POTATO AND SWEET POTATO RESEARCH : A WORLDWIDE MANDATE FOR THE INTERNATIONAL POTATO CENTER

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ABSTRACT

The International Potato Center (CIP) was established in 1971 to address constraints on the production and use of the potato, and more recently of the sweet potato, in developing countries. A flexible thrust research approach based on farmer needs and demand, was developed at CIP to bring together scientists from separate disciplines to focus on common problem areas. The same approach is used to transfer the resulting technologies to national agricultural research agencies. Examples from two thrusts are discussed, which deal with the development of production technology for potato and sweet potato crops in warm climates, and with seed technology.

CIP distributes heat-tolerant potato populations, originating from parents with high degrees of general combining ability, for selection of adapted clones in recipient countries. New sources of heat tolerance are being sought among potato cultivars, breeding lines, and species. Control of bacterial wilt, a disease that can seriously limit potato production in warm climates, is a priority research activity at CIP and methods to control it range from agronomic practices (e. g. crop rotation) to genetic engineering (e. g. insertion of genes coding for antibacterial proteins). Post-harvest concerns are also addressed, for example, processing quality, marketing, and demand, all of which are of particular importance for sweet potato. The need for inexpensive high-quality planting materials for the potato crop has been highlighted, as well as the use of true potato seed and rooted stem cuttings as alternatives to traditional seed tubers. To ensure that CIP's research is farmer-orientated, some of CIP's social scientists are based throughout CIP's eight regional programs in the developing world.

The background

Both the potato and the sweet potato contribute enormously to the nutrition of Third World population's living in the tropics. Indeed it is seldom recognized that potato production in lowland tropical zones accounts for more than half the potato production in developing countries (Midmore and Rhoades, 1987), the total (87 million tons) of which represents nearly 30% of annual potato production worldwide (299 million tons). Sweet potato is also a crop of the tropical Third World, where alost 100% of the world harvest is produced.

The International Potato Center (CIP) is a client-orientated agricultural research and development institute. Established in 1971 to address constraints on the production and use of potato in developing countries, since 1986 its mandate was extended to include the sweet potato. Scrutiny of production figures in developing countries shows a 140% increase in potato production since 1961 (Anderson and Horton, 1989), and a more modest increase of 20% for sweet potato (Horton, 1988). Reasons for this marked difference in expansion of production merit attention, especially if research formulated to increase food production is to bear fruit. One major reason put forward to explain this difference is the lack of research and dissemination of information appropriate to the resource-poor sweet

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potato farmer in the developing world. It is generally the farmer who is faced with the difficulty of expanding sweet potato production in marginal lands.

CIP is conducting a formal survey of national researchers to ascertain their views on the principal constraints on potato and sweet potato production and use. Preliminary results (Fig. 1) highlight the importance of marketing for both crops. Lack of demand, and storage problems are crucial for sweet potato, and the lack of quality planting materials in particular for potato. The marked difference between the two crops in the constraining role of varieties might reflect the greater breeding effort devoted in the past to the potato crop (including the 18 years of CIP's efforts), which has resulted in a greater abundance of suitable genotypes. It might also reflect the fact that potato crop management (e. g. prophylactic treatments, priority assignment of resources to the remunerative potato crop) is more highly developed, and to a certain extent obviates the need for pest, disease, or stress-tolerant genotypes. Whether these or other reasons are responsible for the lesser importance placed on varieties in potato, problems related to planting material (quality, timing, availability, cost, etc.) have yet to be solved through the breeding of varieties with widely suitable attributes.

Comparison of the results of the constraint survey with the numbers of publications within CIP's information data base (Fig. 1) on the same topics, shows that for both potato and sweet potato the high priority given to storage, marketing, and demand is not reflected by the number of published reports on these subjects. Conversely, the number of reports on bacteria and fungi outweighs their estimated importance as constraints on production.

Efforts are currently underway to gather detailed information on constraints in specific agro-ecological zones, to complement the initial survey of national researchers. This type of information has been requested by national scientists who have attended workshops and planning conferences aimed at setting priorities for collaborative research programs in sweet potato. For the potato, the development in union with CIP of unique collaborative research networks (Table 1 and Fig. 2) has already permitted neighbour countries in geographical areas to identify and solve production and utilization problems common to each.

