 cm range; irrigation in the first 30-40 days; careful harvesting and post-harvest curing of storage roots, among others. Even these factors, however, must be adjusted to the conditions of the site of growing and, as far as possible, to the cultivars chosen. According to HORVÁTH AND PROKSZA (2005), during the whole production process, activities must focus on the prevention of diseases. To achieve this, the most important aspects to consider are: growing resistant varieties; proper selection of the growing site considering soil requirements and growing conditions; avoiding damage of storage roots in the course of cultivation, harvesting, storage and transport; thorough curing of storage roots; professional storage. An essential step in the stabilization of sweet potato among the cultivated plants in Hungary would be the establishing of a Pathogen Tested (PT) scheme in transplant production (MONOSTORI AND SZARVAS, 2015).

In our days in Hungary, cultivation methods based on international sweet potato literature or adapted from technologies of other crops of similar requirements (e.g. potato, root vegetables, strawberry) are generally in use and continuously modified by individual experiences. The planning of scientifically recognized experiments for establishing site- and cultivar-specific approaches to all aspects of agronomy must consider all this information.

REFERENCES

AMANTE, V., O'SULLIVAN, J. (DATE UNKNOWN): Vine lifting and harvesting. In: O'Sullivan, J., Amante, V., Norton, G., van de Fliert, E., Vasquez, E., Pardales, J. (eds.): Sweetpotato DiagNotes: A diagnostic key and information tool for sweetpotato problems. http://keys.lucidcentral.org/keys/sweetpotato/key/Sweetpotato%20Diagnotes/Media/Html/TheCrop/CropManagement/Crop%20Mgt%20Vine%20lifting.htm

AMES, T., SMIT, N.E.J.M., BRAUN, A.R., O'SULLIVAN, J.N., SKOGLUND, L.G. (1997): Sweetpotato: Major pests, disease, and nutritional disorders. International Potato Center, Lima, Peru. 153 p.

AMOAH, F.M. (1997): The effect of number of nodes per cutting and potassium fertilizer on the growth, yield and yield components of sweet potatoes (*Ipomoea batatas* Poir). Ghana Jnl. Agric. Sci. 30: 53-62.

ANONYMOUS (1989): Session IV – Country reports. In: Mackay, K.T., Palomar, M.K., Sanico, R.T. (eds.): Sweet potato research and development for small farmers. SEAMEO-SEARCA College, Laguna, the Philippines. Pp. 366-371.

ANTONIO, G.C., TAKEITI, C.Y., DE OLIVEIRA, R.A., PARK, K.J. (2011): Sweet potato: production, morphological and physicochemical characteristics, and technological process. Fruit, Vegetable and Cereal Science and Biotechnology 5 (special issue 2): 1-18.

BARKER, I., ANDRADE, M., LABARTA, R., MWANGA, R., KAPINGA, R., FUENTES, S., LOW, J. (2009): Challenge theme paper 2: Sustainable seed systems. CIP Socil Sciences Working Paper 2009–1. Unleashing Potential of Sweetpotato in Sub-Saharan Africa. Pp. 43-72.

