SWEET POTATO PRODUCTION

EXPERIMENTAL RESULTS AND EXPERIENCES

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MAGYARORSZÁG KORMÁNYA

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Tamás Monostori
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University of Szeged Faculty of Agriculture
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Contents

Foreword

Sweet potato or batata [*Ipomoea batatas* (L.) Lam.] have become an almost constantly available product in domestic vegetable shops, grocery stores and markets during the last decade. The steadily increasing consumer demand has, as expected, quickly led to an increased interest in the crop by producers, which is still evident today. The high consumer prices are due, among other things, to the fact that, despite the significantly increased cultivation area, domestically grown sweet potatoes can satisfy domestic needs for at most half a year from autumn, after which they are replaced by imports.

However, along with the further increase of the growth area necessary to supply the domestic market as fully as possible, the development of cultivation technology is also necessary. Already in the initial period of the rise of domestic sweet potato cultivation, it became clear, based on information from producers and own growing experience, that yield stability problems can occur regularly, even with many years of practice, the cause of which is often not clear. In order to solve these problems, our experiments in cultivation technology were started in 2015 and have been being supported from 2019 by the **Rural Development Programme "Creation of Innovation Operational Groups and support for investment in the implementation of innovative projects"** under the EIP-AGRI project **"Development of site- and variety-specific cultivation technology and pathogen-free production of propagating material for sweet potatoes"**, involving 2 research centres, 3 producers and 2 experts. In addition to the small plot experiments with several replications, the evaluation of the experience of sweet potato cultivation on farms in different production areas in the Southern Great Plain region (Hungary) was part of the programme.

The present publication makes the comprehensive description of sweet potato cultivation technology from practical aspects even more authentic with the authors' own experiences, supported - among others - by experimental results.

The editors

The importance and uses of sweet potato – in brief

Sweet potato is the world's sixth most important food crop after rice, wheat, potato, maize and cassava, but it is also an important fodder crop, which can be explained by its remarkable nutritional value and nutritional effects.

One of the most important physiological effects of sweet potato is to improve blood sugar control, and it may therefore be important in the diet of type 2 diabetics. Its glycaemic index (GI) is generally medium (63±6), but its level (41±5 - 93±5) depends on the processing method (boiling - low GI, roasting - high GI) and, to a lesser extent, on the variety.

Sweet potato (especially the orange fleshed genotypes) is an important source of provitamin A carotenoids and is also an important source of vitamin C, vitamins B (thiamine, riboflavin, niacin), potassium, phosphorus, calcium, magnesium and iron. Purple fleshed varieties are rich in antioxidant and anti-inflammatory anthocyanins. Sweet potato has a low protein content of 2.5 to 7.5% of dry matter. In addition to its storage roots, sweet potato leaves are a remarkable source of nutrition and fodder, with qualities similar to spinach. They also contain a number of antioxidant, antimutagenic, anti-inflammatory, anticarcinogenic, antibacterial and antidiabetic compounds (anthocyanins, polyphenols). The crude protein content of the leaves is 25.5-29.8%, which shows a digestibility of 74-76% in pigs.

Sweet potato is also important as animal feed. Both its storage roots and foliage can be used to feed pigs, cattle and other livestock. However, for most batata genotypes, the high trypsin inhibitory activity detectable in fresh tubers has to be taken into account, which can be most easily reduced to an appropriate level by heat treatment of the tubers (e.g. at 100 °C for 5-15 minutes). Foliage can be fed fresh or in silage form.

The industrial use of sweet potatoes, except in the food industry, is relatively less important today and shows a strong regionalisation. The production of starch from sweet potatoes proves to be economical mainly in the Far East (China, Japan, South Korea), while in the Western countries and the USA, it is still more profitable to market as food. Because of its high carbohydrate content, sweet potato can also be an important raw material for bioethanol production: 14.5 litres of ethanol can be produced from 100 kg of the crop, compared with 11.4 litres for potatoes, 11.9 litres for sugar beet, 17.6 litres for wheat, barley and oats and 44.9 litres for maize. On a per-hectare basis, only sugar cane yields better results (5.2-6.4 m^3 vs. 6.4-9.6 m^3). It can also be used to produce biodegradable and carbon-neutral bio-plastics for the automotive industry, films for crop production and waste bags for households.

Environmental requirements and crop rotation of sweet potato

Sweet potato is the most widely adapted root crop and, despite its in humid tropical and subtropical regions, is successfully grown in temperate regions.

Climate requirements

Batata can be grown safely where it is guaranteed a frost-free period of at least 120-150 days. It is favorable for it if the average daily temperature is 24-25 °C and it does not go below 10 °C permanently, because then the plant stops growing. It prefers plenty of sunlight and warm nights, but has no tolerance for shade. When evaluating one of our own multi-replicate experiment, we had to exclude some plots because they were shaded by a distant tree at certain times of the day, significantly impairing the growth and yield of the plants concerned compared to the average of the other replicates.
The annual rainfall requirement is 750-1000 mm, of which 500 mm is needed during the growing season. The water availability of the first 30 days (40 days according to several authors) is crucial. Once the roots have started to develop, it is drought tolerant, but 20-25 mm of rainfall or irrigation per week is beneficial. Before harvesting, a period with little rain but rather dry is optimal.