The commitment to increase production and use

The commitment of CIP to increase the production and use of potato and sweet potato in developing countries is reflected by the sponsorship of a wide range of research, development, and information activities. To address its priority issues, which are subject to change, CIP has structured its research on a flexible thrust approach. Scientists from various disciplinary backgrounds interact to bring together expertise to focus on a common objective within a research thrust. External consultancy and research contracts, as well as collaborative research in developed and developing countries supplement research efforts in CIP's priority thrusts, and through the well-established regional research program (Fig. 2) practical applications quickly reach the farmer. Two examples of research thrusts would be the thrust on warm climate potato and sweet potato production (staffed by breeders, agronomists, pathologists, and social scientists) and the one on seed technology (staffed by geneticists, seed physiologists, economists, and social scientists). A complete listing of all thrusts is presented in Table 2.

The above-mentioned two research areas will serve as examples for a fuller description of the philosophy, research achievements, and prospects of CIP's efforts. This section will be followed by a brief summary of innovative research and approaches relating to these and other priority areas of CIP's research.

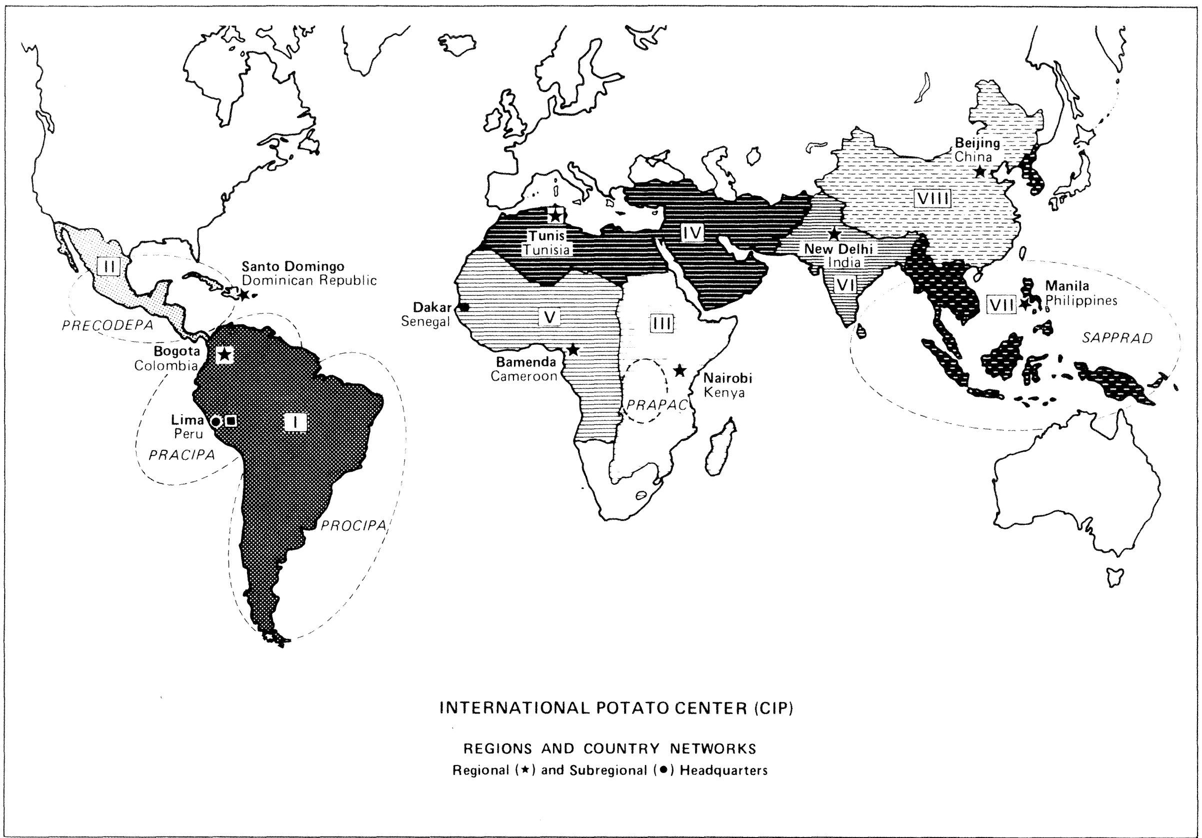

Fig. 1 Constraints on potato and sweet potato production and use as identified in initial survey of national researchers representing 121 regions in 38 countries for potato and 34 regions in 12 countries for sweet potato
Horizontal bars represent mean scores for components of each main category, and horizontal lines represent maximum scores for components if markedly greater than main category score. Scale 0=not present, 1=little practical importance, 2=somewhat important, 3=very important. Also presented are percentages of total publications in CIP's information data base for each category (Source : International Potato Center, 1989).

Table 1 Research networks for potato

PRACIPA	PRAPAC	PRECODEPA	PROCIPA	SAPPRAD
Programa Andino Cooperativo de Investigación en Papa	Programme Régional d'Améloriation de la Culture de Pomme de Terre en Afrique Centrale	Programa Regional Cooperativo de Papa	Programa Cooperativo de Investigaciones en Papa	Southeast Asian Program for Potato Research and Development
Bolivia Colombia Ecuador Peru Venezuela	Burundi Rwanda Uganda Zaire	Costa Rica Cuba Dominican Republic El Salvador Guatemala Haiti Honduras Mexico Nicaragua Panama	Argentina Brazil Chile Uruguay Paraguay	Indonesia Papua New Guinea Philippines Sri Lanka Thailand Malaysia

