Session I

Global scenario on production, utilization and marketing of roots and tuber crops

Oral presentations

Scott, Gregory	Definitive trends for food systems in Latin America? The case of potatoes over the last half century and into the next
Hareau, Guy	Economic returns to improved crops in the center of origin: the case of potato varieties in Peru
Campilan, Dindo	Sweetpotato consumption in Orissa, India and implications for nutrition and livelihood improvement
Taylor, Mary	Root and tuber crops of the Pacific: A resource for meeting the challenges of the 21st century
Huang, Zhenglin	Present status and development strategies of potato industries in Chongqing, China
Naskar, S. Kumar	Progress and status of yam bean (*Pachyrhizus* sp.) research in India

Posters

Devaux, André	Developing a strategic vision for the potato in the Andean region
Rodriguez, Elsa	Good agricultural practices: The case of potato production in the Southeast province of Buenos Aires. Argentina

Definitive trends for food systems in Latin America? The case of potatoes over the last half century and into the next

Gregory J. Scott, School of Graduate Studies

Universidad del Pacifico, Lima, Peru
scott_gj@up.edu.pe

Abstract

Despite being the center of origin for the potato, Latin America now lags behind Africa and Asia in annual output for the crop amongst developing country regions. This paper attempts to answer two basic questions: What were the principal trends in the growth rates for potato production, area, and yields in Latin America over nearly the last half century? In light of these developments, what are the prospects for the commodity in the region in the years ahead? After an analysis of FAO annual secondary data on regional trends in production, the paper identifies some key issues for future research.

Keywords: Growth rates, production, area, yields.

Introduction

Almost all but overshadowed by the events caused by the on-going global financial crisis, 2008 was the International Year of the Potato. And like the financial crisis, trends and prospects for potato production in Latin America is the outcome of years, if not decades, of developments within and related to the sector. With noteworthy exceptions, potato production has shown only modest growth or stagnated in many Latin American countries since the early 1960s. Hence, despite being the center of origin for the crop, Latin America now lags behind Africa and Asia in annual potato output amongst developing country regions.

This paper presents the results of an analysis of FAO annual secondary data to identify changes in growth rates in potato production, area, and yields in Latin America over nearly the last half century. One key theme is the extent to which the evolution of these growth rates foreshadows the most likely future scenario for potato production in the decades ahead.

Growth rates for production, area, and yields

Potato production in Latin America averaged 15.7 million metric tonnes in 2005-07—more than double the 7.2 million metric tonnes (mt) harvested in 1961-63, nearly half a century earlier (Table 1; CIP, 2008). This expansion in potato production resulted from annual growth rates of around 2.0%/yr for nearly the last 50 years. By way of comparison, growth rates for potato production in Asia and Africa averaged <u>over</u> 4% for the entire period, i.e. more than double those for Latin America (CIP, 2008).

For Latin America as a whole, area planted in potatoes shrank, albeit modestly, and at a slightly accelerated pace towards the end of the period 1961-2007. Producers harvested an average of 954,000 ha of potatoes during 2005-07 versus 1.02 million hectares in 1961-63 (CIP, 1999, 2008). More significantly, whereas three of the nine largest potato-producing countries in Latin America had negative growth rates in area planted in potatoes during the period 1985-87 to 1995-97 (CIP,1999), eight of the 11 largest potato-producing countries had negative growth rates in area planted in potatoes during the period 1991-93 to 2005-07 (CIP, 2008). In effect, the modest contraction in area planted in potatoes became more widespread throughout Latin America over the last two decades, thereby reversing positive growth rates for area planted from the early 1960s to mid-1990s in many, but not all of these same countries.

With area planted declining, growth in output of potatoes in Latin America has been driven by increases in average yields since the early 1960s with a few noteworthy exceptions. Growth rates for potato yields in Latin America, while uneven across the region and over time, have <u>averaged</u> 2%/yr for nearly the last 50 years. Growth rates for potato yields in Africa (1.2%, -0.1%) and Asia (1.5%, 0.9%) for the periods 1961-63 to 1991-93 and 1991-93 to 2005-07, respectively, were considerably lower (CIP, 2008). Notwithstanding, growth rates for average annual yields have declined in recent years (Table 1) suggesting earlier projections for growth rates in production (1.72%), area (0.41%), and yields (1.30%) for the period 1993 to 2020 were too optimistic (Scott, et al., 2000).

Average yields—16.5 mt/ha during 2005-07 (Table 1)--remained higher in Latin America than in Africa (11.1 mt/ha) throughout the period, surpassing yields in Asia (15.5 mt/ha) only over the last decade (CIP, 2008). As area planted in potatoes continued to expand rapidly in Asia and Africa into the last decade, comparable improvements in average yields became more and more difficult to sustain in those regions at the same time. Something of the reverse process has been underway in Latin America, although with its own exceptions, as more of total area in potatoes is cultivated by more efficient producers. Partly as a result, average yields for potato in Latin America are now higher than those in the Russian Federation (12.7 mt/ha), the Ukraine (13.1 mt/ha) and nearly as high as those in Poland (17.4 mt/ha), but still lag far behind those in Western Europe (Germany, Netherlands) and North America (United States) (Ibid.).

Table 1. Average annual growth rates for food crops in Latin America, 1961-2007

Crop	2005-07			Growth rate (%)								
	Production	Area	Yield	Production			Area			Yield		
	(000 t)	(000 ha)	(t/ha)	1	2	3	1	2	3	1	2	3
Maize	97.402	27.702	3,5	3,2	3,0	3,1	1,0	0,3	0,7	2,2	2,7	2,4
Cassava	36.433	2.875	12,7	0,8	1,1	1,0	1,3	0,5	0,9	-0,4	0,6	0,1
Rice, paddy	25.316	6.001	4,2	3,1	2,0	2,5	1,9	-0,8	0,5	1,2	2,9	2,0
Wheat	24.845	9.235	2,7	3,1	0,8	1,9	1,2	-0,5	0,3	1,8	1,3	1,6
Bananas	23.293	1.158	20,1	1,8	1,7	1,7	1,1	1,3	1,2	0,7	0,3	0,5
Potatoes	15.901	981	16,2	2,2	1,6	1,9	0,0	-0,1	0,0	2,3	1,6	1,9
Sorghum	11.420	3.678	3,1	9,0	-1,1	3,8	6,0	-1,5	2,2	2,9	0,4	1,6
Tomatoes	10.856	342	31,8	5,3	2,9	4,1	2,3	1,0	1,6	2,9	1,9	2,4
Plantains,	8.407	979	8,6	2,2	1,9	2,1	2,5	1,4	1,9	-0,2	0,5	0,1
Beans, dry	5.598	6.785	0,8	1,5	1,3	1,4	1,8	-0,7	0,6	-0,3	2,0	0,8
Sweetpotatoes	1.983	242	8,2	-1,3	-0,1	-0,7	-0,7	-0,8	-0,8	-0,6	0,6	0.0

1 = 1983-85 vs 1961-63; 2 = 2005-07 vs 1983-85; 3 = 2005-07 vs 1961-63

Perhaps more than other developing country regions, average yields for potatoes in Latin America are misleading because of the differences in farm size within the sector in several, major potato-producing countries. While the vast majority of growers in Latin America plant less than a hectare of potatoes per growing season, large farms (i.e., 50-100 ha plus in potatoes) are conspicuous, if not dominate production in north and northwest Mexico (e.g., Chihuahua, Sinaloa) (Biarnes, et al., 1995), in central Venezuela, in parts of central and southeastern Argentina, central Brazil (Minas Gerais) and the central highlands of Colombia (Rodriguez, 1996). These larger growers can easily get yields that are two to three (or more) times the national average. Across the region, the lowest average yields are in those Andean countries, i.e., Bolivia, Ecuador, Peru (CIP, 2008) where potato production often takes place on postage-stamp sized, non-contiguous plots and involves the use of native varieties and low-input, risk-averse, production practices even with cultivating improved cultivars (Scott, 1985).

Concentration of output

Within Latin America, potato production and area planted are highly concentrated. For the years 1995-97, the five largest—Brazil, Peru, Colombia, Argentina and Colombia--accounted for 78% of output and 70% of area under cultivation (CIP, 1999). By 2005-07 and with 1.2 million more metric tonnes produced annually on average, the top five still produced 75% of all the potatoes and planted 65% of the all the area. They also accounted for 43% of the increase in production and 92% of the drop in area over the last decade. Chile, Venezuela and

Guatemala produced the bulk of the increase in output since 1995-97. Conversely, of the 32 countries in Latin America, 8 produce no potatoes and another six harvest less than 10,000 metric tonnes annually (Table 2). And unlike within Sub-Saharan Africa (e.g. Angola), no new major potato-producing countries have emerged in the region in nearly the last half century.

In the two most populous countries in the region—Brazil (pop. 192 million) and Mexico (pop.105 million)—average annual output rose by 19% and 22% respectively during the period 1995-97 to 2005-07 (CIP, 1999, 2008). In both cases, additional output was the net effect of declining area planted combined with more rapid and increasingly strong growth rates in average yields. Productivity increases resulted from more marginal growing areas falling out of production (for example, the state of Parana in Brazil) and the adoption of yield-increasing technology in the remaining areas (Mina Gerais) (Rodriguez, 2006). Alternatively, Brazil and Mexico produced more potatoes to enable only marginal increases in per capita consumption from the modest prevailing levels of less than 15 kg/capita/ annum respectively in 1994-96 (CIP, 1999) and in response to rising real incomes. Effective demand was for continued, albeit modest diversification of diets to include more potatoes and potato products.

Table 2. Distribution of developing countries producing potatoes by region, 2005-07

Average annual production metric tones (mt)	Region and number of countries				
	Africa	Latin America	Asia	Oceania	Total
0 or no data	16	8	5		29
<10,000 t	10	6	5	2	23
<50,000 t	8	5	2		15
<250,000 t	6	3	9		18
>250,000 t	14	10	17		41
Total	54	32	38	2	126

Source: FAOSTAT and calculations for this study.