Soil requirements

To produce larger quantities and better quality tubers, a well-drained, light, sandy or silty loam soil is needed. On nutrient-rich, compacted soils, sweet potatoes produce high yields of low-quality tubers, while on very poor, light sandy soils, the yield of high-quality roots is low. In our own experiments, sweet potato has been shown to grow well on hard clayey loam soils, with adequate soil preparation, even if only with rotary hoes.
Both surface and internal drainage of the soil are very important. Wet patches caused by poor surface drainage reduce yields, while inadequate internal drainage results in high moisture content and poor aeration, which, in addition to reducing yields, results in large, shapeless, cracked and rough-skinned storage roots. It is advisable to avoid freshly cut grassland and pastures and areas with excessive organic matter.
Sweet potato tolerates soil pH between 4.5 and 7.5, with an optimum of 5.8-6.2.

Crop rotation

To avoid plant protection issues caused by soil-borne pathogens and pests, a rotation of 3-5 years is recommended, but at least 4 years is required for effective prevention against sweet potato weevil, which has not yet been detected in

Hungary. Areas contaminated by herbicide residues or by sweet potato cognates, or by morning glory species (e.g. field bindweed) should be avoided.

It is best sown after cereals (small-grain cereals, maize, sorghums, millet, rice, etc.) but can also be grown successfully after vegetables (e.g. leafy vegetables, onions, tomatoes).

However, root and tuber crops, under which soil-borne pathogens and pests (earthworms, nematodes, wireworms, European mole cricket, etc.) can reproduce, should be avoided. Legumes and pulses, which enrich the soil with nitrogen, should also be avoided, although international practice allows legumes in some traditional crop rotation systems (e.g. beans, cowpeas, soybeans, peanuts).

In our own experiments, we did not observe significant yield depression after 4-5 years in monoculture on phosphorus-rich clayey loam soil, which had been fallow for years and used as poultry yard.

Sweet potato soil preparation

As in other arable crops, after forecrops harvested early and leaving little or no stem and root residues, stubble cleaning and its closing, then – depending on volunteer plant and weed growth – treatment of the cleaned stubble and its closing precede the basic tillage. After late-harvested forecrops of large stem and root residues, the sequence is chopping (or possibly carrying away) of the stem residues and mixing the chopped residues into the soil.

Basic (primary) tillage may be ploughing to a depth of at least 15 cm. However, in order to obtain a suitable storage root shape and to avoid excessive elongation of the tubers, the ploughing depth should not be more than 20-30 cm. Depending on the soil quality and the tillage strategy, non-reverting tillage (with cultivator, possibly with disc) may be used at similar depths.

On small areas, on loose or sandy soil, the soil can also be properly prepared by rotary hoeing, while on hard soil, a sufficiently loose, crumbly soil condition can be achieved by repeating it several times.

Sweet potato can be grown successfully in both flat and ridge/bed cultivation (*Table 1*). Cuttings are usually planted in 1 row in the ridge and in 2 (or more) rows in the bed (*Figure 1*).

Table 1. Comparison of flat and ridge/bed cultivation

Flat cultivation	Ridge/bed cultivation
- primarily on loose soils, but can also be effective on hard soils - better water retention - easier preparation - better mechanisation of planting - more difficult to harvest	- more widespread internationally, regardless of soil type and quality - better drainage - easier harvesting - ridges/bedding height: at least 20-30 cm width: 25-90 cm (too narrow - dries out easily) - formation: with plough, hoe, hand tools

Covering the rows and/or the inter-row space with coloured, mostly black plastic mulch is used in both cultivation methods, but mainly in the ridge/bed technologies. Its advantages include weed control, water retention and, by promoting soil warming, early growth. The use of biodegradable films is an environmentally friendly solution. However, when covering with plastic mulch, irrigation is only possible with a drip system.

Figure 1. Cultivation of sweetpotato in flat, in ridges and in ridges with plastic mulch cover (from left to right)

The justification of growing batata under film or in greenhouses in climatic conditions similar to those in South-East Hungary is questionable. In many countries, mainly in cooler climates (Great Britain, Poland, Canada, etc.), sweet potatoes are successfully grown in greenhouses, under plastic tunnels and other weather-protected conditions.

On sandy soils in the same region of Hungary, a faster initial development of the crop was achieved by covering with vlies, but later on the covering did not result in either increased yield or earlier harvestability - but it did not reduce the yield either.

Figure 2. Sweet potato production in greenhouse (Szeged, Hungary)

In the same region, in a two-year experiment in a double-layer plastic greenhouse on hard soil, the plants produced a large canopy, but yields were far below expectations: the average yield per plant was 195-358 g for the 5 white/pale yellow fleshed varieties tested, 96-240 g for the 2 orange fleshed varieties and 18 g for the 1 purple fleshed variety (*Figure 2*).

Nutrient supply of sweet potato

Depending on site conditions, variety, expected yield and other factors, sweet potatoes require the following amounts of the main nutrients to produce 1 tonne of crop (specific nutrient requirement: kg $tonne^{-1}$):

N: 2.3-4.3 P_2O_5: 0.76-0.80 K_2O: 3.8-7.5 Ca: 1.2 Mg: 0.4

The amount of nitrogen, depending on the variety, geographical location, climate and season, is necessary to increase tuber yield. Excessive amounts, however, may result in excessive foliage development to the detriment of tuber development and may also lead to cracking of tubers.