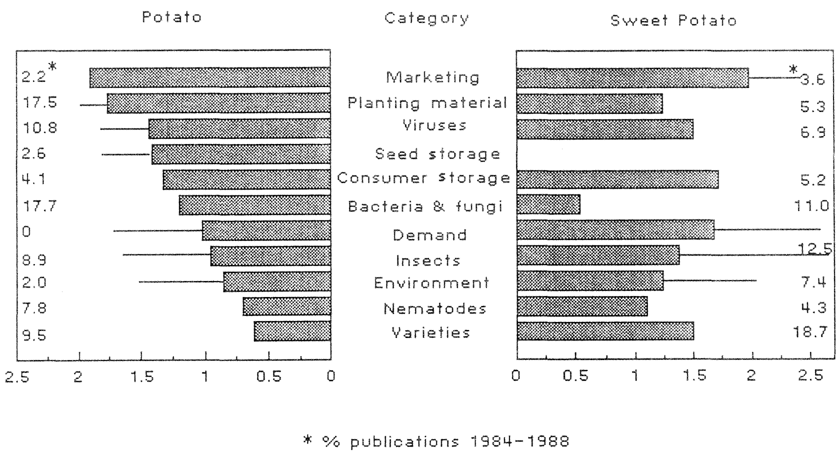

Fig. 2 Distribution of CIP's regional programs and potato research networks

Table 2 Research thrusts at the International Potato Center

Thrust	Title
I	Collection, maintenance, and utilization of unexploited genetic resources
II	Production and distribution of advanced breeding material
III	Control of bacterial and fungal diseases
IV	Control of virus and virus-like diseases
V	Integrated pest management
VI	Warm climate potato and sweet potato production
VII	Cool climate potato and sweet potato production
VIII	Post-harvest technology
IX	Seed technology
X	Potato and sweet potato in food systems

Warm climate potato and sweet potato production

1 Potato

The demand for potato in urban areas in the warm and hot tropics has been interpreted as being analogous to an increase in living standards in those areas (Woolfe, 1987). The demand has more recently been enhanced by the proliferation of fast- and snack-food outlets. The main constraint on potato consumption in these areas is apparently its high unit cost, which invariably includes the high value-added cost associated with transporting potatoes from the cooler production areas. Research from the 1940s onward, intensified by CIP in this decade (see Midmore, 1989 for a review), has demonstrated the feasibility of potato production, particularly during the favourable tropical winter season. Germplasm collected at intermediate tropical altitudes (e. g. *Solanum phureja*, *S. chacoense*) has been crossed with *S. tuberosum* and Neo-tuberosum accessions, and resulted through the population breeding approach in the development of parent clones with a high general combining ability (Mendoza, 1983). These are known to impart attributes of tolerance to their progeny and to increase the gene frequency of desirable traits in new populations. The wide adaptation of this material has been facilitated by the use of three distinct warm/hot CIP experimental stations in Peru for screening purposes. It has been CIP's philosophy to distribute segregating populations as botanical seed, or as tuber families, for the further selection of, and crossing with, clones adapted to specific local conditions. For example, a total of 3,822 new introductions from 59 tuber families were evaluated by the Bangladesh Potato Programme during the growing season of 1978-88, together with 602 second-generation and 91 third-generation clones from the previous year's introductions. A number of sixth-generation clones introduced from CIP await varietal status in Bangladesh (Table 3).