Potato versus other food crops

Over the last nearly 50 years, the growth rate for potato production (1.9%) in Latin America has lagged behind that for maize (3.1%), rice (2.5%), sorghum (3.8%), tomatoes (4.1%), and plantains (2.1%) (Table 1). Of the 11 major food crops produced in the region, only potatoes (0%) and sweet potatoes (-0.8%) showed zero or negative growth rates in area planted. Nevertheless, in 2005-07, potato remained the sixth most important food crop in Latin America as in 1961-63 because of its relatively high growth rates in yields (Ibid.). However, whereas growth rates for potato yields were higher than for maize or rice in the 1960s and 1970s, by the 1980s that situation had reversed itself as maize and rice yields improved at an accelerating rate. Growth rates for maize and rice yields were particularly impressive as they occurred over much larger areas than potatoes and those areas continued to expand over time. Furthermore, the growth rate for potato yields declined even as that for area cultivated stagnated.

Both demand- and supply-side factors for potatoes and substitute crops contributed to these trends. For example, average annual potato output in Colombia fell from 2.8 million metric tonnes in 1995-97 to 1.8 million metric tonnes in 2005-07 (CIP, 2008). The arrival of the potato moth from Central America cerca 1985 eventually devastated the crop in the field. It also affected exports to neighboring Venezuela—declining domestic supply, meant fewer potatoes were available for export and at higher prices. Phytosanitary considerations dampened export demand further. Rising violence in the countryside and terrorist attacks in the city did little to reassure farmers or the associated suppliers of inputs, credit and technical assistance. Ambitious plans aimed at re-energizing the sector through greater collaboration between the various stakeholders (IICA-MADR, 1998; Martínez, 2006) has so far failed to turn the situation around.

In Argentina, output fell by 12% from 1995-97 to 2005-07 to 1.89 million metric tonnes (CIP, 2008). Average annual growth rates in area planted in potatoes have been negative since the early 1960s (CIP, 1999). With low producer prices for potatoes in 1989-90 in the face of growing economic attractiveness of producing cereals and oilseeds for export, the fall in area planted for potatoes accelerated (Moscario, 2004). Although production of potatoes for processing and exports of both fresh and processed potatoes to Brazil have risen sharply since then (Geunthner, 2001: Moscario, 2004; Rodriguez, 2006), they have been unable to reverse the long-term decline in area planted in potatoes (CIP, 2008).

Prospects for potatoes in the future

After 50 years of modest, but declining growth rates in potato production in Latin America, prospects for the next decade seem most likely to be a continuation of the same, long-term trend. After virtual stagnation in area planted in potatoes over the same half century, a massive expansion in area dedicated to the crop seems highly unlikely. Instead, probable increases in output are likely to result from continued improvements in yields, albeit at a declining growth rate and in response to modest increases in the total demand for potatoes.

Sources for the anticipated increases in potato productivity include accelerated access to information about existing technology, the generation of new technology and the gains from/ competitive pressures to innovate. Potato farmers in Latin America today have much more access to information about technology than they had in the 1960s, 1970s, and 1980s. One driving force for the spread of information has been the advent of the internet, electronic mail and the use of websites. Internet cafes, for example, are cheap and commonplace even in places where communication with the outside world was costly and time-consuming, at best, in the past. A second, related contributing factor to better access to information has been the spread of the telephone grid and the widespread availability and use of cell phones to say nothing of extension of all-weather road networks into heretofore isolated areas. With the expanding road network and improved access to markets, potato farmers have an opportunity to improve their competitiveness in traditional product lines and expand into emerging niche markets for new products (Ordinola, et al., 2007). It remains to be seen whether they can out compete other basic staples and broaden the appeal of niche products to achieve increases in overall consumption; or, whether gains in competiveness will be restricted to particular countries—or regions within countries, product lines and the bigger, more market-oriented growers. Under this latter scenario, the vast numbers of smaller farmers will continue to fall victim to the drive toward lower per unit production costs in response to pressures to produce more food at cheaper prices for urban consumers that make up an increasingly overwhelming proportion of Latin America`s total population (Scott, 2002; World Bank, 2007).

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Economic returns to improved crops in the center of origin: The case of potato varieties in Peru

L. Maldonado, V. Suárez, G. Thiele, **G. Hareau**

International Potato Center (CIP)
Av. La Molina 1895, La Molina, Lima, Peru
g.hareau@cgiar.org

In the last four decades, potato production in Peru increased from 1.3 to more than 3 million tons. As a result of this increase, Peru has become the major potato producer in Latina America. In this context, the International Potato Center (CIP) has achieved valuable contributions to the development of new varieties of potato in the last years.

Since 1977 CIP has collaborated in promoting in Peru 24 varieties with different characteristics in order to face diseases, improve its culinary quality or increase yield.

Two of the most successful varieties were jointly developed by CIP and the Peru's national agricultural research institution (INIA): Canchan-INIA was released in 1990 and is planted in more than 58,000 hectares today; Amarilis-INIA was released in 1993 and is planted in more than 18,000 hectares. Together, both varieties occupy more than 30% of total potato area in the country and have a major presence in domestic commercial markets. Both varieties have good culinary qualities but while Amarilis is also sought for its resistance to late-blight, Canchan's other major advantage is its earliness with respect to the variety it tends to replace, Yungay. Previous studies reported a 26% return to investment on Canchan development, but projected adoption area has more than doubled and the source of benefits for farmers has also changed. Adding the large acceptance of Amarilis by farmers has contributed to larger returns to CIP's investment on potato breeding in Peru.

Varietal characteristics and source of benefits

Canchan was released initially as a high-yielding late-blight resistant variety. It provided large net benefits in many areas of Perú going between more than $280 dollars per hectare in the long season to near $600 dollars per hectare in the short season. By the early 2000s the variety resistance begun to break down and this advantage could not be claimed any more as a source of benefit. However, the variety was already well established in the market and had a large acceptance amongst farmers because its earliness (4.5. months to mature tuberization) still allowed good market performance before production from other varieties puts downward pressure on domestic prices. The source of benefits, however, was reduced and is estimated at around $114 dollars per hectare due to lower opportunity costs of land (Maldonado et al., 2008).

For Amarilis, since its release the main source of benefits are its resistance to late-blight compared to the varieties it replaces, its earliness and good yield, although the variety is still adopted regionally in certain areas of Peru and not country-wide. Farmers' surveys have shown that the resistance to late-blight allows a reduction in fungicides costs of 24% and an increase of yields by near 9% (Salazar, pers. comm.). The estimated net benefits of the variety are set at $130 dollars per hectare, 88% of which pertain to the yield effects.

Adoption profile of Amarilis and Canchan in Peru: 1991 – 2020

In order to estimate the returns to investments in both varieties the historic adoption profile is constructed together with an estimate of the adoption ceilings for each variety until 2020. Previous studies had forecasted Canchan's ceiling at 26,000 hectares (Fonseca et al., 1996). Follow-up surveys conducted by CIP with national breeders showed that adoption of Canchan had largely surpassed this figure and the estimate of adoption for 2007 is around 58,000 hectares, making Canchan the largest single variety adopted in Peru with 22,4% of the country area (Walker et al, 2003; Thiele et al., 2008). In fact, the adoption of the variety can be verified in several potato growing regions of the country. To establish an adoption path for the next years one needs to take into consideration the actual demand for the variety and the availability of alternative varieties which will eventually replace Canchan. Peru's national agricultural research institute (INIA) will be releasing a variety, Roja Ayacuchana, which might in the long term be a substitute for Canchan. Therefore, it seems plausible than in the long run Canchan will not be increasing in area substantially and there will be some downward pressures for its adoption. However, the new variety has still to establish a consistent market demand before Canchan can begin to decrease in area. Walker (1994) also has considered that adoption of new potato varieties take longer than other crops, a fact that seems to be confirmed by the past adoption profile of Canchan and Amarilis. We therefore establish an adoption ceiling slightly higher than the current area at 65,000 hectares and with no decrease until 2020.

Although there was not previous estimate of adoption for Amarilis, the 2007 survey put the figure in 18,000 hectares. The same considerations as for Canchan hold in this case, although the variety is on earlier stages of adoption and might continue to increase its area in the near term. We define a conservative estimate of 26,000 hectares for the adoption ceiling of Amarilis until the year 2020. Figures 1 and 2 show both adoption profiles defined with the historic information and the assumptions discussed above, and compares them with the adoption profile defined for Canchan on previous studies.

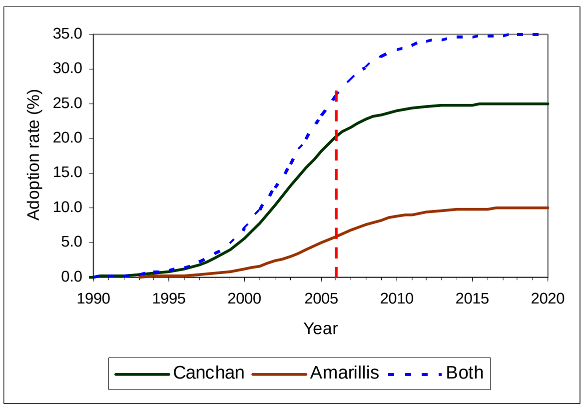

Figure 1. Estimated adoption paths for Canchan and Amarilis, 1991 – 2020

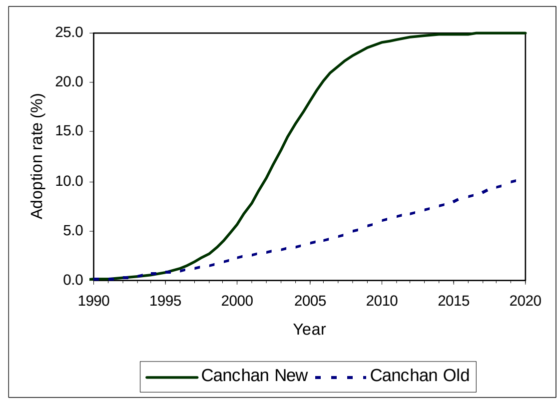

Figure 2. Old and updated adoption profiles for Canchan, 1991 – 2020

Returns to research investments

Research costs for Canchan and Amarilis are kept similar to those in Fonseca et al. (1996) for Canchan. The initial research investment for Canchan is recognized to be made in 1979, while for Amarilis the starting year for research investments is 1986. After lower initial start-up costs, the peak annual cost is near 125,000 dollars on year 12 and then decline to 60,000 dollars by year 17. Research investments are not included after year 20.