Sweet potato is a low phosphorus demanding crop and can be supplied through mycorrhizal means, with efficiency depending on the variety. However, it is questionable whether the phosphorus remaining after the forecrop is sufficient for sweet potato.

Potassium has the greatest effect on yield and quality. Increasing its dose, depending on the variety, may result in an increase in tuber number and weight per plant as well as in tuber weight per hectare. Opinions are divided as to the active ingredient used, but it appears that both K-sulphate and K-chloride can be used safely.

Calcium reduces the fragility of the skin of the tubers and improves their shelf life.

Magnesium and sulphur deficiencies may also occur, so it is worth including their supplementation in the protocol.

Supplementation of micronutrients (Zn, Cu, Mn, Fe, B) can be based on plant analysis, but routine supplementation with up to two applications of foliar fertilisers can prevent deficiency symptoms. Boron supplementation is definitely worth considering, applying 1-4 kg of the active ingredient per hectare to the soil (Borax) or to the foliage (Solubor), as this can prevent blistering and scabbing on the tuber skin.

Doses of active substances of the most important nutrients applied per hectare (kg ha^{-1}):

N: 30-50 P_2O_5: 50-100 K_2O: 100-150

The optimum utilisation of nitrogen is achieved with a ratio of $N:K_2O$ = 1:1.5-2 and N:P:K = 1:2:3.

Care should be taken to avoid excessive nutrient supply. In our own experiment, we have repeatedly found that either excessive applications of basic fertilisers, mainly N, or excess applications of foliar fertilisers resulted in a significant reduction in yield instead of an increase. During the growing season, one indicator of the problem may be the development and densification of the foliage, which is more pronounced than typical for the variety (*Figure 3*). It should be noted, however, that both the underdeveloped foliage and the overdeveloped foliage can generally result in reduced yields.

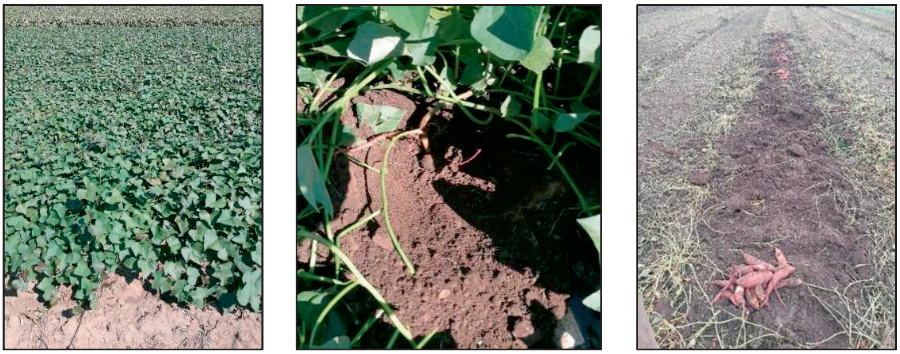

Figure 3. Overdose of nutrients results show: large foliage and low yield (Makó)

Application strategies for the main nutrients are varied:

- Nitrogen
  - incorporated into the soil before planting
  - OR (e.g. in areas prone to leaching) 1/2-1/3 incorporated into the soil before planting + top dressing after 4-6 weeks (possibly +10-12 weeks)
  - OR 14-28 days after planting
- Phosphorus
  - incorporated into the soil before planting
  - OR at planting or shortly after planting
- Potassium
  - 1/4-2/3 incorporated into the soil before planting + rest with N as leaf spray
  - OR 1/4 at planting + leaf spray at the start of the foliage growing period

Among the organic manures, a better response is expected for vegetable compost and green manure than for animal manures, due to a more favourable nitrogen: potassium ratio (N<K). In our experience, however, the use of farmyard manure is generally good, contrary to several literature opinions.

Although there is relatively little experience, but in sweet potato, the use of humic acid and fulvic acid preparations can also be effective.

In microbe-based fertilizers *Azospirillum brasilense*, *Klebsiella sp.*, *Azotobacter sp.*, *Azotobacter vinelandii*, *Acinetobacter sp.*, *Pseudomonas sp.*, *Penicillium sp.* strains, and the mycorrhizal fungi *Claroideoglomus etunicatum*, *C. claroideum*, *Rhizophagus irregularis*, *Funneliformis geosporus*, *F. mosseae* have been used effectively as an alternative to nutrient replenishment of sweet potatoes.

In our own experiments, with a commercially available formulation containing strains of *Pseudomonas putida*, *Azotobacter chroococcum*, *Bacillus circulans*, *Bacillus megaterium*, developed and produced in Hungary, yielded close to the best yielding NPK 8-24-24 fertilizer. Under the given experimental conditions, neither the combined application of bacterial and mineral fertiliser, nor the combined application of fertiliser and foliar fertiliser increased the yield (*Figure 4*). On a per hectare basis, the yield obtained with bacterial fertiliser was only about 0.5 tonnes lower than that obtained with mineral fertiliser (23.1 vs. 23.6 tonnes ha^{-1}), but 8.5 tonnes higher than the untreated control.

