Economic Impact of Virus-Free Sweetpotato Planting Material in Shandong Province, China

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In many developing countries, yields of root and tuber crops are significantly reduced due to diseases and pests in the planting material. (In sweetpotato, the sources of planting material [which are either vine cuttings or roots] are equivalent to clonal seed for vegetative propagation.) The development and transfer of new methods and technologies for producing disease-free clonal seed can overcome this constraint and help unlock the significant yield potential of these crops. In potato, the use of virus detection and tissue culture techniques in tuber seed programs is common especially in developed countries. In sweetpotato, such techniques have not been used even in the United States where propagation material is periodically renewed to maintain clonal purity. Virus elimination is not an objective or consequence of these programs.

In the late 1980s, the International Potato Center (CIP) in collaboration with Chinese agricultural scientists began a project to develop and transfer new methods for propagating virus-free roots and vines for sweetpotato production in China. Such systems are now being developed in the main sweetpotato growing areas of China. The most advanced program can be found in Shandong Province, where virus-free roots were first distributed to farmers in 1994. This paper briefly describes the sweetpotato propagation program, its impact on yield, and its economic consequences.

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Development of the Virus-Free Sweetpotato Multiplication System

Sweetpotato is the third ranking crop in Shandong Province after maize and wheat. In the farmers' traditional system, sweetpotato roots are stored from the fall harvest to the following spring planting. Sweetpotatoes are typically grown on poorer-quality rainfed land in rotation with maize or groundnuts, or in a winter wheat-sweetpotato-maize rotation that produces three crops every two years. The spring sweetpotato crop is planted in late March or April and harvested in September or October. When following winter wheat, sweetpotato is planted as a summer crop in July and then harvested in October after the spring crop is harvested. The spring crop accounts for about 60% of the total sweetpotato area in Shandong and exhibits a higher average yield than the summer crop because of its longer growing season. Planting material for the summer crop comes from vines cut from the previously established spring crop.

In the late 1980s, propagation of virus-free roots was identified by international and national sweetpotato scientists as a possible means of improving farm yields of existing sweetpotato varieties in China. Field observations together with laboratory testing indicated high levels of virus infection in sweetpotato plants in farmer's fields, especially the sweetpotato feathery mottle virus (Zhang, 1996). In 1988 with technical assistance from CIP, training courses were organized to demonstrate how to produce and multiply virus-free sweetpotato roots. The technique involves taking meristem tips from selected plants

and then regenerating the entire plant using a culture medium (Salazar, 1996). Heat treatment is used to reduce virus concentration in the plant's growing tips up to a point where some are freed of viruses. ELISA tests are conducted to confirm that plantlets are free of virus infection. Virus-free plantlets are then grown out in heated greenhouses and used as mother plants for multiplication.

Following the CIP training courses, scientists from the Shandong Academy of Agricultural Science (SAAS) conducted applied research in tissue culture and multiplication techniques to establish the most appropriate medium for the cultures, the best timing for transplanting, and other multiplication methods. Beginning in 1992, SAAS conducted field trials in different locations of the province to compare yields of virus-free roots with yields from farmers' roots. These trials showed an average yield increase of around 40% in plots using virus-free roots of popular new varieties and even larger increases with virus-free roots of older varieties (Zhang, 1995). The success of the trials led to substantial financial support from provincial and local governments for extension and multiplication of virus-free material for propagation. In 1993 and 1994, large-scale extension and demonstration trials were carried out in all of the major sweetpotato producing counties of the province. The first virus-free roots were extended to farmers in 1994 and extension activities were intensified in 1995.

The organization of the virus-free sweetpotato multiplication system in Shandong is depicted in Figure 1. Because of the possibility of getting two multiplications of propagation material per year (the spring and summer crops), the Shandong program has achieved exceptionally high rates of multiplication: one ha planted the first year can provide sufficient clean roots to plant 250-400 ha the following year. In 1998, net houses in the province had a capacity to produce 10,000 plant cuttings per year, enough to produce first generation