Both varieties show similar positive returns to research investments (Table 1). Given the large adoption of Canchan in Peru the internal rate of return (IRR) is near 28% and the total net present value of the net benefits generated is close to 7 million dollars. The IRR is similar to that in Fonseca et al. (1996) even though the source of benefits changed after the year 2000. Canchan's large market demand and precocity helped it to gain acceptance within farmers and the large adoption area more than doubles the area forecasted, therefore the aggregate benefits are still large despite reduced per hectare benefits.

Table 1. Canchan and Amarilis: economic returns

	Canchan	Amarilis	Both
IRR (%)	28%	27%	28%
NPV (Million USD)	6.9	4.2	8.9

The internal rate of return to research investments on Amarilis is estimated at 27%, and the net present value of the net benefits surpasses 4.2 million dollars. The returns to Amarilis are also an acceptable figure compared to international figures and similar to Canchan. In certain areas of Peru where late-blight pressure is high, Amarilis has still large potential but lack of knowledge of the variety attributes and the still reduced availibily of quality seed constraint its adoption. If the variety proves to be successful in those areas then the aggregate benefits will still increase due to larger adoption areas.

Aggregate returns to research investments in both varieties are near 28%, with an aggregate net present value of benefits of near 9 million dollars. This proves that continued investment on producing new varieties have been positive and within the expected range for returns to research investments in agriculture. Both Canchan and Amarilis are popular varieties within Peru in several regions. Canchan is very popular amongst large commercial farmers near the major cities. But it has also been adopted even in remote areas where farmers have less access to markets and where is now considered an excellent cash crop for these resource-poor farmers who also grow large number of native landraces mostly for own consumption. Amarilis, on the other hand, is seen as an excellent alternative to control late-blight in areas where the disease pressure is high and still has large potential to increase adoption as long as good quality seed becomes available.

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Sweetpotato consumption in Orissa, India and implications for nutrition and livelihood improvement

D. Campilan[1], S. Attaluri[2], S. Mallubhotla[3] and A.V. Surya[4]

I International Potato Center, New Delhi, India (d.campilan@cgiar.org)
2 International Potato Center, Bhubaneswar, Orissa, India (s.attaluri@cgiar.org)
3 Micronutrient Initiative, New Delhi, India
4 Social and Rural Research Institute, New Delhi, India

Abstract

This paper presents sweetpotato consumption patterns among poor farming households in Orissa, India and discusses implications for research and development to improve their Vitamin A nutrition and livelihood improvement. It draws from results of a study involving review of secondary information, a sample survey among farming households, and series of stakeholders' workshops.

Orissa is India's primary sweetpotato-growing state, with an average annual production of over 400,000 tons from 47,900 hectares of land. Sweetpotato is commonly grown along with vegetables and rootcrops in Orissa's smallholder farms, Yields averaging 8.56 tons/ha are very low compared to the Asian average of 15 tons/ha.

Orissa is also a major consumer of the crop, especially for the period following harvest (i.e. October to February). The next most important food crop after cereals, sweetpotato is traditionally grown by tribal communities in mountain districts. Orissa ranks first in terms of sweetpotato consumption among farming households, based on a 2008 survey conducted in eastern India. Average daily consumption is estimated at 87.9 g/day. There is higher sweetpotato consumption by those in lower social castes and tribal groups (88%), by pregnant women (93.6 g/day), lactating mothers (84.9 g/day) and children below 5 years (67.1 g/day).

The paper discusses implications for research and development in: 1) introducing orange-fleshed sweetpotato (OFS) as part of a food-based strategy to combat the high rate of Vitamin A malnutrition in India, 2) increasing income generation through sweetpotato livelihoods, 3) addressing needs and opportunities for improved crop productivity under Orissa's less-favorable growing environment.

Keywords: Sweetpotato, consumption, nutrition, livelihood, India.

Background

Since 2003, the International Potato Center (CIP) and national partners in India have undertaken collaborative research to evaluate and select promising orange-fleshed sweetpotato (OFSP) clones. To date, 4 OFSP clones have been recommended/approved for official variety release in India's key sweetpotato-growing states (Attaluri 2008).

CIP and Indian partners have also begun to pilot various mechanisms for introducing OFSP as part of food-based interventions for enhancing Vitamin A nutrition among poor farming households in eastern India. These include farmers' trainings, on-farm demonstration plots, community-based nurseries, and promotional/educational activities for women and children (Attaluri and Rath 2006, Campilan 2006).

At this stage in the OFSP research-for-development process, it is necessary to develop a

comprehensive strategy in high-betacarotene sweetpotato utilization for nutrition and livelihood improvement. A critical step is to assess existing sweetpotato consumption patterns among target consumer groups, and to identify opportunities for integrating OFSPs in local food systems.

This paper presents key findings from a study on sweetpotato consumption in the eastern Indian state of Orissa. CIP's collaborative work on OFSP targets Orissa, being India's leading sweetpotato producer and where the country's highest rates of poverty incidence and Vitamin A malnutrition are found.

Brief profile of orissa state, india

Orissa is considered the poorest of the fourteen major Indian states with 47 percent of its rural population, or 17.35 million people, living below the poverty line (National Family Survey, 2001). Major indicators for income, socio-economic welfare, health and education are consistently below national averages.

More than one-third of the population comes from the lower socio-cultural and economic groups – 36% represent scheduled tribes and castes. Moreover, there is high discrepancy among districts in terms of socio-economic indicators. For South Orissa, 87% of the population is classified poor and its development indicators are often worse than sub-Saharan Africa.

Orissa is located on India's eastern coast, with a terrain that extends from the Eastern Ghat plateau to the flat alluvial land on the Gulf of Bengal coastline. Three quarters of its total land area of 155,707 sqm is hilly with altitudes reaching 1500m. Due to its geographic location, Orissa is highly prone to natural disasters including cyclones, floods and drought.

Agriculture contributes 23% of net state domestic product (NSDP) and provides employment to 65% of the population (Orissa Directorate of Agriculture 2007). The annual agricultural calendar consists primarily of two cropping seasons -- *karif* (wet south west monsoon) and *rabi* (dry post-monsoon). Orissa's agriculture is mainly a rice-based system, although most of it is unirrigated. *Karif* rice is the dominant crop in Orissa, occupying 67% of cultivated land for the season. *Rabi* is primarily for growing horticultural crops – such as pulses and vegetables – with rice grown only on 13% of the land.

Sweetpotato production in Orissa

India is South Asia's main sweetpotato producer, accounting for 68% of the region's total production of 1.6 million tons annually. Within India, Orissa is the main sweetpotato-growing state and contributes one-third of India's overall production.

Orissa's average annual production is over 400,000 tons from 47,900 hectares of land (Orissa Directorate of Agriculture 2007). It is grown in 28 of the 30 districts in the state although it is mostly cultivated by tribal communities in mountain districts, where it is the most important food crop after cereals.

Sweetpotato yields in Orissa are very low, averaging 8.56 tons/ha, when compared to the yield average in its neighboring states, i.e. 13.89 tons/ha in Bihar, and to the Asian average of 15 tons/ha (Indian Horticultural Information Service 2005). It is grown on very small landholdings, mostly between 0.19 and 0.45 ha ((Edison et al 2008). Poor lateritic soils, sub-optimal crop management practices and competition with other food and cash crops are among the key reasons cited for low sweetpotato productivity and production in Orissa.

The crop is grown in both *karif* and *rabi* seasons, although 84% of sweetpotato is harvested during the former (Orissa Directorate of Agriculture 2007). As a rainfed crop, sweetpotato is grown on *chaur* (lowland) after harvesting paddy rice. It is also grown along riverbanks/beds after water recedes from their fields. In addition, sweetpotato is planted along with vegetables and rootcrops in Orissa's smallholder farms, homegardens and riverbeds.

General dietary and nutritional trends

Vitamin A deficiency leads to deaths of up to 1 million children annually around the world. One-third of these occur in India alone, where 57% of children up to 5 years old suffer from this nutrient deficiency. While chiefly caused by inadequate dietary intake, the wider socio-economic causes and consequences of Vitamin A malnutrition are now increasingly recognized.

In times of food shortages, women eat least and last in a society which also discriminates them against opportunities for education, livelihood and political participation. Meanwhile, drug-based supplementation is expensive for developing countries like India to sustain. Also, it does not fully benefit hard-to-reach populations such as ethnic communities in remote regions marginalized by social class, economic status and geographic isolation.

Cereals remain the staple food in Orissa but, as with the rest of the country, the average diet remains largely deficient in micronutrients. Based on the National Family Health Survey (2001), cereals consumption in Orissa meets the recommended dietary level, but protective foods (e.g. vegetables) are consumed lower than the minimum level required for a nutritionally adequate diet.