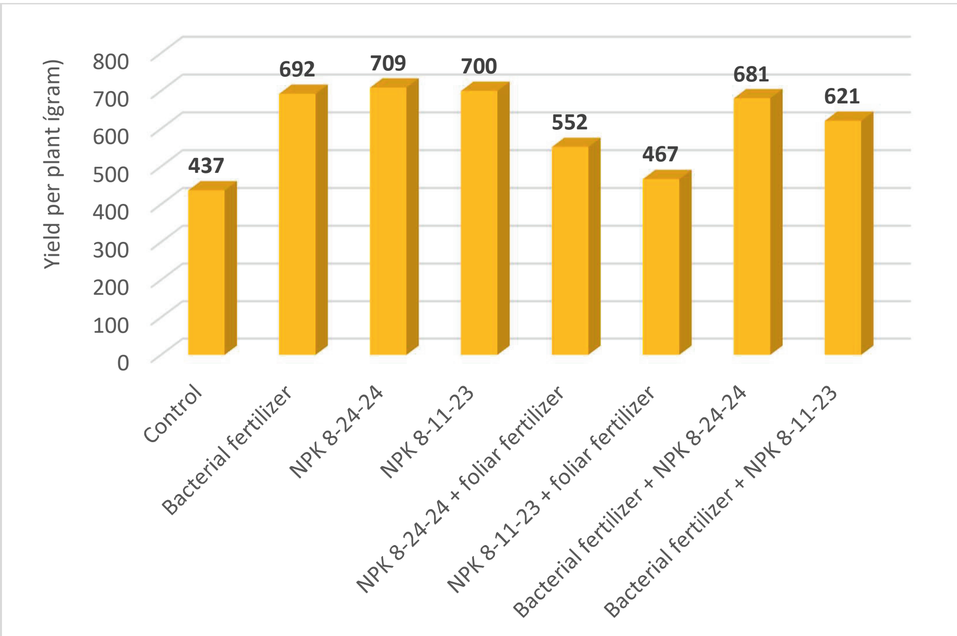

Figure 4. Effects of bacterial fertilizers, mineral fertilizers, foliar fertilizers and their combinations on the production of sweet potato (Hódmezővásárhely, Hungary)

The potential of microbe-based fertilizers was further demonstrated with an experimental formulation containing *Trichoderma afroharzianum, Trichoderma harzianum, Pseudomonas resinovorans, Bacillus velezensis* and *Arthrobacter globiformis strains*, which outperformed both the untreated control and the nutrient solution treatment using the same farm technology. The difference varied from 5 to 12 tonnes per hectare in the former case and from 1.9 to 13 tonnes in the latter, depending on the treatment. Soil inoculation at the beginning of intensive foliar development as an additional treatment had a positive effect on yield.

Sweet potato planting material and planting

Planting material

Sweet potato is a vegetatively propagated plant. Its planting material, unlike that of potatoes, is not its tubers (which are ROOTS modified for storage, unlike the tubers of the potato of STEM origin) but cuttings (’slips’) produced by the sprouting of storage roots (in tropical-subtropical areas, the ends of the vines of the batata). The slips may be derived directly from tubers deposited for the production of cuttings, or by further division and propagation of the primary cuttings obtained this way.

Sweet potato cuttings can also be produced relatively easily at home by providing suitable growing conditions. There is a lot of information about these on the internet, we will not discuss them in detail here - the principle reason for this is detailed below. It should be noted, however, that the production of pathogen-free cuttings in large quantities is only possible based on *in vitro* micropropagation, virus testing (e.g. PCR, ELISA) and virus control systems.

Since the production of sweet potato planting material in Hungary is currently (2022) not under control by the authorities, as it has been mandatory for our traditional crops for decades, many producers produce and sell cuttings of often unclear origin and uncertain health status. We do not wish to support this activity, our aim is to ensure that growers obtain pathogen-free, variety-identical planting material from a reliable source. This is the only way to prevent the deterioration of the domestic sweet potato population until official controls on the production of the planting material are introduced.

Currently, planting material of two certified, domestically bred sweet potato varieties is available in Hungary:

- Tápiói 96 (year of certification: 2003): variety with yellowish-white flesh, purplish-red skin
- Ásotthalmi12 (year of certification: 2015): variety with orange flesh and red-copper skin

In addition to these, several international varieties (e.g. Beauregard, Covington) are suitable for Hungarian cultivation based on the growers’ experiences. Once again, we would like to draw your attention to the fact that from the wide range of varieties, you should only purchase from a seller where the disease-free, especially virus-free status of the planting material is guaranteed.

There are several types of sweet potato cuttings in use. The most common are primary cuttings (*Figure 5*, left), but secondary cuttings (*Figure 5*, middle), produced by further division and propagation of primary cuttings, are also known to growers. In our three-year experiment, we did not observe any significant difference in the yield obtained with the two types of cuttings (*Figure 6*). Special care must be taken when using cuttings in soil block (*Figure 5*, right). These are only suitable for use with small roots, as overdeveloped roots will result in curved, tangled storage roots. Unlike in tropical-subtropical countries, the use of the vines of productive plants as cuttings is not common or feasible in countries of the temperate zone.