BARKLEY, S.L., JENNINGS, K.M., SCHULTHEIS, J.R., MEYERS, S.L., CHAUDHARI, S., MONKS, D.W. (2015a): Fomesafen programs for Palmer amaranth (*Amaranthus palmeri*) control in sweetpotato. In: Barkley, S.L.: Optimizing cultural management practices and consumer acceptance of sweetpotato in North Carolina. Chapter II. MSc Thesis. Raleigh, North Carolina. Pp. 33-59.
BARKLEY, S.L., SCHULTHEIS, J.R., JENNINGS, K.M., MONKS, D.W. (2015b): In-row plant spacing and harvest date affect yield of 'Covington' and 'Evangeline' sweetpotato. In: Barkley, S.L.: Optimizing cultural management practices and consumer acceptance of sweetpotato in North Carolina. Chapter IV. MSc Thesis. Raleigh, North Carolina. Pp. 102-126.
BAVEC, F., BAVEC, M. (2006): Sweet potato. In: Bavec, F., Bavec, M.: Organic production and use of alternative crops. CRC Press, Taylor & Francis Group. Pp. 189-200. 214 p.
BRANDENBERGER, L., SHREFLER, J., REBEK, E., DAMICONE, J. (2014): Sweet potato production. Oklahoma Cooperative Extension Service, HLA-6022. Oklahoma State University, 8 p.
BUŠIĆ, Ž. (date unknown): Batat. Hrvatski Zavod za Poljoprivrednu Savjetodavnu Službu. 8 p.
CLARK, C. (2013): Cultivation and storage. In: Clark, C.A., Ferrin, D.M., Smith, T.P., Holmes, G.J. (eds.): Compendium of sweet potato disease, pests, and disorders. Second edition. APS Press, St. Paul, Minnesota. Pp. 4-7.
CLARK, C.A., DAVIS, J.A., ABAD, J.A., CUELLAR, J., MUKASA, S.B., TUGUME, A.K., TAIRO, F.D., VALKONEN, J.P.T., FUENTES, S., KREUZE, J., GIBSON, R. (2012): Sweetpotato viruses: 15 years of progress on understanding and managing complex diseases. Plant Disease 96(2): 168-185.
CLARK, C.A., HOLMES, G.J., FERRIN, D.M. (2009): Major fungal and bacterial diseases. In: Loebenstein, G., Thottappilly, G. (eds.): The sweetpotato. Springer Science + Business Media B.V. Pp. 81-103.
CLARK, C.A., MOYER, J.W. (1988): Compendium of sweet potato diseases. The American Phytopathological Society. 74 p.
COWAN, D. (date unknown): Measure and Manage - Sweet potato fertility guide. Agri-Food Laboratories CCA.On. 2 p.
DAFF - DEPARTMENT OF AGRICULTURE, FORESTRY AND FISHERIES (2011): Sweet potato (*Ipomoea batatas* L.) production. Department of Agriculture, Forestry and Fisheries. Republic of South Africa. 20 p.
DUMBUYA, G. (2015): Effect of tillage, vine length and fertilizer application on the growth, yield and quality of sweet potato (*Ipomoea batatas* (L) Lam). MSc Thesis. University of Science and Technology, Kumasi, Ghana. 113 p.
ECHER, F.R., CRESTE, J.E. (2011): Boron fertilization on sweet potato: effect of sources, rates and application form. Semina: Ciências Agrárias, Londrina 32(1): 1831-1836.
EDMUNDS, B., BOYETTE, M., CLARK, C., FERRIN, D., SMITH, T., HOLMES, G. (2008): Postharvest handling of sweetpotatoes. North Carolina Cooperative Extension Service. Raleigh, NC. 53 p.
EKANAYAKE, I.J., COLLINS, W. (2004): Effect of irrigation on sweet potato root carbohydrates and nitrogenous compounds. Food, Agriculture & Environment 2(1): 243-248.
EKMAN, J., LOVATT, J. (2015): Pests, diseases and disorders of sweetpotato. A field identification guide. Horticulture Innovation Australia Ltd. 69 p.
FIUME, F. (2015): Sweet potato. http://sperimentazione.altervista.org/Sweetpotato.html
HALIRU, M., AUDU, M., LUKMAN, S.A., SAUWA, M.M., ALIYU, I., HAYATU, N.G. (2015): Effect of cow dung, NPK and their combinations on soil properties and performance of

sweet potato (*Ipomoea batatas* L.) in Sudan savanna, Nigeria. American Journal of Experimental Agriculture 6(3): 189-195.

HENDERSON, C. (2015): Managing sweetpotato plant beds in Australia. Literature review March 2015. For HIA Ltd Project VG13004 – Innovating new virus diagnostics and plant bed management in the Australian sweetpotato industry. Horticulture Innovation Australia Ltd, State of Queensland. 18 p.

HORVÁTH L. (1991a): A batáta és termesztése: Az édesburgonya Magyarországon. Kertészet és Szőlészet 40(15): 16-17.

HORVÁTH L. (1991b): A batáta Magyarországon: Védelem, tárolás. Kertészet és Szőlészet 40(16): 16.

