

Sweet Potato Production, Handling, Curing, Storage, and Marketing in North Carolina

L. G. Wilson, C. W. Averre, and H. M. Covington¹

North Carolina has an excellent climate and soil for producing high yields of quality "yam-type" sweet potato cultivars. 'Jewel,' which stores well for over 9 months, originated from this state. Over the past 30 years, the combined efforts of research and extension scientists and interested growers and persons in agribusiness industries have minimized the effects of diseases and insects, and introduced improved production, harvesting, curing, storage, and marketing techniques. North Carolina is the leading sweet potato producing state in the United States and produces over one-third of the crop. Growers and shippers have a well-organized, effective association to promote their products nation-wide and to support all aspects of the sweet potato industry. Sweet potatoes are the leading horticultural commodity in North Carolina and are sold in every marketing area east of the Rocky Mountains. Discussion includes problems, current investigations, and future trends.

The sweet potato (*Ipomoea batatas*) is grown commercially as an annual crop in the United States, even though it grows as a perennial in the Neotropics, its centre of origin. This crop has been grown in North Carolina for nearly two centuries and has been the leading horticultural crop in this state for much of this century. North Carolina has led all states in sweet potato production since 1969, due in no small part to its ability to produce efficiently and thereby compete effectively in many markets.

The success of the North Carolina sweet potato industry is partly attributable to the many contributions of a group of research and extension scientists at North Carolina State University, the members of support industries in the agribusiness community, plus growers who are interested in developing better ways to grow sweet potatoes. An important factor responsible for North Carolina's success has been the keen interest of growers and shippers and their formation of the North Carolina Yam Commission, Inc. in 1961. This well-organized, cohesive group of growers and shippers has successfully promoted research and development, and the production and marketing of quality sweet potatoes. Their voluntary assessment on this product (2¢ per bushel fresh, 2¢ per cwt processed) has provided funds to gain market territories through merchandising, promotion, and advertising efforts. They have imposed seasonal limitations on themselves on the sale of freshly harvested, uncured sweet potatoes. They continue to strive for an improved

consumer quality image and greater operational efficiency with the capability of relating to the needs of world markets in the future.

Another aspect of the success story in North Carolina is related to the peculiar prominence of tobacco, its allotment system, and the consolidation of tobacco allotments. The number of farms in North Carolina is second only to the State of Texas. Many of these farmers are constantly seeking new crops to grow, since tobacco production is essentially a "closed shop" and ever larger farming units are necessary. Sweet potatoes and tobacco are somewhat complementary crops with regard to labour utilization and field operations.

Cultivars

'Porto Rico,' and more recently 'Centennial,' were the predominant cultivars in North Carolina until the early 1970s. In 1969, 'Jewel' was released by the North Carolina State University Agricultural Experiment Station. Although poorly received by the industry at first, North Carolina growers and shippers soon realized that 'Jewel' was a high yielding (ca. 500 bushels/acre avg, up to 1000 bushels/acre experimentally), high quality, fresh market sweet potato with excellent storage, and good processing qualities. They found it to be widely adaptable, early sizing ("chunky" shape), soft-fleshed, and resistant to several diseases (i.e. *Fusarium* wilt, internal cork virus, and southern root-knot nematode) and some insects (i.e. flea beetle). Its popularity has increased annually, and in 1976 over 75% of the acreage of sweet potatoes in North Carolina were planted to 'Jewel.' This cultivar is also popular in many

¹Agricultural Extension Services, North Carolina State University, Raleigh, N.C. 27607, USA.

other sweet potato producing areas of the United States.

Major weaknesses of 'Jewel' include its susceptibility to "souring" in wet soils (anaerobic soil conditions) and skinning. For these reasons, some growers still plant some 'Centennial' and other "wet tolerant" cultivars. These problems maintain high priorities in the current sweet potato breeding program in North Carolina.

Transplant Production

The "seed program" of each grower is critical and much thought and effort is expended on this phase of each successful operation. The North Carolina Crop Improvement Association, primarily through the North Carolina Certified Sweet Potato Growers' Association, cooperates with North Carolina State University and the sweet potato industry. This organization is responsible for certifying each sweet potato cultivar as to purity and freedom from certain pests and diseases. Crop improvement personnel perform field and storage inspections and work closely with the sweet potato breeding program at North Carolina State University. Growers are urged to purchase 5–10% of their requirements each year as either certified seedstock or certified transplants so that their planting stock is never more than two generations removed from certified stock.