Figure 5. Primary and secondary sweet potato cuttings and cuttings in soil block (from left to right)

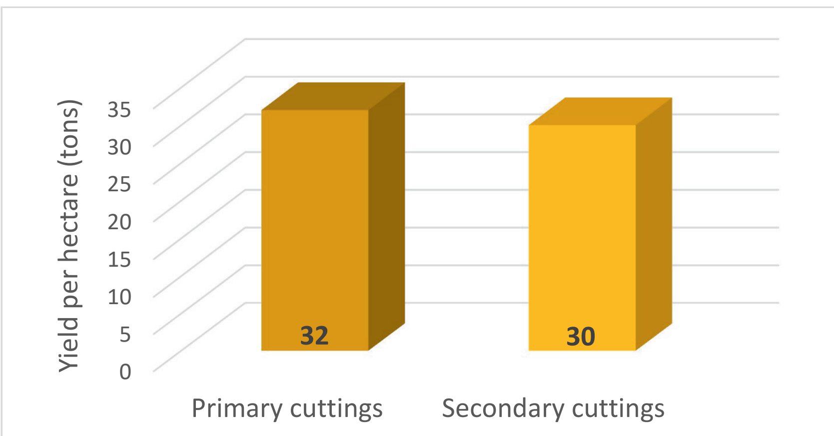

Figure 6. Yield trends of batata obtained with primary and secondary cuttings (Deszk, Hungary)

Planting

Planting sweet potato should start after the last frosts, when the soil temperature is at least 15 °C for 4 consecutive days at a depth of 10 cm. In Hungary, this means the last decade of May as the optimum period, but depending on the season, planting can be successful from the first decade of May until the end of June. However, our own experiments have confirmed that an early harvest, made possible by early planting, can result in a higher yield (*Figure 7*).

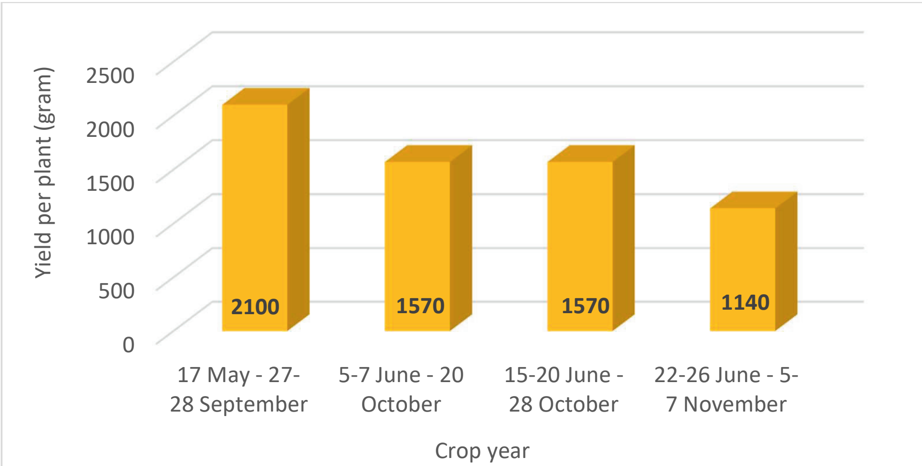

Figure 7. Effect of planting and harvesting time on batata yield (Tiszasziget, Hungary)

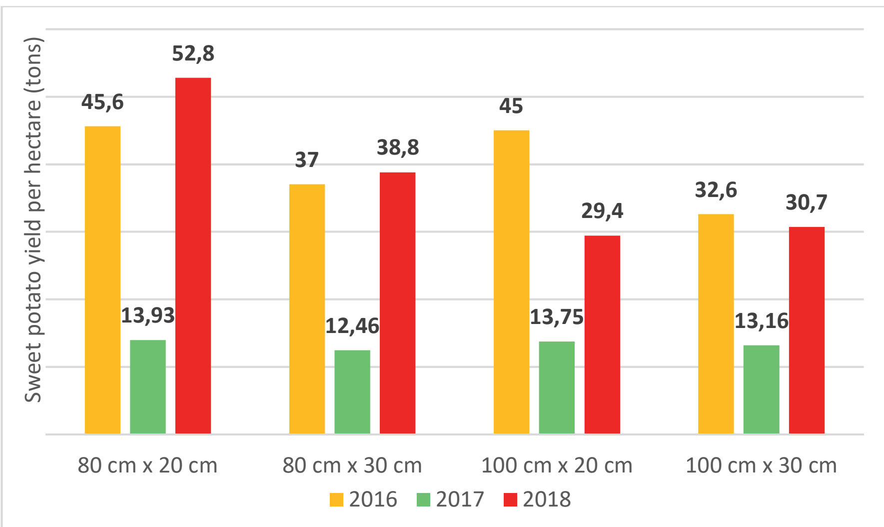

Figure 8. The effect of row and plant-to-plant distance on sweet potato yield (Domaszék and Ásotthalom, Hungary)

In flat and ridge cultivation, the row distance is 80-100 cm, and the plant to plant spacing is 20-30 cm. Within a bed/ridge, the row spacing is 30-40 cm and the plants are typically staggered between rows in a triangular pattern (*Figure 8*).
Planting can be done with disc- or finger-type and other planting machines, or in smaller areas with hand tools (*Figure 9*).