HORVÁTH L. (1991c): A batáta szaporítása. Kertészet és Szőlészet 40(21): 7.

HORVÁTH L., PROKSZA P. (2005): Burgonyatermesztőknek az édesburgonyáról. Burgonyatermesztés – A gyakorló burgonyatermelők részére 6(1): 19-22.

HORVÁTH L. (date unknown): Batáta. A batáta hazai termesztésének legfontosabb kérdései. NÖDIK, Tápiószele. 2 p.

HUE, S.M., LOW, M.Y. (2015): An Insight into Sweet Potato Weevils Management: A Review. Psyche. Article ID 849560. 11 p.

IFIA - INTERNATIONAL FERTILIZER INDUSTRY ASSOCIATION (1992): World fertilizer use manual. Paris. 632 p.

KANUA, M.B., RANGAT, S.S. (1989): Indigenous technologies and recent advances in sweet potato production, processing, utilization, and marketing in Papua New Guinea. In: Mackay, K.T., Palomar, M.K., Sanico, R.T. (eds.): Sweet potato research and development for small farmers. SEAMEO-SEARCA College, Laguna, the Philippines. Pp. 271-285.

KAPINGA, R., BYARUHANGA, P., ZSCHOCKE, T., TUMWEGAMIRE, S. (2009): Growing orange-fleshed sweetpotato for a healthy diet. A supplementary learners' resource book for upper primary schools. International Potato Center (CIP), Kampala, Uganda. 142 p.

KUEPPER, G. (2014): Small-scale technology and practices for sweet potato growing in Southeast Oklahoma. Kerr Center for Sustainable Agriculture, Poteau, Oklahoma. 12 p.

LA BONTE, D.R., WRIGHT, M.E. (1993): Image analysis quantifies reduction in sweetpotato skinning injury by preharvest canopy removal. HortScience 28(12): 1201.

LEBOT, V. (2009): Tropical root and tuber crops: cassava, sweet potato, yams and aroids. Crop Production Sience in Horticulture 17. CABI. 413 p.

LIU, H., SHI, C., ZHANG, H., WANG, Z., CHAI, S. (2013): Effects of potassium on yield, photosynthate distribution, enzymes' activity and ABA content in storage roots of sweet potato (*Ipomoea batatas* Lam.). Australian Journal of Crop Science 7(6): 735-743.

LIU, Q, LIU, J., ZHANG, P., HE, S. (2014): Root and tuber crops. In: Van Alfen, N. (ed.): Encyclopedia of agriculture and food systems, Vol. 5. San Diego: Elsevier. pp. 46-61.

LOEBENSTEIN, G., THOTTAPPILLY, G., FUENTES, S., COHEN, J. (2009): Virus and phytoplasma diseases. In: Loebenstein, G., Thottappilly, G. (eds.): The sweetpotato. Springer Science + Business Media B.V. Pp. 105-134.

LU, J., CHEN, F., XU, Y., WAN, Y., LIU, D. (2001): Sweet potato response to potassium. Better Crop International 15(1): 10-12.

MEYERS, S.L. (2013): Slip planting tips. Mississippi Sweetpotato News - Spring 2013. Pp. 2.

MONOSTORI, T., SZARVAS, A. (2015): A review on sweet potato production with special focus on Hungary I: utilization, biology and transplant production. Review on Agriculture and Rural Development 4(1-2): 68-81.

MULONGOY, K., CALLENS, A., OKOGUN, J.A. (1988): Differences in mycorrhizai infection and P uptake of sweet potato cultivars (*Ipomoea batatas* L.) during their early growth in three soils. Biol Fertil Soils 7: 7-10.

NAIR, G.M., RAVINDRAN, C.S., MOORTHY, S.N., GHOSH, S.P. (1989): Sweet potato: indigenous technologies and recent advances of production, processing, and utilization in India. In: Mackay, K.T., Palomar, M.K., Sanico, R.T. (eds.): Sweet potato research and development for small farmers. SEAMEO-SEARCA College, Laguna, the Philippines. Pp. 301-312.

NOGUERA-RAMKISSOON, A. (2011): Sweet potato nutrient requirements. Reference Materials – Module 3. 11 p.