In a 2003 household survey by the National Institute of Nutrition, over half (57%) of Orissa's population consumed less than 50% of the recommended daily allowance for Vitamin A. In times of disasters and food shortages, poor households cope by shifting from cereals to cheaper alternative staples, and by reducing overall food consumption, as reported by 80% and 73% respectively (Pandey et al 2007). Women are the most affected during these crisis situations, since men and children are prioritized for food.

Sweetpotato consumption patterns

Besides being India's lead sweetpotato producer, Orissa is also a major consumer of the crop.

A 2008 survey was conducted in three eastern states (Orissa, Bihar and Uttar Pradesh) jointly by CIP, The Micronutrient Initiative and Social and Rural Research Institute in India.

The survey revealed that sweetpotato consumption is higher for the period October-February, which follows the usual harvesting time for sweetpotato and when rice supply begins to decrease. Of the 200 survey respondents, 68% eat sweetpotato during the year but this increases to 80% during the October-February period.

Orissa ranks first in terms of average daily consumption, at 87.9 g/day. The survey indicated high sweetpotato consumption among lower social castes and tribal groups (88%). Across social categories, there was also high level of consumption by pregnant women (93.6 g/day), lactating mothers (84.9 g/day) and children below 5 years (67.1 g/day).

The three primary reasons cited for consuming sweetpotato are: 1) good for health and nutrition, 2) preferred food by children, and 3) easy to prepare. On the other hand, the least commonly cited reasons: are 1) readily available, 2) important food for religious festivals, and 3) easy to digest.

From the same survey, Tables 1 and 2 present consumption patterns in Orissa as compared with two other eastern Indian states, and among children and women. In Orissa, sweetpotato is generally eaten during breakfast (63% of respondents) before leaving for work or school. Among children and lactating mothers, at least half of respondents said there is no fixed time for eating sweetpotato although it is generally consumed during daytime.

Sweetpotato is consumed in boiled form by 100% of survey respondents in Orissa. Burning/roasting sweetpotato roots is also highly popular (80%). Sweetpotato food preparation is similar whether for children, lactating mothers or pregnant women.

Over 80% of respondents expressed willingness to try OFSPS, but 43% of them said they might not do so if it is more expensive than the current price of traditional sweetpotato varieties. Sweetpotato consumers eat other Vitamin-A rich vegetables and fruits (e.g. spinach, tomato, carrot, papaya, mango). However, these other food sources are much more expensive, thus amounts consumed were estimated to be of limited quantity and frequency.

Table 1. Daily time schedule in sweetpotato consumption

Time of consumption	All	BIHAR	ORISSA	UP	Children	Lactating mothers	Pregnant women
Base: All	**200**	**60**	**41**	**99**	**100**	**61**	**39**
Morning/breakfast	33	5	63	37	36	26	36
Afternoon/lunch	26	3	39	34	27	23	28
Evening/supper	21	3	54	17	22	16	23
Night/dinner	3	3	2	3	5	0	3
Any time (no fixed time)	54	92	15	47	50	61	34

Table 2. Manner of preparing sweetpotato food

Manner of preparation	All	BIHAR	ORISSA	UP	Children	Lactating mothers	Pregnant women
Base: All	**200**	**60**	**41**	**99**	**100**	**61**	**39**
Boil it	98	100	100	95	99	95	97
Burn/Roast it	58	18	80	73	58	57	59
As vegetable	11	0	44	3	11	10	10
For preparing desserts	2	0	0	3	2	2	0

Implications for nutrition and livelihood improvement

Available information from the field survey and secondary sources validates the potential role of sweetpotato nutrition and livelihood improvement among Orissa's poor farming households. Sweetpotato remains a major crop cultivated and consumed especially by those in the lower socio-economic and nutritionally vulnerable groups in the state. These findings support the targeting of Orissa for OFSP research-for-development efforts by CIP and national partners.

To develop a strategy for incorporating OFSP in a food-based intervention for nutrition improvement in Orissa, the following key considerations are recommended:

1. There is a need and opportunity to improve sweetpotato yields in Orissa. Adaptive research could focus on developing and introducing improved crop management practices under Orissa's less-favorable growing conditions and low-external input systems. Efforts to promote the cultivation of OFSP could capitalize on its potentially superior agronomic traits over traditional varieties including shorter maturity, higher yield and higher use-value and consumer demand. Equally important is the development of a support scheme to make available planting materials of OFSPs through community-based systems for multiplication, maintenance and distribution of sweetpotato planting materials. This is a critical measure in the absence of a functioning formal seed system for sweetpotato.
2. Unlike in other regions in Asia and Africa where it is a staple crop, sweetpotato is primarily consumed in Orissa as supplement to rice, snack item and/or buffer food during crises. To better contribute to the goal of Vitamin A nutrition improvement, OFSP has to be integrated in a strategy for dietary diversification while exploiting sweetpotato as a cheap and readily available food source. This also requires an inter-sectoral platform among organizations – both public and private – working in agriculture, health and education. To date, CIP has already expanded its partnership platform in Orissa which now includes a broader set of organizations from the NGO and private commercial sectors.

3. Increased consumption of OFSP and integrating this in local diets require efforts to stimulate demand from the consumption-utilization end of the value chain. There is room for diversifying food preparations, including processed products, beyond the traditional practice of boiling and roasting. While only a small portion of sweetpotato roots are currently sold, the potential for reaching target consumers through market chain development could be explored especially in the urban setting.
4. India's increased policy support for food-based nutrition interventions, to reach the hard-to-reach populations, provides a better enabling environment for OFSP introduction in Orissa. Research-for-development initiatives for OFSP directly supports the Indian government's current plan of action to combat micronutrient deficiencies, which put locally available micro-nutrient rich food as a priority over or alongside synthetic sources of Vitamin A. Similarly, the 2008-2012 collaborative workplan between the Indian Council of Agricultural Research (ICAR) and CIP includes OFSP-related research priorities: a) sweetpotato crop improvement for high beta-carotene content with wide local adaptability, and b) sweetpotato product development for economic and health gains.

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Root and tuber crops of the Pacific: A resource for meeting the challenges of the 21st century

Mary Taylor[1], Valerie Tuia[1], Rosa Kambuou[2] and Tevita Kete[1]

Secretariat of the Pacific Community, Private Mail Bag, Suva, Fiji[1]
maryt@spc.int;
National Agriculture Research Institute, Papua New Guinea[2]

Abstract

The Pacific Island Countries and Territories, home to an estimated 9.5 million people, are geographically, ecologically, sociologically and economically diverse. This region faces numerous social and physical challenges simply by nature of the size of the islands, and their geographical isolation. The 21st century, however, has brought new challenges from climate change to increasing food prices to the alarming increase in lifestyle-related diseases, which is strongly associated with the over-consumption of nutritionally poor foods, often imported. The response to the increasing food prices has been to strengthen local food production. Increasing local food production and promoting local food consumption provides an excellent opportunity to address the nutrition-related health problems. However, local food production has to be sustained in the light of climate change.

This paper describes the work of the Secretariat of the Pacific Community (SPC) in promoting and supporting the conservation and utilization of root and tuber diversity, as one of the solutions to manage these many challenges. For example, the SPC Centre for Pacific Crops and Trees (CePaCT), which houses a unique collection of over 850 accessions of taro (*Colocasia esculenta*), as well as other crops and trees of importance to the region, is building a "climate-ready" collection, consisting of local crops and varieties selected because such diversity will provide the farmers in this region with the traits, such as drought and salt tolerance. Evaluation, participatory crop improvement and value-adding programmes all encourage utilization of the root and tuber diversity conserved in the CePaCT.

Keywords: Pacific, Aroids, diversity, taro, root and tuber.

Introduction

Pacific Island countries cover a land area of only 553,959 km^2 spread in the world's largest ocean (33 million km^2), with Papua New Guinea (PNG) accounting for 83% of the land area. The Pacific is home to about 8 million people, speaking 50% of the world's languages, with over 800 in PNG alone. The population is predominantly rural; however urbanization is occurring at a rapid rate, resulting in more than 40% of the population residing in urban areas in a few countries (Secretariat of the Pacific Community, 2004). Pacific Island countries face many challenges, including small populations and economies; weak institutional capacity in both the public and private sector; remoteness from international markets; susceptibility to natural disasters and climate change; fragility of land and marine ecosystems; limited fresh water supply; high costs of transportation; limited diversification in production and exports; dependence on international markets; export concentration; and income volatility and vulnerability to exogenous economic shocks such as cost of fossil fuels.

Traditionally, the Pacific Islands have depended on local staples, such as root and tubers for food and nutritional security. However, increasing urbanization, the introduction of modern plantation systems, the opening up of Pacific Island markets to global trade and the promotional prowess of the modern food companies have contributed to the decline of traditional crop production and an increased dependence on imported foods. The food crisis that was experienced globally in 2007 highlighted the level of vulnerability of many countries in the region. The extent to which individual countries are reliant on imported foodstuffs varies across the Pacific with the countries of western Melanesia having the lowest dependency on imported foods. On the other hand, countries such as Kiribati, Marshall Islands and the Federated States of Micronesia are very reliant on imported foods and as such extremely vulnerable to global crises. A UNICEF report highlighted the significant increase in consumer prices in Kiribati in the 12 months leading up to July 2008. Rice prices increased by 30%, flour by 20% and sugar by 20%. (UNICEF, 2008)

The dependence on imported food, often nutritionally poor, has also impacted severely on the health of the Pacific people. Rice and flour have now replaced root crops as the single most important source of starch and energy. Despite the nutritional superiority of traditional root crops (Parkinson, 2004), all Pacific Island countries and territories, apart from Fiji, Papua New Guinea and Solomon Islands, rely exclusively on cereal imports. The low nutritional value of these imported foods is a major factor contributing to food-related chronic disease and mortality in the Pacific, such that the people of the Pacific have some of the highest rates of obesity in the world. This in turn leads to elevated rates of non-communicable diseases (NCDs). Pacific Island countries and territories have the highest death rates from ischaemic heart disease, cerebrovascular disease and diabetes. (WHO, 2006)

The Pacific Island region generally has historically managed to avoid acute food shortages, through strong local food production systems, traditional food preservation techniques and supplementation of diets with wild crops. However, these coping mechanisms are not as resilient as they have been in the past. Knowledge of traditional farming practices and food preservation techniques have been and are being lost with the rural-urban drift experienced in the Pacific. The poor investment in agriculture over the years has significantly weakened research and extension systems in most agriculture ministries in the Pacific, with a predictable impact on local food production. The over-inflated status of imported foods and the poor status of traditional foodstuffs have also served to discourage interest in local food production and consumption. This decrease in the utilization of traditional food crops, in particular the root and tuber crops has presented a significant threat to the genetic diversity of these crops in the Pacific. Genetic erosion has been exacerbated by market forces. For example, Fiji is the largest exporter of taro – an export market that is based on largely one variety. The influence this market has had is visible in the limited diversity that exists in taro gardens in Fiji. A recent study carried out on the New Zealand market for taro found that it is currently under-supplied, which could pose further threats for taro diversity (Thomson, pers.comm.)