Tolerance to heat in the potato crop takes a number of forms, the most important being the plant's ability to tuberize. However, the plant's ability to intercept solar radiation and assimilate CO_2 is also of great importance, and screening of breeding lines and *Solanum* spp. for desirable attributes of these characters is in progress (International Potato Center, 1989).

Cultivation techniques for the potato crop in warm climates have been developed with two major considerations in mind : to modify the edaphic environment to suit the temperate crop, and to minimize crop loss due to bacterial wilt (*Pseudomonas solanacearum*). Quantification of potato growth and development following cost-effective agronomic practices within CIP's stations in Peru permitted elaboration of crop production principles adaptable for implementation in other lowland potato production areas (e. g. in the Philippines ; Batugal *et al.*, 1985). Practices effecting a quick crop cover over the soil (e. g. close spacing) or reducing soil heating (e. g. mulching, relay cropping) were particularly effective for lowland potato production (Midmore, 1989). The simple rotation of the potato with non-solanaceous crops, particularly paddy rice or sugar cane, or intercropping with maize, beans, or cowpea, reduces incidence and spread of bacterial wilt. At the other end of the technical scale, genetic engineering for bacterial disease resistance using *Agrobacterium* vectors is also underway. Insertion of antibacterial proteins such as cecropin A, for which the cDNA sequence has been determined, has great promise especially since various bactericidal compounds may be coded. These compounds should amplify the spectrum of resistance and perhaps impart resistance to both bacterial wilt and *Erwinia*, another bacterium of increasing importance in warm climate potato production (Schmiediche *et al.*, 1988).

Production issues in either traditional or non-traditional areas cannot be addressed in isolation from marketing and demand issues. Indeed, agricultural research should be demand-driven. Marketing and demand relate to seasonal availability and price fluctuation, which can be alleviated through policy decisions relating to production and storage, and to the quality and suitability of potato for consumption in varied forms. Breeding for

Table 3 Pedigree and major characteristics of potato clones awaiting release in Bangladesh (unpublished data of Dr. L. Sikka)

Cultivar No.	Pedigree	Characteristics
CIP 720088 (B Cl-240.2)	(MPI 61375.23 X B-2565)	Main season variety (90 days) ; moderate yield ; field-resistant to late blight bacterial wilt and leaf-roll ; low degeneration rate, heat-tolerant, excellent storability in farmer's store ; white round tubers.
CIP 379667.501	[(BR63.65 X Katahdin) X Maria Tropical]	Early (70-90 days) ; fast growing ; consistently high yield ; low degeneration rate ; white oval tubers.
CIP 379668.230	[(BR63.65 X Atlantic) X CGN-69.1]	Medium maturity (80-100 days) ; quick growing ; field resistant to insect-transmitted viruses ; red round tubers.
CIP 379659.657	Atzimba X Maria Tropical	Very early (60-80 days) ; excellent yield ; very low degeneration rate ; white oval tubers.
CIP 379673.150	[(BR63.74 X Anital) X Maria Tropical]	Early (70-80 days) ; high yield ; very low degeneration rate ; white oval tubers.
CIP 379687.93	[(BR-63.65 X Katahdin) X CGN 69.1]	Early maturity (80-90 days) ; vigorous growth ; high yield ; having in its pedigree field resistance to late blight and bacterial wilt; low rate of degeneration and attractive white, round oval tubers.
CIP 379697.153	(BR 93.65 X Atlantic) X CGN 69.1	Medium early (85-90 days) ; consistent high yielder ; attractive white round tubers with shallow eyes, low rate of degeneration, good storability.
AVRDC 1282-19	—	Medium early (80 days) ; good yield ability ; low rate of degeneration ; heat-tolerant ; white oval tubers ; setting berries under tropical conditions.
K. Lalima	K. Red X A & 14 (Wisconsin X 37)	Main season variety (90-100 days) high yield ; excellent storability in farmer's stores ; red round tubers with shallow to medium eyes.
CIP 800224	Atzimba X A I	Main season variety (90-100 days) ; high yield ; low rate of degeneration ; field-resistant to late blight, and bacterial wilt; white round oval tubers of medium size. Occasionally set berries.