NOVAK, B., ŽUTIĆ, I., TOTH, N. (2007a): Effects of mycorrhizal fungi and colored mulch in sweet potato production. Acta Hortic. 729: 245-248.

NOVAK, B., ŽUTIĆ, I., TOTH, N., DOBRIČEVIĆ, N. (2007b): Sweet potato [*Ipomoea batatas* (L.) Lam] yield influenced by seedlings and mulching. Agriculturae Conspectus Scientificus 72(4): 357-359.

O'KEEFE, D.M., SYLVIA, D.M. (1992): Chronology and mechanisms of P uptake by mycorrhizal sweet potato plants. The New Phytologist 122(4): 651-659.

O'KEEFE, D.M., SYLVIA, D.M. (1993): Seasonal dynamics of the association between sweet potato and vesicular-arbuscular mycorrhizal fungi. Mycorrhiza 3(3): 115-122.

OLIVEIRA, A.P., SANTOS, J.F., CAVALCANTE, L.F., PEREIRA, W.E., SANTOS, M.C.C.A., OLIVEIRA, A.N.P., SILVA, N.V. (2010): Yield of sweet potato fertilized with cattle manure and biofertilizer. Horticultura Brasileira 28: 277-281.

O'SULLIVAN, J. (DATE UNKNOWN): Nutrient disorders. In: O'Sullivan, J., Amante, V., Norton, G., van de Fliert, E., Vasquez, E., Pardales, J. (eds.): Sweetpotato DiagNotes: A diagnostic key and information tool for sweetpotato problems. http://keys.lucidcentral.org/keys/sweetpotato/key/Sweetpotato%20Diagnotes/Media/Html/TheProblems/nutrient%20disorders.htm

OVERSTREET, C. (2009): Nematodes. In: Loebenstein, G., Thottappilly, G. (eds.): The sweetpotato. Springer Science + Business Media B.V. Pp. 135-159.

ÖNDER, D., ÖNDER, S., ÇALIŞKAN, M.E., ÇALIŞKAN, S. (2015): Influence of diferent irrigation methods and irrigation levels on water use efficiency, yield, and yield attributesof sweet potatoes. Fresenius Environmental Bulletin 24(10a): 3398-3403.

PHILLIPS, S.B., WARREN, J.G., MULLINS, G.L. (2005): Nitrogen rate and application timing affect 'Beauregard' sweetpotato yield and quality. HortScience 40(1): 214-217.

PORPÁCZY, A. (1953): Batátatermesztési kísérletek. A Magyar Tudományos Akadémia Agrártudományi Osztályának Közleményei 2: 19-28.

RASHID, M.M. (1989): Indigenous technologies and recent advances in sweet potato production, processing, utilization, and marketing in Bangladesh. In: Mackay, K.T., Palomar, M.K., Sanico, R.T. (eds.): Sweet potato research and development for small farmers. SEAMEO-SEARCA College, Laguna, the Philippines. Pp. 287-300.

ROY, R.N., FINCK, A., BLAIR, G.J., TANDON, H.L.S. (2006): Nutrient management guidelines for some major field crops. In: Roy, R.N., Finck, A., Blair, G.J., Tandon, H.L.S.: Plant nutrition for food security - A guide for integrated nutrient management. FAO Fertilizer ans Plant Nutrition Bulletin 16. Pp. 235-261.

RUBATZKY, V.E., YAMAGUCHI, M. (1997): World vegetables. Principles, production and nutritive values. 2nd edition. Springer-Science+Business Media, B.V. 843 p.

SCHULTHEIS, J.R., WALTERS, S.A., ADAMS, D.E., ESTES, E.A. (1999): In-row plant spacing and date of harvest of 'Beauregard' sweetpotato affect yield and return on investment. HortScience 34(7): 1229–1233.

SMITH, T.P., VILLORDON, A.Q. (2009): Nitrogen management in Louisiana sweet potatoes. Louisiana State University Agricultural Center, Publ. 3138. 4 p.

SORENSEN, K.A. (2009): Sweetpotato insects: identification, biology and management. In: Loebenstein, G., Thottappilly, G. (eds.): The sweetpotato. Springer Science + Business Media B.V. Pp. 161-188.