This loss of diversity and an associated lack of the traditional knowledge associated with these crops also undermine the capacity of the Pacific region to manage climate change. As the Stern Review highlighted "adaptation is essential to manage the impacts of climate change that have already been locked into the system" and the development of "more climate-resilient crops" is one of the main strategies for adaptation (Stern, 2006). Losing diversity reduces the options available with which to modify an agriculture production system, that is, to adapt. Having at hand a range of crops and varieties is similar to having a well-equipped toolbox – the tools being diversity that can either be used directly or in crop improvement programmes.

In summary, the increasing dependence of Pacific Island countries on imported foods has rendered the people of the Pacific vulnerable to non-communicable diseases and food insecurity. Is it therefore now time to return to our traditional food crops, in particular our root and tuber crops and to give them the attention they deserve? Can a focus on these crops assist the Pacific in meeting the many challenges it faces?

Diversity of root and tuber crops in the Pacific

The diversity of root and tuber crops in the Pacific varies both for the crop and also across the Pacific. For taro (*Colocasia esculenta*) and giant swamp taro (*Cyrtosperma merkusii*) the Pacific is a primary centre of diversity whereas for sweet potato it is a secondary centre of diversity. Diversity in the Pacific in general declines markedly from west to east, due to the history of colonization, and the fact that the crops in question are vegetatively propagated.

Aroids

Of the aroids used in the Pacific, *Colocasia esculenta* (taro) is the most important. The question of the centre of origin of taro remains unanswered and has been the focus of many discussions (Lebot, 2009). The Asian origin of taro has been well-documented (Matthews, 2002a). There is now circumstantial evidence that *Colocasia* may have been domesticated in western Melanesia. Thus, most cultivars found throughout the Pacific were not brought by the first settlers from the Indo-Malayan region as previously thought (Plucknett *et al.* 1970; Leon 1977; Kuruvilla and Singh 1981), but were domesticated from wild sources existing in Melanesia. Two independent domestications of taro in Southeast Asia and Melanesia have been confirmed using AFLP markers, as has the relatively limited genetic diversity existing in Polynesia compared to Melanesia (Kreike, 2004)

Attention was focused on taro in the early 90s when production in Samoa was severely affected by taro leaf blight. This event highlighted the role diversity can play in managing diseases and reminded scientists, researchers and to some extent, policy makers, as to the importance of genetic diversity. As a result AusAID funded a regional project - TaroGen (Taro Genetic Resources: Conservation and Utilization), which commenced in mid-1998 and ended in late 2003. The objectives were to complete the description and conservation of the bulk of taro genetic diversity in the Pacific Region; and to provide growers in Pacific Island countries with taro varieties with improved resistance to taro leaf blight. Some 2199 accessions were collected and described by partners, and 211 accessions were recommended for inclusion in a regional core collection based on phenotype and molecular characterization (Mace, *et al*., 2006). The majority of these are safely stored at the Secretariat of the Pacific Community Centre for Pacific Crops and Trees (SPC CePaCT). The Taro Network for Southeast Asia and Oceania (TANSAO) also began in 1998, funded by the European Commission. Its objective was to improve taro in Southeast Asia by selecting varieties with high commercial potential as a table food and for processing. The project was completed in December 2001, having successfully established taro genebanks in all seven member countries complete with passport and characterization data. From the 2,298 accessions collected, a core of 168 was selected based on morphological and isozyme data, representative of the genetic diversity of the countries involved (Lebot *et al.,* 2004). The TANSAO core is conserved in the SPC CePaCT for sharing with other countries

Three other aroids are cultivated to varying extent in the Pacific – *Alocasia macrorrhiza* (giant taro), *Cyrtosperma merkusii* (giant swamp taro) and *Xanthosoma sagittifolium* (cocoyam). Compared to *Colocasia*, these species have attracted very little research and development attention. *Alocasia* is important, in some Pacific islands, notably American Samoa, Samoa, Tonga and Wallis and Futuna The number of varieties is low and it is presumed that the species has a narrow genetic base (Lebot 1992). *Xanthosoma* was introduced to West Africa, Oceania and Asia in the 19th century (Coursey 1968; Wilson 1984). Compared to the other aroids, it is of least importance in the region in general.

An Indo-Malay centre of origin has been proposed for *Cyrtosperma* (giant swamp taro), however "coastal New Guinea region" has also been suggested because of the variation in wild forms found in that region (Lebot, 1999). *Cyrtosperma* is cultivated in most Pacific Island countries, more rarely today as a staple food but, nevertheless, still retained for its important cultural uses, especially in the atoll islands (Iese 2006). A recent study carried out in four Pacific Island countries, identified the number of accessions; Federated States of Micronesia (48), Fiji (5), Kiribati (18) and Tuvalu (12) (Englberger *et al*. 2003; Iese 2006). Morphological and molecular comparisons were made, traditional knowledge collected and dendrograms of morphological characters drawn to show that some varieties were closely related between countries, while others were unique. Preliminary DNA fingerprinting studies supported the view that some varieties were rare and needed attention to prevent their loss (Iese 2006).

Sweetpotato

There are a number of suggestions as to how this crop arrived in the Pacific. One hypothesis suggests there was a direct prehistoric transfer by Peruvian or Polynesian voyagers from South America to Polynesia (Yen, 1974, 1982a). Alternatively sweet potato could have been introduced to the Pacific during Spanish voyages from Mexico to the Philippines which traded across the Pacific. DNA fingerprinting shows little relationship between Oceania germplasm and that of Peru-Ecuador, suggesting that human dispersal from Mesoamerica is more likely (Rossel *et al*., 2001). Based on DNA fingerprinting, it is quite clear that there are two major groups of cultivars, those from New Guinea and those from South America. The genetic base of the New Guinea cultivars appears to be narrower than the South American base. DNA analysis shows that New Guinea cultivars after a long, isolated evolution in a specific agro-ecological environment have significantly diverged from their ancestors, confirming their ancient presence on the big island (Zhang *et al*., 1998a).

The SPC CePaCT holds a number of sweet potato varieties selected from a fairly rigorous and extensive varietal screening programme conducted under the European Union funded Pacific Regional Agriculture Programme (PRAP) sweet potato project (June 1990 to December 1998). The varieties were selected from a total of 1,167 varieties, which included material accessed from within PNG and also introduced from overseas (Pacific and elsewhere). The CePaCT now conserves and distributes the top varieties from this selection programme

Yams

Dioscorea spp are found throughout the tropics and different species of edible yams have been domesticated independently in America, Africa, Madagascar, South and Southeast Asia, Australia and Melanesia. Of more than 600 *Dioscorea* species, *D. alata, D. cayensis* and *D. rotundata* are the most cultivated species. AFLP markers have shown that *D.alata* shares a common genetic background with *D. nummelaria* and *D. transversa* (Malapa *et al*., 2005a, b). It is suggested that *D. alata* was domesticated 60,000 years ago, after the arrival of the Australoids, in the present New Guinea, or in Melanesia (Lebot, 1999). This geographic region is also the centre of diversity of the species (Lebot *et al*., 1998). *D. esculenta* is an ancient crop in the Pacific, as found by the dating of starch grains in Fiji, 3050-2500BP (Horrocks and Nunn, 2006). Other yams with their origin in the Pacific include *D. bulbifera, D. nummelaria, D. pentaphylla and D. transversa.*

The South Pacific Yam Network (SPYN), a regional project funded by the European Commission focused on *D. alata*, recognizing that this species has potential for increased commercial exploitation. SPYN, a four-year project, was established to enhance the competitive position of yam in traditional cropping systems of five Pacific Island countries. Cultivars were selected for desired agronomic characteristics, such as tuber shape and tolerance/resistance to anthracnose. A core sample from the final collection made during this project is now conserved at the SPC CePaCT.

Cassava

The debate on the origin of cassava is complex but it is likely that it was introduced into the Pacific in the late 19th – early 20th century (Lebot, 2009). Cassava accessions are conserved in the CePaCT, but these are largely accessions obtained from CIAT, to date only five varieties have been collected from the Pacific, namely Fiji. However there has been increasing interest in cassava from a food security standpoint. The food crisis in 2007 saw increased plantings of cassava in Fiji, and enthusiasm for new varieties, especially early-maturing. Its ability to stay for long periods in the ground and its adaptability to marginal areas also adds value as a food security crop. Commercial interest also exists; for biofuel and frozen cassava as an export product.

The numbers of accessions of root and tuber crops conserved in the SPC CePaCT are shown in Table 1.