processing quality is a recent innovation at CIP, and substantial progress has been made in screening heat-tolerant germplasm and in the study of quantitative variation for processing characteristics. Narrow sense heritability estimates indicate medium to high additive genetic variability for tuber yield, specific gravity, and reducing sugars, the latter measured 10 and 60 days after harvest (International Potato Center, 1989). Two CIP clones, LT-7 and TS-2, were outstanding progenitors for these characteristics. Within CIP's collection of pathogen-tested clones, a number have desirable frying (MEX-32) and chipping (CFC-69.1) qualities.

Two important roles that CIP's Social Science Department plays are providing support for marketing studies conducted by national agricultural research organizations, and strengthening the capacity for local expertise in marketing and demand studies by national scientists. In one such study in Bangladesh, a country with a high average temperature and a single potato season per year, potato production was shown to be profitable for most farmers despite market surpluses and price declines. The same study showed that traditional potato storage is more profitable than cold storage in certain parts of the country, and confirmed the correct focus of research efforts to develop low-cost ventilated consumer storage structures, prototypes which already have permitted storage of up to 150 days (Sikka, personal communication). Screening for genotypes with long dormancy, and for the ability to resist loss of dry matter and moisture under hot conditions, which is underway, will make low-cost consumer storage even more attractive to small farmers, who already receive higher prices for their product in market places than large growers at the farm-gate (International Potato Center, 1989).

This brief summary illustrates how CIP is successfully enhancing the potato's performance in warm climates for the benefit of both the farmer and consumer.

2 Sweet potato

Sweet potato production is apparently as "demand-driven" as that for potato. Global production trends are weighted downward by the decline in production in China, which is attributed to government policy and lack of incentives for the handling by market agents of perishable roots (International Potato Center, 1989). Marketing and demand appear to be the two most important constraints on sweet potato production and use (Fig. 1). However, these two areas are also the most poorly represented by expertise of national scientists.

Post-harvest treatment of sweet potato roots, converting them into more desirable products, is one line of collaborative research sponsored by CIP to increase demand for processed sweet potato, particularly in Southeast Asia. Sweet potato is a highly versatile crop that is used widely as a staple food, a source of starch or alcohol, a vegetable, a dessert, or as animal fodder (Gregory *et al.*, 1989) and potentially for erosion control. World statistics reflect the production that passes through market channels in the form of storage roots, but the statistics underestimate the importance of alternative forms of use, including the use as a subsistence crop. The low input and hardiness of the sweet potato crop favour production in subsistence agricultural systems, therefore much of CIP's focus on sweet potato research is to enhance these characteristics, particularly through germplasm enhancement and manipulation of agronomic practices such as intercropping.

Active collection of sweet potato germplasm from Latin American countries, the center of diversity for sweet potato, has taken place, and all new accessions are being kept under quarantine conditions at CIP's headquarters. During 1987 a total of 579 cultivated accessions were collected, together with 8 wild *Ipomoea* species from the section Batatas, one *I. trifida* x *I. triloba* natural hybrid, two potentially new species, and 29 other *Ipomoea* species from other taxonomic sections. Much effort is being placed on the development of 4x interspecific hybrids between hexaploid cultivars and 2x *I. trifida*. The latter is an important potential source for resistance to sweet potato weevil (*Cylas formicarius* Fabr.) and drought. Crossing with interspecific hybrids will also raise the level of heterozygosity of the cultivated sweet potato germplasm. However, cross-incompatibility generally leads to very little seed set. Fruits produced throught interspecific crosses between *I. trifida* and cultivated *Ipomoea* were harvested to study embryo rescue, and a number of fruits left to mature gave fertile seeds (International Potato Center, 1988a). Of the 250 plants transplanted to the field, 182 were 4x as expected, and the rest were 5x and 6x. Approximately 7% of Central and South American *I. trifida* accessions produced 2n pollen without chromosome reduction, and these are being used to produce tetraploid progenies when crossed with 4x *I. trifida* as a means of gene introgression from the 2x to the 4x level.