Presprouting seedstock at curing temperatures (ca. 30 °C) for approximately 4 weeks prior to bedding results in more prolific sprout production (Covington 1962) and has become a standard practice in North Carolina. Unfortunately, some growers do not fully comprehend that metabolic activity of the seedlings increases during presprouting, presenting a greater demand for oxygen and producing more carbon dioxide. Insufficient ventilation results in poor sprout production and often causes seed stock to rot before bedding.

Sweet potato seed stocks are placed in beds elevated about 10 inches (25 cm) and are most commonly about 3 ft (1 m or less) in width, depending on the grower's operation. Due to the high cost of labour, careful hand placement of the roots has generally been replaced by pouring seed roots from boxes or pallet bins. Most seed roots are dipped in, or drenched with, a fungicide and the beds are treated with a herbicide. A uniform covering of 2 inches of soil and 2-mm clear plastic covers are recom-

mended. Fertilization and irrigation promote more prolific sprouting.

Transplants are generally pulled, but where scurf or black rot are suspected, growers are careful to cut sprouts off above the ground to avoid transmitting these fungi to their fields. Rotting of roots in the plant beds and/or inferior sprout production is a problem, and deserves attention.

Considerable effort continues to be applied to develop effective systems for direct planting of seed pieces in the field in hopes of reducing the labour requirement for transplant production, which represents approximately one-half of the total cost of sweet potato production in North Carolina. Breakthroughs in seed piece planting do not appear possible with all cultivars due to genetic characteristics.

Field Preparation

There are approximately 2 million acres (910 000 ha) of soil in eastern North Carolina that are well suited for the production of quality sweet potatoes. Much of this is Norfolk fine sandy loam soil (typically containing 65% sand, 20% silt and 15% clay, with about 1% organic matter), which has good internal drainage and permits good root development. Fertilizers and soil moisture are retained within the sweet potato root zone because these soils are underlaid, 18–20 inches below the surface, with heavier soils containing a much higher percentage of clay. Field selections are generally made in the fall and the soil pH adjusted to 5.8–6.2. The benefits of greater fertilizer efficiency warrant liming, even if the field is rented for only a single season.

After the soil is broken in early spring, it is ridged to promote optimum drainage. This is especially important during the later stages of growth and development when the storage roots are most susceptible to "souring." About 2 weeks prior to transplanting, a preplant fertilizer is incorporated into this ridge along with an appropriate nematicide. Several nematicides are approved and recommended (dichloropropene, EDB (Dowfume, Soilbrom), ethoprop (Mocap), and fensulfothion (Dasanit) (North Carolina State University 1976).

Weed control is accomplished by cultivating plus the use of recommended and approved herbicides (diphenamid (Dymid or Enide), DCPA (Dacthal), chloramben (Amiben) and vernolate (Vernam)). Vernolate must be in-

corporated prior to planting, but the others can be band- or solid-sprayed over the transplanted rows.

Crabgrass (*Digitaria sanguinalis*), ragweed (*Ambrosia artemisiifolia*), lambsquarter (*Chenopodium album*), and cocklebur (*Xanthium americanum*) are the major weed pests in North Carolina sweet potato fields.

Fertilization of sweet potato fields depends on the results of soil analyses, rainfall, and the individual grower's operations. Generally, it is recommended that 90–110 lb/acre (108–132 kg/ha) of nitrogen be applied; about 30 lb (36 kg/ha) at preplant, 40 lb (48 kg/ha) sidedressed at the last cultivation, and another 20 lb (24 kg/ha) broadcast 4–5 weeks later. An additional 20 lb/acre (24 kg/ha) of nitrogen may be used any time following rainfall, which may cause excessive leaching. Phosphorus (P_2O_5) is required at about 60 lb/acre (72 kg/ha) and should all be preplant applied. Potassium (K_2O) is required at about 150 lb/acre (180 kg/ha), 30 lb (36 kg) of which is preplant applied and the remainder sidedressed at the last cultivation. Many growers have developed their own fertilizer programs. However, a typical schedule may resemble the following: 500–600 lb/acre (560–672 kg/ha) of 6-12-6 banded in the row or broadcast as a preplant application, about 500 lb/acre (560 kg/ha) of 8-0-24 sidedressed at the last cultivation (mid-July) and 100–200 lb/acre (112–224 kg/ha) of sodium nitrate applied as a topdressing 4–5 weeks after the last cultivation (mid-August) and/or as required due to excessive leaching. Since the physiological storage disorder, "blister" affects some varieties grown in North Carolina (i.e. 'Jewel'), 0.5 lb/acre (0.6 kg/ha) of boron is also applied; usually it is formulated in the preplant fertilizer as Borax or Solubor if requested by the grower.