Table 1. Root and tuber crops conserved in SPC CePaCT (September 2009)

Crop	Species	Number of accessions
Taro	*Colocasia esculenta*	852
Giant taro	*Alocasia macrorrhiza*	10
Cocoyam	*Xanthosoma sagittifolium*	8
Giant Swamp Taro	*Cyrtosperma merkusii*	17
Sweet potato	*Ipomoea batatas*	230
Yams (*Dioscorea* spp)	*D. alata*	164
	D. esculenta	4
	D. nummelaria	2
Cassava	*Manihot esculenta*	31

Nutritional value of root and tuber crops

The poor nutritional value of many of the imported foods consumed in the Pacific has been discussed, which begs the question as to the value of some of the traditional food crops. Significant work has been carried out on some crops, in particular, banana, (Englberger, 2004) but less attention has been focused on the root and tubers. However, what is recognized is that these food crops provide superior nutrition to the white rice and flour products consumed today in the Pacific (Parkinson, 2004). Nutritional studies conducted on swamp taro have shown, as with banana, that the nutritional value is often linked to the variety. A study carried out by Englberger *et al.*, (2008) showed that the carotenoid contents of giant swamp taro varieties in Micronesia varied across a range from zero to 4,000µg/100g, with at least four varieties with beta-carotene contents well over 1000µ/100g.

Securing and utilizing the root and tuber diverstiy of the pacific: activities within the SPC genetic resources programme

The Pacific is home to a wealth of root and tuber diversity however, as previously stated this diversity is under threat. The threat to diversity and the limited resources for diversity conservation at the national level was acknowledged in 1996 when Pacific Ministers of Agriculture resolved to put in place, both in their countries and through regional cooperation, policies and programmes to conserve, protect and use Pacific plant genetic resources effectively and efficiently for development. In response to this resolution from the Ministers of Agriculture, the Secretariat of the Pacific Community (SPC), an inter-governmental agency with a membership of 22 Pacific Island countries and territories, established the Centre for Pacific Crops and Trees (CePaCT) in 1998. The basic aim of the CePaCT is to provide the region with the means to safely and effectively conserve crop diversity, and to facilitate access to useful diversity, both within and outside the region. *In vitro* techniques are used, and collections exist for taro and other aroids, yam, sweet potato, banana, breadfruit, cassava, pandanus, aibika (*Abelmoschus manihot*) and kava (*Piper nigrum*).

The response of SPC to the ministerial decision in 1996 did not stop with CePaCT. In May 2001, Pacific Directors of Agriculture recommended that a Pacific Agricultural Plant Genetic Resource Network (PAPGREN) be established. The overall objectives of PAPGREN are to strengthen national plant genetic resources programmes and collaboration among them, so as to use scarce resources more effectively to solve common problems. Both CePaCT and PAPGREN are the major components of the Genetic Resources programme within SPC.

The core business of the Genetic Resources programme is to conserve and promote the use of diversity, in particular the root and tuber crops. This focus has been not only a conservation effort, but importantly a response to the serious challenges facing the region. How to ensure food security despite adverse climatic conditions? How to meet existing market demands, such as taro for export, and find and secure new markets? How to raise the status of these crops so that they are in demand locally and are not put to one side in preference to white rice?

Efforts over the past ten years have focused very much on building up the collection of aroids, and promoting utilization. This effort has been supported by the previous work of the two taro networks (TANSAO and TaroGen), and the absence of a Consultative Group for International Agricultural Research (CGIAR) Centre with a mandate to cover edible aroids. The taro collection is particularly unique, being the largest *in vitro* collection of taro diversity globally – over 850 accessions (Pacific and Southeast Asian in origin). In fact the uniqueness of both the taro and yam collections, and the role these collections can play in ensuring food security has been acknowledged at the international level with the recent signing of a long-term agreement with the Global Crop Diversity Trust. The Trust has agreed to provide funding support *ad infinitum* for these collections – this agreement is the **first** to be signed with a genebank outside of the CGIAR Centres.

The CePaCT has developed virus testing expertise for taro and yams in order to ensure safe utilization of the collection. Research is on-going to determine the optimum virus elimination technique (with regards to effectiveness and speed with which a usable plant is available) for the more common taro viruses, such as DsMV (Dasheen Mosaic Virus) and TaBV (Taro badnavirus), both of which occur relatively frequently in the Pacific, but impact on distribution of germplasm. Another area of study linked to viruses is investigating the impact of DsMV infection on the yield of the crop in two countries, namely Fiji and Samoa.

The size of the taro collection has also prompted research into more resource-effective conservation systems. With this in mind, a cryopreservation technique (droplet vitrification) has been developed to enable those accessions of currently limited interest to be cryopreserved (Sant *et al.*, 2007). This technique has proved successful with a number of accessions from the collection; it is currently being evaluated for its applicability across a wider range of accessions from the taro collection and also to include the other edible aroids (*Alocasia, Xanthosoma* and *Cyrtosperma*).

The TaroGen project in its efforts to develop cultivars with tolerance/resistance to taro leaf blight supported two breeding programmes in Papua New Guinea and in Samoa. The programme in Samoa, which continues to be supported by SPC in collaboration with the University of the South Pacific (USP) is of particular interest, because of its participatory approach. This Taro Improvement Programme has worked with farmers since its inception, breeding and selecting lines which have good taste, yield and importantly are tolerant/resistant to taro leaf blight. The farmers are currently evaluating Cycle 6 of the breeding programme, the result of crossing lines obtained as a result of the two taro networks from Asia and the Pacific. These Cycle 6 lines have received excellent feedback in Samoa and are currently being virus-tested in CePaCT for wider distribution and evaluation. This participatory programme has recently expanded its breeding programme to include selection for drought tolerance.

To date work on the other aroids has focused on collecting and at the same time virus testing these new accessions so they can be made available. Their ability to tolerate more marginal conditions has made them very suitable for the climate-ready collection. Some preliminary salt tolerance evaluation work is in progress, with taro and swamp taro, using a simple culture system on medium containing sodium chloride and identifying toxicity levels. It is hoped that this work will expand soon to include drought tolerance investigations as well.

The sweet potato work within the Genetic Resources programme is largely concerned with maintaining the existing collection, which consists of Pacific and non-Pacific germplasm. More recently material has been imported from CIP – these accessions, all orange-fleshed sweet potato (OFSP) have demonstrated salt and drought tolerance in Asia. These are extremely interesting accessions for evaluation in the Pacific with the double benefit of nutritional and climate-ready value. Early reports from some countries indicate that some OFSP varieties have performed well and are liked for their taste, texture and yield.

The work on yams is very similar to that of sweet potatoes. With the exception of the SPYN project, there has been very little focus on yams. However, CePaCT is endeavoring to increase the diversity of the yam collection, which currently consists mainly of *D. alata*, to include other yam species, especially *D. esculenta*, which is a hardier yam that appears to perform well in atoll conditions. *D. nummelaria* is another yam species of interest, known because it is very hardy, resistant to diseases and high yielding.

The conservation focus of the SPC Genetic Resources Programme has been *ex situ*. Some studies have conducted on *in situ* conservation (Jansen, 2002; Maemouri and Jansen, 2004). This work is being continued with some countries, for example, Papua New Guinea through the network (PAPGREN, and the need to link these two methodologies and to have in place a complementary approach to conservation is acknowledged (Taylor *et al.*, 2004).

Root and tuber crop diversity: helping to address the challenges

The SPC Genetic Resources programme considers diversity to be essential in managing the many challenges facing the Pacific, not least, climate change. Scientists have shown that diversity provides a natural insurance policy against major ecosystem changes, be it in the wild or agriculture (McNaughton, 1977, Chapin *et al.*, 2000, Diaz *et al.*, 2006). With this in mind a major activity within the Genetic Resources programme is the establishment of a 'climate-ready' collection within CePaCT. The collection currently consists of 107 accessions of a range of crops, of which 93 are roots and tubers, sourced from within and outside the region, recognized for their climate-tolerant traits, such as, the salt and drought tolerant sweet potato accessions from CIP. This collection will provide the farmers of the region with a range of diversity required to sustain food production in a changing climate. As the nature of climate change is dynamic, this collection will also be dynamic, with collections being evaluated and constantly updated. Germplasm is collected, virus tested and then made available through the PAPGREN for evaluation in the different countries and different agro-ecological environments. Consideration is given to evaluating this material in challenging environments, such as on atoll islands.

The root and tuber crops, and the diversity this group provides, can also assist the region in addressing the problem of lifestyle related diseases. The Centre promotes varieties with known nutritional value, such as the orange fleshed sweet potatoes from the CIP collection. Interestingly some of Cycle 6 lines from the participatory breeding programme in Samoa are orange-fleshed, and have attracted interest from farmers and consumers. In collecting missions, nutritional traits are also considered, and targeted. The Genetic Resources programme works closely with the Island Food Community of Pohnpei, a NGO based in the Federated States of Micronesia promoting local food consumption, and in particular emphasizes the importance of diversity in achieving nutritional needs. Pohnpei is the location for an interesting collection of over 60 accessions of swamp taro, which will shortly be characterized and duplicated in CePaCT.

Finally with the urgent need to establish new markets for trade, the root and tuber crops offer considerable potential. The Genetic Resources programme is working with an EU-funded project "Facilitating Agricultural Trade in the Pacific" to source and identify varieties which have potential for local and overseas markets, whether fresh or processed. The bulk of the *D. alata* accessions in CePaCT were selected for their commercially-suitable shape. More recently there has been interest from a local grower and exporter in purple-fleshed yams, for both nutritional value and consumer-attractiveness. The New Zealand and Australia markets are strong markets because of the population of Pacific Islanders and Asian immigrants, though quarantine regulations can be restricting, reducing the price competitiveness of crops, such as taro. However, small volumes of partially processed and flash-frozen taro are currently being exported, for example by Fiji, but the size of the market and its profitability has not yet been determined (Thomson, pers.comm.). For all the root and tuber crops, snack foods, vacuum packed products and speciality flours are a possibility. As "convenience" is admittedly another factor contributing to the poor attraction of root and tuber crops, processing these crops so that they are available in convenient supermarket style packages can only improve demand. For taro, speciality starch is an area of promise (Lebot, 2009). The nutritional benefits of these crops are yet to be exploited, for example, their low glycaemic index.