To avoid the centralization of germplasm collection and maintenance in Latin America, CIP has also sponsored germplasm collecting activities in other areas of the world. Recently, in the Philippines, a secondary center of diversity for sweet potato, 260 clones were collected in Luzon and are being maintained in the field, while collection in cooperation with the International Development Research Center (Canada) has also taken place in the central highlands of the Philippines. A comprehensive proposal on sweet potato collection for Indonesia, with emphasis on the compilation of farmer knowledge of sweet potato clones, has been prepared with the integral assistance of CIP scientists.

Already germplasm is being screened for yield ability under a range of stressful and non-stressful environments (International Potato Center, 1988a). Major emphasis in Peru is being placed on the short-season trait. The same polycross population based on improved Peruvian cultivars was tested in four different environments. Yields exceeded 10 t/ha in 90 days at three sites (Table 4), but barely so at the hottest site in Yurimaguas, where yield potential was apparently limited by acid soils and high night temperatures. Breeding efforts in Peru are separated into two programs, one focusing on adaptation to salinity and drought, for which reasonable levels are present in the Peruvian germplasm, and the other for adaptation to hot humid tropical zones —major areas of sweet potato production— for which foreign germplasm has been identified (Asian Vegetable Research and Development Center, 1987) and must be imported to Peru.

Field and *in vitro* selection for drought tolerance is also underway in Peru. Initial results from the field with increasing drought intensity as the season progressed, demonstrate the wide variability in water use efficiency (expressed as kg of storage root per m^3 of water supply) and storage root yield (Ekanayake *et al.*, 1989). The lack of interaction between clones and irrigation treatment for either trait suggests that under the conditions of that experiment drought tolerance was simply related to inherent crop vigour and yield, and not to specific drought tolerance characters. Certain clones, e. g. Ingles and Negrito de Ihuance, have consistently yielded well in various drought studies within Peru. A simple root-pulling technique to quantitatively estimate the size and distribution of the root system was applied successfully to the potato crop (Ekanayake and Midmore, 1989) and is now under evaluation for sweet potato. *In vitro* screening for drought tolerance is underway and will soon be related to field response of test clones. Concurrently, sectors of the Peruvian and Philippine germplasm collections are being evaluated for shade tolerance to improve yield under intercrop situations, and additionally in Peru for tolerance to acid soils, waterlogging, low soil fertility, and adaptability to relay-cropping. Although yield reduction due to shade was more than proportional to reduction of irradiance (Table 5), as a result of later storage root formation, when intercropped with sweet corn at 8 : 1 and 4 : 1 ratios of sweet potato : sweet corn, sweet potato yields were only slightly less than sole sweet potato yields (Demagante and Vander Zaag, unpublished).

Of all the constraints on sweet potato production, the damage caused by the sweet potato weevil is rated as the most limiting (Horton, unpublished). Screening at CIP for resistance to the tropical sweet potato weevil (*Euscepes postfaciatus*) has been based upon the closed-container test through which antibiosis effects may be measured. Of the initial 15 resistant clones out of 700 accessions tested, all exhibited stem damage when subjected to field evaluation; however, certain clones were damaged to a significantly lesser degree than others.

Table 4 Top performing sweet potato clones derived from a single polycross and evaluated at far sites within Peru

La Molina. Winter, 1988. Growing period : 120 days.

Clone	Yield (t/ha)
LM88.049 (Morado de Magollo)	17.6
LM88.033 (Oreia de Galgo Blanco)	17.2
LM88.062 (Huayro)	14.4
LM88.002 (Torreblanca)	11.6
LM88.072 (Tucapel)	11.1
LM88.037 (Airampo)	9.6
LM88.113 (Camote de Oxapampa)	9.5
LM88.059 (Pacaranero)	8.9
LM88.005 (Ihuanco)	8.9
LM88.107 (Pacaranero)	8.9

Yurimaguas. May-Sept. Winter 1988. Growing period : 90 days.