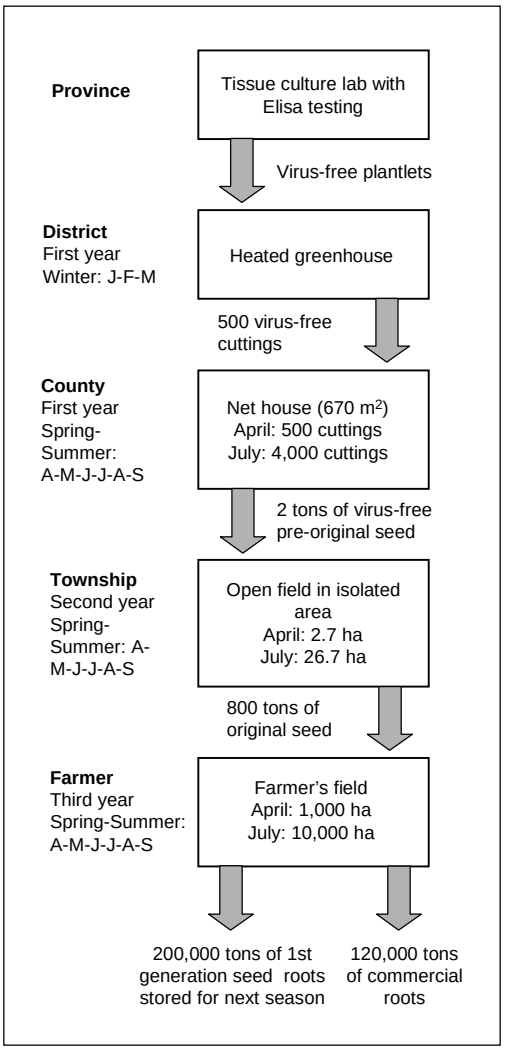

Figure 1. The virus-free seed propagation system in Shandong Province.

production roots for more than 500,000 ha two years later.

Data and Methods for Impact Assessment

Two main sources of information were used to examine the impact of virus-free sweetpotato plant material on farm yields, production, and income: (1) a survey of sweetpotato farmers in 30 villages conducted in 1998; and (2) data on yield demonstration trials, plant material production, and costs of research, extension, and plant multiplication provided by SAAS.

The village survey was designed and conducted by a multidisciplinary team of researchers from SAAS and CIP in August and September 1998. Thirty villages in Shandong Province were selected from the seven districts with the greatest area planted to sweetpotato.

Results and Discussion

Market structure

Responses from the surveys suggest that demand is highly elastic. Not only is production impact regional, but more than 80% of the sweetpotatoes produced in the province are either fed to livestock (where they compete with locally grown and imported maize-based feed) or are processed into starch and/or noodles for export to other provinces or countries. In the survey, farmers were asked whether the sweetpotato market prices had been affected in recent years by the increase in production attributed to virus-free planting material. In all cases, farmers responded that market prices for sweetpotatoes had been stable over the past several years and that demand from the processing industry was strong and could absorb whatever they produced.

Survey responses also provide evidence of an inelastic supply, at least with respect to the adoption of virus-free planting material. Inelastic supply coupled with elastic demand is our preferred "baseline characterization" of market structure for estimating the economic impact of virus-free planting material in Shandong Province.

Estimation of benefits

According to the sweetpotato multiplication program, virus-free plants were estimated to have reached 84% of the sweetpotato area in Shandong Province by 1998. This estimate includes areas planted to new and first and second generation planting material. Among the 30 villages surveyed, virus-free roots were first used in 1995 and by 1998 had spread to 78% of the sweetpotato area in the villages (Figure 2).

The rapid diffusion of virus-free roots can probably best be explained by its significant and noticeable effect on yield. Both large-scale demonstration plots conducted by the Shandong agricultural extension service during 1993-1994 and the village survey show similar levels of average yield improvement from virus-free roots. For the most widely grown variety, Xushu 18, virus-free roots are estimated to have increased yield of the spring crop by 11 t/ha, or by more than 30% over the yield obtained from farmers' own roots. Yield gains from other important varieties (Lushu 7, Lushu 8, Beijing 553) for the spring crop ranged from 6.7 to 10 t/ha according to the village survey and by between 13 and 16 t/ha in the demonstration plots.

For the summer crop, yield of Xushu 18 was estimated by farmers to have increased by an average of 10.6 t/ha, or by 41%. Summer crop yields of other varieties were estimated to have increased by from 8.5 to 10 t/ha.