The Centre for Pacific Crops and Trees (CePaCT) is one of a kind in the Pacific and is a resource that has been built up over the years through the commitment of donors and SPC. Importantly it is a resource the Pacific region now truly values for its role in conserving traditional crop and tree diversity, and providing "new" material to fulfill all the functions required of diversity. With the challenges of the 21st century this role is becoming increasingly important. The demands are huge on the fragile resources of the Pacific, maintain food security with the unpredictability of climate change, address the problems of nutritional security, and respond to the needs of the markets, but with the diversity of traditional food crops, in particular the root and tuber crops, these challenges will be more easily addressed.

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Progress and status of yam bean research in India

S. K. Naskar

Director, Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India

Abstract

Yam bean (*Pachyrrhizus erosus*) is a native of Mexico and Central America and is widely cultivated throughout the tropics, in both hemispheres. In India, it is popularly grown in parts of West Bengal, Bihar, Orissa and Assam approximately in an area of 200 to 300 ha. The plant has many uses: the young tubers are edible and rich in ascorbic acid, while mature tubers yield high quality starch and the seeds can be used as insecticides. Central Tuber Crops Research Institute (CTCRI) and All India Coordinated Research Project on Tuber Crops centres especially Rajendra Agricultural University, Dholi maintains more than sixty germplasm accessions collected from different parts of India. One yam bean variety "RM 1" was released by AICRPTC centre at Rajendra Agricultural University. Parental material for initiating breeding work has been isolated at CTCRI. Yam bean genotype L-19 was found to be highly suitable for Orissa. Agronomic practices for cultivating yam bean have been standardized. Work on intercropping of yam bean is also in progress. Stem borer is the major pest on yam bean and sometimes diseases like severe blight spots on leaves, stems and pods could also be seen. Yam bean seed extract was found to be a biocide for *Sitophilus oryzae* and *Aphis craccivora.* Aphids on taro and cowpea can be controlled by yam bean seed extract. Yam bean starch characterization is done. Seeds are multiplied at CTCRI Regional Centre in Bhubaneswar and at AICRPTC centre at RAU, Dholi for distributing to farmers.

Introduction

Yam bean (*Pachyrizhus erosus* (L) Urban), also known as potato bean in English, belonging to the family Leguminaceae and sub family Fabaceae (Papilionaceae), is a starchy root crop with comparatively high sugar content and a moderately good source of ascorbic acid. In India, tender tubers are consumed as a fruit and the taste resembles that of Chinese water chestnut. Its crisp and fruity underground tubers are eaten raw. It is commonly called Misrikand, Kesaru, Shankalu or Sankesh in different parts of India. Tubers contain more than 82% water, 1.5% protein, 10% starch and 5-6% sugar. The mature seeds have high content of alkaloids and insecticidal properties. In India, it is mostly grown in North Bihar extending parts of West Bengal, Assam, Orissa and eastern Uttar Pradesh. As it is a crop of small farmers, information on area and production of this crop has not been documented. Large area under yam bean is in Bihar state of India from where it is marketed all over the country. It is also a popular crop in the gangetic alluvial tract of West Bengal.

The advantageous features of yam bean are: good adaptability to a wide range of climatic and edaphic ranges, well balanced and nutritious composition of protein/ starch contents, acceptable taste, good post harvest/ storage characters, biological N fixation etc. Owing to these features the crop should be effectively exploited to meet a wide range of needs in developing countries. Research work carried out in India on breeding, agronomy and utilization of yam bean seed extract for crop protection aspects are briefly summarized.

Germplasm accessions

The germplasm accessions are being maintained at CTCRI (63 nos.) and AICRP Centres (205 nos). The germplasm accessions comprise of land races and exotic collections. Most of the exotic collections are from Mexico. All the accessions from CTCRI were characterized and evaluated. Except one with white flowers, the remaining accessions produce velvet flowers. The tuber yield of the accessions ranged between 10.33-25.78 t ha^{-1}. Five accessions were identified with yield more than 25 t ha^{-1}. Analysis of the biochemical constituents of the tuber revealed, variations in dry matter (9.33-29.78%), starch (3.02-7.96%) and sugar (3.02-7.96%) contents (Vimala, Personal communication).

Breeding efforts in yam bean

Yam bean research in India has not received much attention from the national research system. Hence farmers in the country still rely on traditional land races. In India, research on yam bean is being undertaken at Central Tuber Crops Research Institute (CTCRI), Thiruvananthapuram, Kerala, India and two centers (Bihar and West Bengal) of the All India Co-ordinated Research Project on Tuber Crops (AICRPTC). There has been little attempt for genetic improvement through breeding. Breeding in yam bean is limited to selection only. Nature of compatibility was studied in a set of diallel crosses involving eight genotypes. The breeding objectives include earliness, high dry matter, improved nutrition, drought tolerance and pest and disease resistance. Attempts have already been made to develop hybrids of Mexican and local types and some of the lines were promising (Mnukhopadhyay *et al.*, 2008).

Induction of variability through mutagenesis

The information available on the breeding of this crop is very much limited in India. Genetic variability is limited in yam bean. For inducing specific genetic changes, an exploratory gamma irradiation was carried out in seed samples of a superior collection (Sreekumari *et al.* 1983; Nair and Abraham, 1988, 1989). Yam bean seeds treated with gamma radiation (5 - 25 kR) or ethylmethane sulphonate (EMS, 0.5 – 1.25%) induced greater variability with regard to shoot length, number of branches, number of leaves and tuber yield. Treatment with gamma radiation greater than 7.5 kR significantly reduced vegetative vigour and yield. Yam bean seeds treated with gamma radiation (5 kR) stimulated vegetative vigour, induced greater shoot length, number of branches, number of leaves and tuber yield than control plants. The occurrence of multiple shoot (twins, triples and quadruplets seedlings) which accounted for nearly 2% of germinated seeds has also been reported in yam bean (Sreekumari and Abraham, 1980).

Varieties

Though, a native of Mexico, the crop is well distributed in the tropics. Yam bean is one of the under-utilised tuber crops which has been gaining importance in recent years. In India two types of cultivars (Mexican and local) are grown. Mexican types are larger in size and attain a diameter of 10-15 cm and weigh up to 1.5 – 2.0 kg. The Mexican types are less sweet compared to local ones and develop cracks on tubers. The local types have smaller tubers (200 – 300 g), moderate to high sweetness, less fibre, conical shape, white flesh and are soft with creamy skin. They do not develop cracks on tubers. Rajendra Mishrikand 1 (RM-1), an improved selection, released by the AICRP on tuber crops is very popular in Bihar and West Bengal. Its average tuber yield is 40 – 55 t ha^{-1} in 110 – 140 days. The individual tuber weighs 0.6 – 0.7 kg, sweet, comparatively free from cracking with smooth surface, napiform with cream coloured tuber skin. Flesh is white. Other promising Mexican line L-19 produces better yield in Bihar, West Bengal and Orissa.

Agro-climatic requirements

Yam bean requires a hot humid climate and adapts well in sub-tropical and hot temperate zones. The basic requirement is frost free condition during the growth period. It grows up to an altitude of 1000 m. It has been observed that thermo-periodism has got a definite effect on tuberization. Though yam bean requires 14-15 hours of photoperiod for good vegetative growth, shorter days are preferred for better tuberization. Hot days and cooler nights favour tuberization. A well distributed rainfall during the growth period is required for optimum tuber yield. Excessive rain is deleterious to the crop. Cool climate during early growth period adversely affects the tuber initiation and also results in a prolonged vegetative phase.

Fertile, well drained, sandy loam soil is best suited for cultivation of yam bean. This crop adapts well to loamy and clay loam soil. It can tolerate a higher clay content if the soil is well drained with good humus content. Water logging adversely affects yam bean cultivation. Optimum soil pH requirement is 6.0 - 7.0.

Agronomic research in yam bean

Research work done so far on the Agronomy of yam bean has enabled the development of the following production technologies for yam bean cultivation in India:

Planting season, spacing, method and seed rate

Traditionally yam bean is sown during June-July with the onset of rain in North-Eastern India and is usually harvested in December-January (Varma *et al.*, 1996; Palaniswami and Shirly Raichal Anil, 2006). The time of sowing of seed varies from June to September according to the purpose of the crop. For seed purpose, seeds are sown during June-July at a spacing of 30 x 30 cm (Ravindran, 2000). If smaller size tubers are required, seeds may be sown in August-September at a closer spacing of 30 x 15 cm or even 15 x 15 cm. When the crop is sown late in September and harvested in December-January, it gives a comparatively lower yield due to smaller sized tubers. Tubers from this late crop are free from cracking and can fit well in various multiple cropping systems as it is a short duration crop. The ideal time of sowing yam bean was from September to middle of October, beyond which growth, tuber development and quality are reduced drastically due to lower temperature under gangetic alluvial zone (Sen *et al.* (1996). In Uttar Pradesh, the crop is sown during September to October. In Maharashtra, the plant population, when grown on ridges, was optimized at 1,33,000 per ha (Bhag Mal and Kawalkar, 1982). In field experiments conducted at CTCRI, Regional Centre, Bhubaneswar to study the effect of spacing on dry matter production and tuber yield, significantly highest dry matter production per plant (64.3 g) and tuber yield per plant (144.3 g) were recorded at 60 x 60 cm plant spacing. The spacing of 60 x 30 cm also produced reasonably good size tuber (109.8 g per plant) with moderate yield (4.62 t ha^{-1}) (Nedunzhiyan *et al.,* 2001).