Clone	Yield (t/ha)
YM88.090 (Negro Pepa)	12.4
YM88.026 (Airampo)	9.2
YM88.072 (Toparino)	8.4
YM88.023 (Tucapel)	8.3
YM88.108 (Negro Pepa)	8.2
YM88.025 (Tucapel)	8.2
YM88.030 (Ihuanco)	7.4
YM88.034 (Sanpedrano)	6.8
YM88.035 (Ihuanco)	6.4
YM88.015 (Toparino)	6.4

San Ramon. Winter, 1988. Growing period : 90 days.

Clone	Yield (t/ha)
SR88.029 (Blanco Coyungo No. 1)	13.8
SR88.033 (Japones Portugues)	13.4
SR88.023 (Sanpedrano)	11.6
SR88.075 (Camote de Oxapampa)	10.0
SR88.030 (Maria Angola)	9.6
SR88.053 (Camote de Oxapampa)	9.0
SR88.101 (Sanpedrano)	8.8
SR88.115 (Japones Portugues)	8.0
SR88.072 (Morado de Magollo)	6.9
SR88.117 (Morado de Magollo)	6.0

Tacna. Summer, 1988. Growing period : 90 days.

Clone	Yield (t/ha)
ST87.062 (Camote de Oxapampa)	31.7
ST87.061 (Guiador)	23.7
ST87.107 (Camote de Oxapampa)	23.3
ST87.083 (Bulk ST)	17.5
ST87.051 (Amarillo Zapallo)	15.8
ST87.105 (Tucapel)	15.0
ST87.023 (Melchorita)	15.0
ST87.077 (Yema de Huevo)	14.9
ST87.103 (Goyon)	14.3
ST87.095 (Bulk ST)	12.2

Meteorological data for each site presented in International Potato Center, 1989

Table 5 Influence of irradiance on yield (t/ha) of five sweet potato clones grown in the lowland Philippines

	Clone				
Irradiance	Miracle	Sinukisuk	VSP3	VSP4	VSP5
100%	30.4	28.9	34.5	38.8	32.2
70%	17.5	5.7	17.8	21.1	19.7
30%	4.3	0.7	6.6	7.4	4.5

LSD (0.05) Irradiance 3.2 ; Clone 4.0 ; Interaction ns
December 1988-March 1989 (unpublished data of A. Demagante and P. Vander Zaag)

Seed technology

Following marketing, planting materials was the second most important disciplinary constraint on potato production (Fig. 1). High cost, due in part to storage requirements for seed potatoes dictated often by the annual cropping season, was considered as the single most important constraint for planting materials. In contrast, for sweet potato, planting materials was rated as a constraint of relatively less importance, perhaps due partly to the greater temporal distribution of sweet potato in a climate characterized by year-round production, which facilitates the provision of planting materials.

Research at CIP has concentrated on the development of practices that permit a reduction in potato seed costs (e. g. the use of low-input diffused-light storage technology for seed tuber storage), and on the incorporation of virus resistance, important for the vegetative method of propagation and important to break the dependency on imported sources of clean seed. In addition, CIP has also been actively involved in researching alternatives to the use of seed tubers as planting materials and techniques that permit maximum returns from limited supplies of quality seed tubers.