Gross benefits are estimated by multiplying the estimated area planted with virus-free roots by the average production increase per ha by age of the planting material. For new roots, the production increase is estimated to be 10.35 t/ha, for first generation roots the production increase is estimated to be 9.6 t/ha, and for

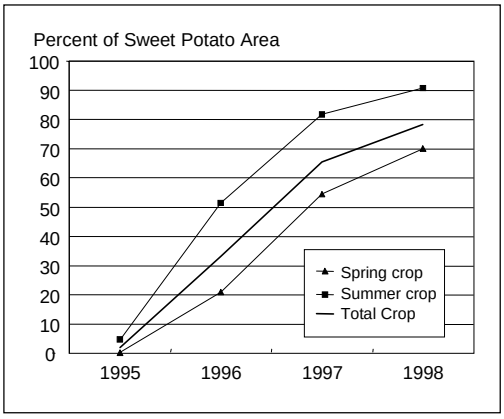

Figure 2. Diffusion of virus-free sweetpotato seed in the 30-village survey.

second generation roots it is estimated to be 6.9 t/ha. These figures are derived from the village survey. Area planted to virus-free roots is derived from data on virus-free planting material production that was provided by the provincial seed program and assumes a seeding rate of 750 kg/ha. The benefit estimation also assumes that the total area planted to sweetpotatoes will remain at about 533,000 ha in the future and that the diffusion of virus-free roots reaches an upper limit of 78% of the total sweetpotato area. Both assumptions are probably conservative.

The program is estimated to increase sweetpotato production in the province by 3.965 million metric tons annually equivalent to a value of gross benefits of US$167 million/yr. Benefits are assumed to remain at this level until the end of the activity in 2020. The diffusion of virus-free roots between 1994 and 1998 resulted in a 22% increase in sweetpotato production in the province, equivalent to a 2.6% increase in global production.

Costs of research, extension and seed multiplication

Research and extension costs were incurred early in the project and were soon dwarfed by expenses for the multiplication of planting material. Research was the principal activity for the first four years of the program. As virus-free roots were being tested and provided to farmers, government subsidies—especially for technical training, construction, and materials—played an important role in getting the multiplication system established and providing farmers with relatively low-cost material. Once farmers were convinced of the benefits of virus-free roots and adopted them, revenues from sales of virus-free roots soon supported most of the costs of the program. By the eighth year of the program, about 90% of the annual US$19.6 million cost of the program was derived from seed sales.

The initial subsidies provided to the program helped keep the price of improved planting material low, and thus promoted its rapid diffusion. One factor that furthered rapid diffusion was that virus-free roots were relatively cheap compared with the benefits of higher yield. Partial budgeting shows that adoption of first generation virus-free roots for the spring sweetpotato crop produced on average nearly 7 Yuan in additional value of yield for each 1 Yuan of added costs. Although it may have been possible to fund a larger share of the program from root sales, it would have required charging farmers higher prices for improved seed and could have dampened diffusion. After large-scale adoption has occurred, it should be possible to recover the initial subsidies through a small, temporary tax on virus-free root sales. Such a tax could provide revenues for funding the development and diffusion of improved planting material in other regions.

Benefit-cost measures and sensitivity analysis

Under the baseline assumptions described above, benefit-cost analysis shows that the virus-free roots program in Shandong Province had an internal rate of return of 202%, and, assuming a 10% discount rate, yielded a net present value of $550 million. Once the program was fully established (1998 and beyond), virus-free roots provided net benefits of $145 million per year.

Other scenarios in Table 1 show the sensitivity of the results to the estimates of yield gains and project costs. Even under grossly conservative assumptions, the virus-free roots project appears to have resulted in impressively high returns.

Poverty and the distribution of benefits to producers

Villages located in the more industrialized parts of Shandong Province, such as those in Yantai and Weifang districts, are noticeably better off than villages in other parts of the province. Villages in the mountainous central and southern districts (including RiZhao, LinYi, and Jinzing districts) are significantly poorer. In the poorer districts, sweetpotato area per

Table 1. Benefit-cost analysis of virus-free sweetpotato seed in Shandong Province, China.