Figure 9. Machine planting of batata in Portugal and in Southern Hungary

It is important that at least 2, but preferably 3, nodes of the slips get in the soil, and that at least 2 leaves remain above the soil. It is not necessary to remove the leaves from the part of the stem that is in the soil. The planting can be done vertically, at an angle or bent up (with the bottom part in the soil horizontal and above the soil surface vertical). The latter solution makes it possible to form evenly developed tubers side by side so that the adjacent cuttings almost touch each other in the soil. Depending on the variety, growing site and production system, the number of plants per hectare can be between 33,000 and 63,000. If the cuttings are of good quality and the planting conditions and cultivation techniques are suitable, the number of plants produced will be very similar to the number of the planted ones. The good quality of the cuttings is maintained by using them as soon as possible after they leave the nursery (cutting them from the tuber). They can safely survive for several days, however, if wrapped in damp paper or stapled in a soil-peat mixture, even after arrival at the grower. However, dipping in water or storing in water even overnight should be avoided by all means, as it can cause bacterial soft rot, fusarium infection, dry rot and other diseases. To prevent the transmission of possible infections resulting from seed tubers, many growers remove the lower 2-3 cm of the cuttings.
An important prerequisite for the rapid rooting of cuttings is the use of “silting” irrigation immediately after planting or by modifying the planting machine (*Figure 10*).

Figure 10. Front-mounted IBC tank for irrigation at the same time as planting (Portugal)

New roots start to grow about 24 hours after planting. The number of roots that become storage roots is determined by the conditions of the first two weeks after planting. If they are ideal, a significant proportion of the roots will develop into tubers. If conditions are unfavourable or the root is damaged, a fibrous root system will develop. When the initially favourable conditions later become unfavourable, long, slightly thickened 'pencil roots' covered with capillary roots develop (*Figure 11*).

Figure 11. "Pencil roots" of sweet potato

Plant care of sweet potato

Irrigation

Sweet potato is - at least moderately - drought tolerant and responds very well to irrigation.

During the 1-30 (40) days after planting, soil moisture is a critical factor in determining the number of storage roots. The importance of soaking irrigation at planting has already been mentioned. The relative drought tolerance of the plant depends, among other things, on the water availability on demand during the first 4-6 weeks, which can ensure that it can survive subsequent water shortages.

In dry conditions, applying 20-25 mm of irrigation water per week can be a prerequisite for crop security. Irrigation should be completed at least 2 weeks and up to 1-1.5 months before the planned harvest. However, irregular watering should be avoided, as both too little and too much water can reduce yield and quality. Uneven water supply causes growth cracks and drought can reduce yields. In excessively wet soils, oxygen deficiency is a problem: lenticels in storage roots expand, and if water surplus persists for a prolonged period, storage roots will turn sour and rot.

Under Hungarian conditions, there is little experience of the clearly beneficial effect of irrigation interrupted for 5 days between days 40 and 60 or at the end of July to promote tuber development. Reducing the amount of irrigation water to 30% between days 40 and 50, however, proved to have a favorable effect on tuber formation.

Figure 12. Irrigation with micro-sprinkler, sprinkler and drip irrigation in sweet potato

Various irrigation systems can be effectively applied to sweet potato, the most common being sprinkler and drip irrigation (*Figure 12*). In small areas, furrow irrigation is also rarely used, often in combination with ridges. Perhaps the most common of the sprinkler irrigation methods is the use of micro-sprinklers, which has the advantage of being applicable to any type of cultivation without a plastic cover and, in addition to water replenishment, also contributes to reducing atmospheric drought. The disadvantage is that it stimulates weed growth. Drip irrigation is a water-saving technique that allows targeted application of nutrients and even pesticides. Currently available drip systems are no longer necessarily more expensive than sprinklers, but they are the only effective option for water replenishment when used with a plastic mulch cover.

Mechanical weed control, lifting vines

Sweet potato can suppress weeds in the second half of its growing season, but until then it is advised to keep the stand free of weeds. Depending on the size of the area, the inter-row space can be cultivated with a cultivator or a hand hoe. The inter-row cultivation also contributes to soil aeration, which is particularly important on compacted soils.

Lifting the rooting vines of sweet potatoes prevents the formation of underdeveloped secondary storage roots at nodes touching the wet soil. This is to ensure that the tubers only develop under the base of the plant, and that those growing elsewhere do not deprive them of nutrients. However, for the less spreading varieties, the lifting of the vines is not expected to affect the size of the crop. In our own two-year experiment, for a spreading variety (which is typical of varieties grown in Hungary), we did not find a significant difference in yield between stands of lifted and non-lifted vines, and the effect was not clearly positive (*Figure 13*). Likewise, there was no clear positive effect of lifting the vines on the quality of the storage roots (proportion of tubers of class 1-2).