The major alternative to seed tuber use is true potato seed (TPS), the sexual propagule of the potato plant. The true sexual alternative to seed tubers, i. e. the production of consumer potatoes from direct-seeded or transplanted seedlings, is hampered however by the proliferance of small-sized tubers (Vander Zaag *et al.*, 1989). Nevertheless, if the harvested tubers are to be used as seed, this step from seedlings to first generation (or "seedling") tubers is turned into an efficient and favourable multiplication step. If tuber size is not a discriminatory factor reducing the acceptance of TPS-produced consumption potatoes, then the success of the true sexual alternative will depend largely on the TPS quality. TPS production techniques differ from those for seed tubers ; high nitrogen doses (Pallais *et al.*, 1987) and long yet decreasing daylength favour profuse flowering, pollen production, and seed set (Pallais, personal communication). Correct storage procedures (drying at 20° to 25°C and low humidity for 2 days, followed by >6 months at 20°C and 6% moisture) and seed priming dictate that vigorous plants, more likely to withstand transplant shock, will be produced quickly under nursery conditions. Hybrid progenies are not invariably superior to open-pollinated (OP) seed lots, especially if only vigorous seedlings are selected and transplanted to the field (Golmirzaie and Mendoza, 1986). In Chile, hand emasculation to avoid self-pollination contributes 30% to 60% to the cost of hybrid seed. Although self-pollination can be avoided through emasculation, or removal of bumble bee-visited flowers, it is, nevertheless, desirable to introduce cytoplasmic male sterility through protoplast fusion and organelle transfer to female parent clones, which permits tetrad production and bumble bee attraction. This work is taking place through collaboration between CIP and the Weizmann Institute in Israel, and the first field evaluation of true hybrids has been reported (Golmirzaie *et al.*, 1989).

The profuse ability of nodal segments from the potato stem to form roots and shoots has been the single most important factor responsible for the implementation of rapid propagation systems for the potato. Multiplication schemes that avoid passing through the field stage represent a potential saving in both unit price of seed tubers and risk of infection. Rooted nodal segments can also be treated as TPS seedlings and transplanted to the field to produce consumer potatoes. Stem cuttings from tuber-derived mother plants (Benz *et al.*, 1987), from *in vitro* plants (Bryan, 1988), or from TPS seedlings (Midmore, 1989), sprout cuttings (Van Ho *et al.*, 1988), and nodal cuttings from *in vitro* plants (Bryan, 1988) have all been used successfully as planting materials to produce consumer potatoes in the tropics. These systems reduce the reliance on traditional tuber seed-producing schemes, and can obviate the need to store large quantities of seed tubers for prolonged periods that require refrigerated storage.

Since plantlets derived from nodal or apical sections of mother stems carry the stimulus to tuberize experienced by the mother plant, inhibition of the stimulus through high rates of N_2 application and imposition of daylength extension and low light intensity, and the choice of clones (generally late ones) that do not readily tuberize, are indispensible for success with stem cuttings under short-day tropical conditions (Escobar and Vander Zaag, 1988). The adoption of alternatives to seed tubers will undoubtedly reflect site specific needs, which experience has shown to be related to climate, cropping periodicity, farmer aptitude, and other site-specific factors.

Further innovative research and activities related to CIP priority research areas

With farmers as prime recipients of improved technologies, it is understandable that they should have a full say in the inception of a technology, as well as its design and development, CIP has consistently benefitted from the analyses of current food systems carried out by CIP's social scientists, who interacting with biological scientists, assist in the testing of new technologies under farmer conditions (International Potato Center, 1988b). Variety development (especially with integrated virus resistance, and major-gene-free resistance to late blight (*Phytophthora infestans*)) and integrated pest control (with natural control agents, e. g. granulosis virus and deterrent weed species for potato tuber moth (*Phthorimaea operculella*)) are typical examples. In cooperation with CIP's strong regional operation, mapping of potato production areas worldwide provides a framework through which bottlenecks and advances to potato, and for the future sweet potato, production can be evaluated and quantified.

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Discussion

Saxena, M. C. (ICARDA) : Could you indicate the gene vector used for transferring gene-coding for antibacterial protein ? Are the transgenic potatoes being used for commercial utilization with bacterial wilt resistance ?

Answer : We are using *Agrobacterium tumefasciens* and *A. rhizogenes* as the gene vectors. The potatoes are still under test and the data presented are only preliminary.

We have yet to test that they are indeed transformed plants. It is hoped that this material which codes for antibacterial protein will be useful for the prevention of bacterial wilt (*Pseudomonas solanacearum*) and infection with *Erwinia*.

Nkansah, G. O. (Ghana) : How could you integrate the use of sweet potato into the life style of the populations ?

Answer : We expect that two developments will improve the acceptability of sweet potato, firstly by developing non-sweet types that can be used as staple crop, and secondly developing new processing practices, at various levels of expertise, for new sweet potato products acceptable as fast-food and snack-food.