Assumptions	Internal rate of return (%)	Net present value[a] (million US$)	Annual net benefits at full diffusion (million US$)[b]
1. Baseline assumptions	202	550	145
2. Adoption peaks at 90%	202	620	168
3. Costs of research, extension, and seed multiplication doubled	170	467	124
4. Yield improvement estimate halved	170	234	62
5. Costs doubled and yield improvement halved	132	151	40

[a] Net present value is calculated assuming a real discount rate of 10%.

[b] Figures in 1998 US dollars.

household is larger and sweetpotatoes make up a larger component of household income. Survey responses from the 12 villages in Yantai and Weifang indicated an average total income for 1997 of 3,064 Yuan/capita (or 9,817 Yuan/household), and an average agricultural income of 1,798 Yuan/capita. In these villages, average area planted to sweetpotatoes was 0.07 ha/household, and sweetpotatoes contributed 15% of agricultural income. Among the 18 other villages in the survey that were located in poorer areas, average income was reported to be 2,091 Yuan/capita (or 7,316 Yuan/household), with 1,394 Yuan/capita from agriculture. Sweetpotato area per household was 0.14 ha, and sweetpotatoes contributed 25% of agricultural income. The virus-free roots diffused equally well in poor villages as in relatively rich villages and yield effects were not significantly different between rich and poor villages.

First generation virus-free roots gave a net benefit of 3,500 Yuan/ha for the spring crop and about 1,600 Yuan/ha for the summer crop. Multiplying these figures by the average sweetpotato area planted to virus-free roots suggests that in the Yantai and Weifang area, improved sweetpotato planting material increased household incomes by an average of 160 Yuan/household/yr. In the poorer villages of the hilly regions in the center and south of the province, adoption of virus-free roots increased household incomes by an average of 265 Yuan/household/year because of the larger area planted to virus-free roots per household. In the richer areas, virus-free roots only increased average household income by around 1.6%/yr, and in the poorer regions the increase in total household income from virus-free roots was 3.6%/yr. The income effects were thus progressive, with a larger share going to households in relatively poor regions. The effects on household income do not appear to be large because the benefits are so widely distributed among seven million small farmers of the province, each of which, on average, plants about 0.10 ha to sweetpotatoes annually.

Summary and Conclusions

The rapid diffusion of virus-free sweetpotato planting material in Shandong Province, reaching 80% of the province's small growers in only 4 years, can be explained

by several factors. Most importantly, users of the new roots saw yields increase by 10 t/ha, or 30%. Further, the technical package was simple and required only one small change in the farmers production system: the replacement of the source of planting material. Strong demand for sweetpotatoes from the food processing industry also contributed to rapid diffusion by keeping prices from falling in the face of increased supply. This enabled farmers, including late adopters, to continue to capture the gains from technical change. Finally, government subsidies for the establishment of the multiplication program made large-scale production possible in a short time and helped keep the price of improved planting material low.

Shandong Province represents only about 9% of the total area planted to sweetpotatoes in China, and it would seem that virus-free roots would have considerable potential for increasing yield in other provinces as well. In fact, virus-free roots programs are currently under development in all of the major sweetpotato-producing provinces in the country. A straight-line extrapolation of the net value of productivity increases achieved in Shandong in 1998 (when 80% of the sweetpotato area was estimated to have been planted to virus-free roots) would imply potential benefits to all of China of around US$1.5 billion per year.

It is not yet known whether China's success with virus-free sweetpotato planting material can be extended to other countries. Experiments with virus-free seed in East Africa, for example, have not resulted in much yield gain. The reasons for this are not yet well understood, but they may imply that the success of the multiplication program in Shandong Province might not be replicable in some other important sweetpotato-growing areas, such as those found in Sub-Saharan Africa.

References

Salazar, Luis. F. 1996. Potato viruses and their control. International Potato Center, Lima, Peru.

Zhang, Liming. 1995. Progress of research and application of virus-free sweetpotato seed in Shandong. Proceedings of the 1st Chinese-Japanese Symposium on Sweetpotato and Potato. Beijing Agricultural University Press, Beijing, China.

Zhang, Liming. 1996. Propagation system and production techniques of virus-free seed sweetpotato. Chinese Sweetpotato 7:67-71.