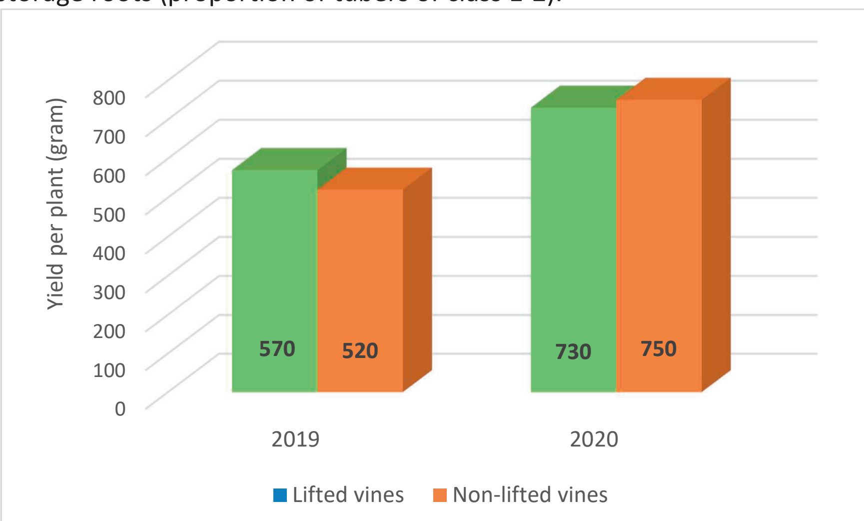

Figure 13. Effect of the lifting of batata vines on yield (Sarkad, Hungary)

Plant protection of sweet potato

In this publication, we address the most important plant protection issues for sweet potato commodity production practices. Viral infections, which are a serious problem for the production of propagating material, are not covered. We only note that 7 viruses or virus complexes of sweet potato have been identified in Hungary to date (Kiemo et al., 2022, https://doi.org/10.1111/ppa.13519). It is also worth mentioning that the most important pest at international level, the sweet potato weevil (*Cylas formicarius*), is not yet known to be a problem in Europe.

Regarding the plant protection of sweet potato, it is important to clarify that currently (2023) there are no pesticides authorised for sweet potatoes in Hungary. Emergency authorisations for Amistar Top, Dual Gold 960 EC and Force 1.5 G have already been applied for, but these are only valid for the period for which the producer requests them. Growers have gained further experience on the applicability of the pesticides, but numbers of them are solving crop protection problems with biological control.

Soil disinfection

Sweet potato is almost impossible to grow without soil disinfection, because soil-borne pests (nematodes, white grubs, wireworms, mole cricket, etc.) cause serious damage to the crop. This is where the use of a drip system really comes into its own, as several biological preparations can be released during the growing season. It is important to use these several times from planting. Sweet potato also has foliar pests (mainly caterpillars of various moth species), but they cause so little damage due to the large mass of foliage that it is not worth to control them.

Soil pest control

Green manure for crop protection

Fast-growing plants producing large amounts of biomass for green manure (e.g. oilseed radish, mustard, facelia, sweet clover, lupins, rye) are grown to incorporate the green parts into the soil (*Figure 14*). They can be mixed into the soil to improve its physical and biological conditions, improve nutrient management, increase organic matter content, protect the soil surface from erosion, suppress weeds and reduce the population of soil-borne pests (e.g. oilseed radish and facelia the nematodes). The glucosinolate compounds secreted by the roots of these plants are not liked by wireworms, i.e. if such plants are sown, the number of perennial larvae will be reduced.

Figure 14. Facelia (left) and white mustard (right) as green manure crops

Microbiological products
Artis Pro
Active ingredient: the product contains spores of the fungus *Beauveria bassiana*
Dose: 1.5-6.0 kg ha^{-1}
It contains a fungal strain which reduces the living conditions of many soil-dwelling insect larvae and nematodes, significantly reducing or even eliminating their damage. It is described as fast-acting and is available in small packages. It has the advantage of being applied by drip irrigation.

Bora
Active ingredient: the product contains spores and mycelia of the hyperparasitic fungus *Beauveria bassiana*
Dose: 1.5-3.0 kg ha^{-1}
A microbiological plant growth promoter that has a yield-enhancing effect on both monocotyledonous and dicotyledonous plants. Once in the soil, it promotes plant growth while creating almost unmanageable conditions for pests.

Chemical soil disinfectants
Force 1.5 G
Active ingredient: 15 g kg^{-1} tefluthrin (pyrethroid)
Dose: 7-10 kg ha^{-1}
Force 1.5 G soil disinfectant is authorised on an ad hoc basis. For use against soil-dwelling pests (wireworms, white grubs), applied before planting.

Cyperkill 25 EC
Active ingredient: cypermethrin
Dose: 0.4 l ha^{-1}

Cyperkill should be applied through the drip irrigation system. It is effective against wireworms and white grubs.

Protection against soil-borne fungi

Trifender Pro

Active ingredient: conidia and hyphal remains of the antagonistic fungal strain *Trichoderma asperellum*

Dose: 1-3 kg ha^{-1}

For the control of soil-borne fungi (e.g. *Sclerotinia*, *Pythium*, *Fusarium*, *Phytophthora spp.*), Trifender Pro can be used as a biocontrol product. In sweet potato in Hungary only the soil-borne fungus “scurf" (*Monilochaetes infuscans*) has caused major problems for growers. It appeared in 2021 and unfortunately causes such severe quality damage to the crop that it becomes unsaleable (symptom: black, brownish spots on the tuber surface). The infested area should be left fallow for several years and treated with Trifender Pro.