STATHERS, T., BECHOFF, A., SINDI, K., LOW, J., NDYETABULA, D. (2013a): Everything you ever wanted to know about sweetpotato: Reaching agents of change ToT manual. Vol. 5: Harvesting and postharvest management, Processing and utilisation, Marketing and entrepreneurship. International Potato Center, Nairobi, Kenya. Pp. 189-270.

STATHERS, T., CAREY, E., MWANGA, R., NJOKU, J., MALINGA, J., NJOKU, A., GIBSON, R., NAMANDA, S. (2013b): Everything you ever wanted to know about sweetpotato: Reaching agents of change ToT manual. Vol. 4: Sweetpotato production and management; Sweetpotato pest and disease management. International Potato Center, Nairobi, Kenya. Pp. 143-188.

STODDARD, C.S. (2013): Phosphorous and boron fertilizer impacts on sweetpotato production and long-term storage. CDFA FREP Final Report. https://www.cdfa.ca.gov/is/ffldrs/frep/pdfs/completedprojects/13-0266-SA_Stoddard.pdf

SUMNER, P.E. (1984): Harvesting, curing and storage of sweet potatoes. Cooperative Extension Service, The University of Georgia College of Agriculture. 9 p.

THOMPSON, P., WILLIAMS, M., BYRD, J., THOMAS, J., PARVIN, D., KILLEBREW, F. (2014): Commercial sweetpotato production in Mississippi. Mississippi State University Extension Service. Publication 1678. http://msucares.com/pubs/publications/p1678.html

TRAYNOR, M., BLACKBURN, K., DICZBALIS, Y. (date unknown): Sweet poteto irrigation. http://www.nt.gov.au/d/Primary_Industry/Content/File/horticulture/vegetables/PAGES+FROM+TB221-SWEET+POTATO+IRRIG.pdf

TUCKEY, D.M. (2001): Crop profile for sweetpotatoes in Virginia. http://www.ipmcenters.org/cropprofiles/docs/VAsweetpotato.pdf. 14 p.

UWAH, D.F., UNDIE, U.L., JOHN, N.M., UKOHA, G.O. (2013): Growth and Yield Response of Improved Sweet Potato (*Ipomoea batatas* (L.) Lam) Varieties to Different Rates of Potassium Fertilizer in Calabar, Nigeria. Journal of Agricultural Science 5(7): 61-69.

Internet sources (downloaded: 31.06.2014 – 30.11.2015):

URL1: http://bonnieplants.com/growing/growing-sweet-potatoes/

URL2: http://media.wix.com/ugd/a6aecc_7311b235e08a49cf817a3bd7de7bb6fe.pdf

URL3: http://media.wix.com/ugd/a6aecc_f3c3133791ef46058953d4699683dca1.pdf

URL4: http://www.batatapalanta.hu/termeszteacutesi-tudnivaloacutek.html

URL5: http://www.clemson.edu/extension/hgic/pests/plant_pests/veg_fruit/hgic2215.html

URL6: http://www.infoagro.com/hortalizas/batata.htm

URL7: http://www.mintakeres.hu/wp-content/uploads/2015/01/batata2.pdf

URL8: http://www.ncsweetpotatoes.com/sweet-potato-industry/growing-sweet-potatoes-in-north-carolina/cultivating/

URL9: http://www.ncsweetpotatoes.com/sweet-potato-industry/growing-sweet-potatoes-in-north-carolina/curing-and-storing/

URL10: http://www.ncsweetpotatoes.com/sweet-potato-industry/growing-sweet-potatoes-in-north-carolina/growing-your-seedstock/

URL11: http://www.ncsweetpotatoes.com/sweet-potato-industry/growing-sweet-potatoes-in-north-carolina/planting/

URL12: http://www.ncsweetpotatoes.com/sweet-potato-industry/growing-sweet-potatoes-in-north-carolina/soils-and-fertilization/

URL13: http://www.organicgardening.com/learn-and-grow/sweet-potato

URL14: http://www.uq.edu.au/_School_Science_Lessons/SPotProj.html