Diseases

Historically, sweet potato diseases have been a major problem confronting the industry in North Carolina, but they are under reasonable control at this time. Internal cork (a virus disease) and blue stem (*Fusarium oxysporum* f. sp. *batatas*) were extremely serious when 'Porto Rico' and other cultivars were widely grown; 'Centennial' and 'Jewel' possess acceptable levels of resistance. Black rot (*Ceratocystis fimbriata*) and scurf (*Monilochaetes infuscans*) have been under control for approxi-

mately 15 years with a carefully followed plan of crop rotation, sanitation, and use of certified seed. Pox (*Streptomyces impomoeae*) is not present in the major sweet potato growing areas of North Carolina. Southern blight or circle spot (*Sclerotium rolfsii*) occasionally causes locally serious problems. The fungus is soil-borne and is widespread.

The root-knot nematode (principally *Meloidogyne incognita*) is widespread in the sweet potato growing areas of North Carolina. Some growers continue to sustain losses due to nematodes even though excellent control procedures, based on soil sampling and the use of nematicides, have been proven effective. Losses are compounded because yields are reduced and quality is lowered.

Rots of mature and/or harvested storage roots probably cause losses of over 15% annually. These rots are caused by several fungi and possibly some bacteria and viruses. In most cases, however, the indirect or predisposing factors include: soils waterlogged for more than 1 day, bruises, chilling below 10 °C, heating and drying in the sun, and poor curing conditions. These rots continue to be a problem and control is based on proper field selection and handling of harvested roots.

Insects

At the present time, insects do not cause problems of major proportions in sweet potato production in North Carolina. Numerous insects feed on the foliage but there is no evidence that they cause yield reductions.

Wireworms (*Condoerus falli*, *Condoerus vespertinus*, and *Melanotus communis* in order of importance, respectively) can cause damage by making small holes in the storage roots. These insects are controlled by broadcasting a granular insecticide (i.e. fonophos or Diazinon) over the foliage when the storage roots begin to form.

Various species of white grubs occasionally damage sweet potatoes. Such damage can be minimized by avoiding soils that are high in organic matter and/or by broadcasting and incorporating a granular insecticide into the soil prior to planting.

Flea beetles (*Chaetocnena confinis*) attack sweet potatoes causing damage resembling "writing" on the surface of the storage roots. This insect is best controlled by planting resistant varieties, such as 'Jewel.' Fortunately,

no sweet potato weevil (*Cylas formicilarius elegantulus*) infestations presently exist in North Carolina. To prevent this most destructive insect from getting established, growers are careful to use only seed stock and plants from noninfested areas. If it is necessary to import plants or seed stock from other states they must be certified "weevil-free" by the official certifying agency in the state of origin.

Occasionally, lepidopterous larva (i.e. *Heliothis zea*) on the foliage at harvest may damage exposed, harvested roots by feeding on them.

Harvesting and Handling

Most sweet potatoes in North Carolina are turned out of the ground by plow and hand-graded into field boxes or 20-bushel pallet bins. This labour-intensive method requires constant, close supervision to ensure that all of the sweet potatoes are "scratched out" of the ground and that they are graded accurately, and to minimize handling damage.

Riding harvesting aids are popular because they keep labourers together and take some of the drudgery out of their work, although they do little to reduce the total labour requirement. The roots are dug and elevated to a horizontal conveyor where they are separated from their vines and graded by hand into appropriate containers. New devining equipment has been developed that virtually eliminates hand vine separation.

A mechanical harvester is available that harvests sweet potatoes and transfers them field-run into 20 bushel pallet bins. This equipment is best suited for freshly harvested green sales, but with careful handling with appropriate hydrohandling equipment, sweet potatoes harvested in this manner can be cured and stored for packaging and marketing at a later date. Avoiding mechanical injuries, prompt placement of roots under curing conditions, and sanitation (in such a system) are essential to minimize storage rots. When properly operated, the paddlewheel transfer system, recently developed in North Carolina, is well suited to such a hydrohandling system.

Experiments with bulk harvesting systems that will handle 100–200 bushel units from the field to storage are currently in progress. This "systems approach" to mechanization could revolutionize sweet potato production and handling.

Approximately 30% of the annual North Carolina sweet potato crop is processed. This represents that portion of the crop that does not meet quality specifications for the fresh market; none are grown specifically for processing. Processed sweet potatoes are generally handled in bulk.

Curing and Storage

Those sweet potatoes not sold directly from the field at harvest time are cured for 7–10 days at 29 °C at a relative humidity of 90% or higher. Much of the more than 6 million bushels of storage facilities in the state include modern curing facilities. These consist of floor trenches to provide heat and high humidity, fans for the necessary aeration (ventilation), and adequate insulation.