Weed control

Sweet potato has no specific weeds. It has a very diverse weed flora, which depends mainly on the soil type (*Figure 15*). Weed control is only necessary during the first four to six weeks of planting, as after this period most sweet potato plants suppress weeds completely and effectively. Effective weed control is a critical aspect of successful sweet potato production, as weeds compete with the crop for nutrients, water and sunlight, thus reducing yield and quality.

Frequent crop rotation is beneficial in reducing weeds, as the use of alternative herbicides reduces weed production and subsequent weed build-up.

Figure 15. Portulaca oleracea (left) and *Amaranthus retroflexus* (right) as common weeds in sweet potato

Mechanical weed control (hoeing, rototilling) should be carried out at an early stage of weed development, and later on the vines of the sweet potato will invade the soil surface to suppress the weeds.

The use of Dual Gold 960 EC (active ingredient: S-metholachlor), a highly selective pre-emergence, anti-sprouting monocot herbicide, with a significant seed-borne dicot eradication effect, is also permitted in sweetpotato cultivation. After application, a wash-in rainfall is required and a minimum waiting period of one week is very important, which means that the transplanting of cuttings can be started one week after application.

Other plant protection issues

Control of greenhouse whiteflies

The greenhouse whiteflies (*Trialeurodes vaporariorum)* causes the foliage to wrinkle. Due to the large foliage mass, the plant can withstand the damage, but it is worth spraying the stand once, as the pest can be a vector for viruses. A suitable product for control is Karate Zeon 5 CS (active ingredient: 50 g l^{-1} lambda-cyhalothrin/pyrethroid family of active ingredients).

Protection against damage caused by game

Repellent bags 'Vadóc'

The bags should be placed on stretched twine, fences, trees or bushes at a height of 40-120 cm (at the height of the animals' nose), usually every 6-8 metres. The bags must not be punctured or dropped on the ground.

Protection against common vole (*Microtus arvalis*)

Repellent granulate 'Delu'

Active substance: calcium carbide

The preparation should be introduced into the lesion and the hole sealed (*Figure 16*).

Figure 16. Rodent damage on a tuber

Sweet potato harvesting and storage

Harvesting

Sweet potato is a perennial crop, grown as an annual in temperate climates. Thus, the storage roots are considered biologically mature when the foliage has yellowed or browned, so that the formation of assimilates is complete. Tubers, however, can be harvested at any time when they have reached technical maturity, i.e. market size. In the case of small tubers or early harvesting, it is advised to carry out a cutting test: ripeness is considered satisfactory if no black discolouration is observed. In Hungary, the harvest lasts from the beginning of September until the first frosts (around the end of October). It is worth bearing in mind that the vulnerability of sweet potato tubers increases below 13 °C, but especially below 7 °C.

Figure 17. Removed foliage in a sweet potato field before harvesting (Ásotthalom, Hungary)

Harvesting is preceded by defoliation, which takes place immediately before or 2-3 or even 15 days before the tubers are collected. It can be done efficiently with a weed whacker, or in smaller areas with pruning shears or hedge trimmers *(Figure 17).*

For harvesting, it is important to know that the skin of the tuber is very susceptible to mechanical damage, which requires extra care even when picking by hand! Harvesting in small areas can be carried out entirely by hand tools and by hand: lifting with a spade or spade fork, picking manually. There are several possibilities for mechanised harvesting. A special sweet potato harvesting machine or (early) potato harvesting machine (if necessary, by coating the sticks of the applicator belt or other parts in contact with the tubers with rubber or plastic) can save a lot of manual labour. It is effective and greatly reduces the extent of damage to the tubers to lift the rows with a shaking row lifter or an undercutter treelifter and to pick up the unrolled tubers by hand (*Figure 18*).

Figure 18. Sweet potato harvesting with a shaking row lifter, an undercutter and a modified potato harvester (from left to right)

The average yield of sweet potatoes under Hungarian conditions is expected to be between 20 and 40 t per hectare, with an optimum yield of at least 1 kg per plant.

Curing and storage

Sweetpotato (in international trade: "green" sweet potato) sold shortly after harvest is even less sweet than tubers that have been heat-treated and stored for a longer period. The primary purpose of heat treatment is to "heal" or "cure" the damage sustained during cultivation, harvesting and transport, allowing the tubers to be stored for months (in our experience, up to 7-8 month).

The heat treatment is also necessary for the sweet taste of the variety, as it starts to break down the starch into simple sugars within a few hours. Heat treatment should preferably be started within a few hours of harvesting, but for several years we have not observed any significant loss of quality even if it has been started within 1-2 days. Heat treatment can be done in several ways. It is most effective at 30-35 °C in 5-7 days, but can also be safely carried out at room temperature of 21-22 °C, in which case it should be carried out for at least 21 days. To reduce storage ("shrinkage") losses, it is important to ensure high humidity (85-90%) during treatment.

Sweet potato storage roots are sensitive to both low and excessively high temperatures during storage. Optimum is between 13-16 °C. Below 10 °C, the quality deteriorates: the central parenchyma hardens. At temperatures around 20 °C, however, the tubers sprout.

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