The curing process is primarily one of wound healing (periderm formation) to minimize the invasion of rotting organisms. Curing also promotes the culinary quality of this commodity by inducing the increase of enzymes (primarily α -amylase), which promotes the hydrolysis of starches to sugars (Walters et al. 1975). The sooner sweet potatoes are cured after harvest the better their quality will be maintained during storage. Delays (between harvest and curing) result in excessive shrinkage in storage and losses due to rots. After proper curing, sweet potatoes are held at 13–15 °C and high humidity with occasional ventilation, until marketed.

Packaging and Marketing

Nearly all of North Carolina's fresh sweet potatoes are packaged in one bushel fibreboard boxes weighing 50 lb (22.7 kg). Wirebound boxes and bushel baskets, which were used extensively in the past, are now used only for local marketing. Most of North Carolina's sweet potatoes are marketed in eastern and central U.S. population centres. Occasionally, however, they are marketed over the entire country. The crop is marketed fresh all year, but primarily in September through January, with peak marketing periods coinciding with U.S. holidays such as Thanksgiving, Christmas, and Easter.

There are three large sweet potato processing plants in North Carolina. One of these plants produces dehydrated sweet potato flakes, using

a flaking procedure developed at North Carolina State University.

Sweet potato chips are in the advanced stage of development at North Carolina State University. This product shows promise of becoming a highly desirable snack food similar to potato chips.

At this stage, the postharvest problems of sweet potatoes probably require more attention than any other single area of this crop. The education of handlers and consumers is needed to promote proper handling and storage conditions (especially temperatures) for enhanced

sweet potato quality maintenance and further reduction of losses.

Covington, H. M. *Pre-sprouting sweet potatoes*. North Carolina Extension Service, Hort. Info. Leaf. 104, 1962.

North Carolina State University. *North Carolina agricultural chemicals manual*. North Carolina State University, Agricultural Experiment Station and Cooperative Extension Service, Raleigh, N.C., 1976.

Walters, W. M., Purcell, A. E., and Nelson, A. M. *Effects of amylolytic enzymes on "moistness" and carbohydrate change of baked sweet potato cultivars*. *J. Food Sci.* 40, 1975, 793-796.

Sweet Potato Production in Hawaii

J. S. Tanaka and T. T. Sekioka¹

This paper describes the general cultural practices of sweet potato production in Hawaii. Presented are cultivars grown, method of planting, fertilizer application, pest control, harvesting, and factors contributing to increased yield.

There are two types of sweet potatoes (*Ipomoea batatas*) grown for the market. The type referred to as sweet potato in Hawaii is dry-fleshed with white to pale yellow or purple flesh and is used mostly for boiling or frying. The other type, popularly called "yam," is moist-fleshed with orange flesh and used mostly for baking.

The sweet potato is grown all year round and is planted on all islands, with 71% being grown on the island of Oahu. Approximately 20 ha of sweet potato are harvested yearly with a production of 373 tons. Data for sweet potato production in Hawaii from 1965 to 1974 can be found in "Statistics of Hawaiian Agriculture, 1974." Approximately 246 tons of sweet potato are imported to the state of Hawaii annually from the United States mainland.

Cultivars

There are dozens of native clones of sweet potato in Hawaii. Many of these clones are still grown to a limited extent. Kona B is the best-yielding baking or yam-type sweet potato, whereas Waimanalo Red is the earliest, best-yielding, highest quality dry type. Other moist

type cultivars are Iliula and Onolena, whereas other dry-type cultivars are HSPA-3, Miyashiro, and Kaneohe Red. All of the cultivars mentioned above are of local origin except Waimanalo Red, which was introduced from Okinawa.

Planting

The sweet potato is propagated by means of tip cuttings in Hawaii because planting materials are available throughout the year and tip cuttings are relatively free from vine borers and diseases. The cuttings are about 8-12 inches in length with all except two or three of the terminal leaves removed from the vine.

The cuttings are planted at an angle with two-thirds of the stalks covered with soil. They are spaced 6-12 inches apart in the rows, with rows set 3 ft apart. Close spacing of plants in the rows encourages the development of roots that are of the best shape and size for the market. Wider spacings tend to produce extra large roots that are a lower grade and thus fetch a lower price.

Fertilizer Applications

A fertilizer with a medium amount of nitrogen and phosphate and a great amount of potash is best. Rates (kg/ha) of fertilizer recommended are: N 40-50, P₂O₅ 70-110, and K₂O 70-110.

¹University of Hawaii, Honolulu, Hawaii 96822. Paper published with the approval of the Director of the Hawaii Agricultural Experiment Station as Journal Series No. 2011.