Deep ploughing of land twice using a mould-board plough is essential. Plank the soil after each ploughing to have a well pulverised soil as well as to conserve moisture. A good tilth is required for yam bean cultivation. Yam bean seeds can be sown on hills at the rate of 3-5 seeds per hill. Hills are prepared at a spacing of 0.75 - 1.00 m with 15 cm height. Planting the seeds on ridges resulted in better yield (Ravindran, 2000).

Yam bean is usually raised by seed. The seed rate varies according to the spacing adopted. Normal seed rate is 20 - 60 kg ha^{-1} depending upon the time of sowing of seed, spacing and the purpose (Ravindran, 2000). In Uttar Pradesh, the seed rate recommended is 62-74 kg ha^{-1} (Srivastava *et al.*, 1973).

Nutrient management

Despite the earlier evidences that there is no need to supply additional N to this leguminous crop, many workers have found later that yam bean responded positively well to application of N fertilizer. Yam bean responds well to nitrogen application and 120 kg N ha^{-1} is optimum for both tuber and seed production (Nath *et al* 2007). Nutrient requirement is standardized for yam bean as FYM @ 15-20 MT or compost along with NPK @ 80:40:80 kg ha^{-1} under the aegis of AICRPTC centre at Rajendra Agricultural University, Dholi (North Bihar). Entire dose of P and K is applied as basal dose at the time of planting along with half dose of N and the remaining half dose of N is top dressed at 40-50 days after sowing along with interculturing and earthing up. A fertilizer dose of 80:60:80 kg N, P and K ha^{-1} is recommended for the state of Tamil Nadu (Ramaswamy *et al.,* 1980). In West Bengal, the maximum tuber yield was obtained with NPK @ 120:60:80 kg ha^{-1} (Sen and Mukhopadhyay, 1989). There is no significant influence of fertilizer application upon total soluble solid content of tubers. Higher levels of K (150 kg ha^{-1}) and split application reduced cracking of tubers and enhanced marketable grade tubers (Mishra *et al.,* 1993*).* However, either levels or methods of application of K could not affect the chemical constituents of yam bean tuber.

Reproductive pruning

Flowering in yam bean commenced from 58-68 days after sowing and lasted up to 92-103 days (Prasad and Prakash, 1973). Normally, yam bean starts flowering 75 days after sowing (Ravindran, 2000). For getting better tuber yield it is desirable to remove the flowers without allowing the plant to bear pods. There is significant negative correlation between tuber yield and pod formation. It is essential to remove the buds before they flower. Removal of buds by hand is the usual practice. Deflowering by spraying 2,4-D (50 ppm) at the flower initiation stage causes dehiscence of flowers and results in better yield of tubers (Mishra and Mishra, 1985; Ravindran, 2000). Manual deflowering is the most efficient up to 10 days after removal, but the efficiency steeply declined thereafter due to emergence of new flushes of flower buds (Panda and Sen, 1995). Highest mortality of flowers and thereby highest tuber yield was obtained by spraying NAA (1500 ppm) at flower bud initiation stage.

After care

Weed infestation is more in a June - August sown crop compared to September sown crop. The field is kept weed free by mulching the crop. Mulching also regulates soil temperature and conserves soil moisture. The first interculturing is done at 40 days after sowing and the remaining half dose of nitrogen is applied along with earthing up. Second weeding is done 30 days after the first weeding.

Irrigation

Normally, yam bean is grown as a rain-fed crop but one or two irrigations particularly in the drier months promote tuber development. Frequent irrigation with higher doses of fertilizer makes tubers more succulent and reduces keeping quality. Normally there is no need to irrigate a June-July crop. In case there is scarcity of rains, irrigation is necessary as yam bean requires adequate moisture. For September sown crop, supplementary irrigation increases tuberization.

Mulching is also practiced for conserving soil moisture under rainfed cultivation of yam bean. Paddy straw mulching encouraged branches per plant, total dry matter production, crop growth rate, average tuber weight and tuber yield (26.3 t ha^{-1}), 26.4 % more than rain-fed situation (Jana, 2005).

Cropping systems involving yam bean

In West Bengal, intercropping yam bean with pigeon pea in 3:1 proportion proved to be remunerative and generate highest net return and B:C ratio of 4.62 (Panda *et al.*, 2003). NK @ 80 kg ha^{-1} applied in two splits produced highest marketable tuber yield of yam bean and grain yield of pigeon pea (Panda *et al.* 2003). The residual effect was studied in the succeeding mung bean crop. For highest grain yield of succeeding mung bean, NK level of 100 kg ha^{-1} is required. In North Bihar, yam bean is intercropped with maize, where maize plants are utilized as trailing stand. But in other parts of India, normally trailing is not adopted for growing yam bean. Cowpea (fodder)-jute-yam bean, maize-rice- yam bean, sesame-rice-yam bean, green gram- upland taro- yam bean, green gram- elephant foot yam- yam bean and ground nut- rice-yam bean crop sequences are possible and yields of yam bean remained unaffected (Panda *et al.* 2003). Moreover the sequence cowpea (fodder)-jute-yam bean and ground nut- rice-yam bean improved the soil nutrient status. Kharif maize – yam bean – onion and kharif maize-yam bean- wheat + moong are feasible and economically viable cropping systems (Singh and Singh, 2008).

Harvesting

In India, yam bean is harvested at 150 days after sowing (DAS). But it can be harvested after 100 days according to the demand in the market and smaller sized tubers fetch better market price. However, optimum time of harvesting is 90 - 105 DAS in certain part of the country (Nedunzhiyan *et al.* 2001, 2002).

If harvesting is delayed, chances of cracking of tubers are more. This in turn results in the deterioration of tuber quality and thereby affecting market value. Shallow irrigation may be given just before digging the tubers manually. The above ground portions are trimmed before digging out the tubers. Harvested tubers can be stored for 2-3 days without any deterioration. If the tubers are stored for a longer period, the creamy colour of the skin changes to purplish brown and loses water, which causes reduction in weight. The harvest can also be delayed by leaving the crop in the soil without removing top portion. The seed crop is usually harvested 240 days after sowing *ie* during March-April. The seed pods are generally harvested when they start drying and beans obtained by beating the pods with sticks.

The average yield of local cultivars is 18-20 t ha^{-1} while that of improved varieties like Rajendra Mishrikand is 36-40 t ha^{-1}. With improved cultivation practices it is possible to get an yield of 40-45 t ha^{-1} and a net profit of Rs.12000-15000 ha^{-1} (One US $ = INR 50).

Pests and diseases management

No serious pests are reported in yam bean. Root rot and mosaic are the common diseases. Root rot (*Sclertotium rolfsii*) affects the crop under water logged conditions. Providing good drainage prevents the disease incidence. Use of disease free seeds and field sanitation reduces the mosaic incidence (Devadas, 2007). But when the crop is grown for seed purpose, pod borer becomes serious. Leaf blight in germ plasm accessions is reported (Jeeva, Personal communication).

Insecticidal properties of yam bean extract

Mature seeds of yam bean contain a toxic compound called rotenone ($C_{23}H_{22}O_6$) which has insecticidal properties. Detailed studies were conducted at CTCRI on the efficacy of yam bean seed extracts on various pests which are common on stored products of tropical tuber crops. Petroleum ether extract of yam bean seed (YBSE) 3% was effective against adults of *Sitophilus oryzae* and larvae and adults of *Tribolium castaneum.* Yam bean seed extract (@1%) resulted in high mortality (over 95%) at 5 DAT of field pests such as *Aphis craccivora* Koch (cowpea aphids), *Spilosoma obliqua* Walker (Bihar hairy caterpillar), *Spodoptera litura* Fabricius (army worm) and *Pericallia ricini* Fabricius (castor defoliator) (Jayaprakas, Personal communication).

Future thrust

Yam bean will be an important crop to meet the nutritional and fuel requirements in the near future. Hence more scientific knowledge has to be generated about the production and chemical constituents to exploit the potential of the crop. Yam bean is a leguminous tuber crop and its cultivation improves the soil fertility. The crop comes up well even under semi arid conditions and gives good tuber yield indicating that there is scope for extending its cultivation to non-traditional areas to improve the rural economy. All the wildest possible range of endangered land races of yam bean should be conserved both *in situ* and *ex situ*. Early maturing, high yielding varieties with improved nutritional qualities, resistance to biotic and abiotic stress is to be developed. Low cost crop management practices need to be standardized for high yield and quality of yam bean. There is need to study fatty acid composition of seed and processing technique for eliminating rotenone from seeds.

In India, the young tubers are consumed and other uses of the various plant parts especially that of pods are yet to be exploited as there is wide scope for it. Emphasis should be given to exploit yam bean pods on a commercial basis for production of rotenone based crop protective agents.

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Developing a strategic vision for the potato sector in the Andean region

André Devaux1, Miguel Ordinola2, Rubén Flores3, Alberic Hibon4, Jorge Andrade-Piedra5, Jorge Blajos6, Iván Reinoso7

[1]CIP/Papa Andina (a.devaux@cgiar.org); [2]INCOPA project (cip-incopa@cgiar.org); [3]OFIAGRO S.A. (ofiagro@andinanet.net); 4Consultant (ahibon@speedy.com.pe); [5]CIP/Papa Andina (j.andrade@cgiar.org); [6] PROINPA Foundation (j.blajos@proinpa.org); [7]*Programa de Papa*, INIAP (reinoso@fpapa.org.ec)

Abstract

The potato, particularly the highland native varieties, is a central element to families' and national economies in Bolivia, Ecuador and Peru. The Papa Andina Initiative from the International Potato Center (CIP) took advantage of the International Year of the Potato 2008 to promote, through an ample partners' network, the development of a strategic vision for the potato sector in the Andean region.

The building of this strategic vision was done in cooperation with PROINPA Foundation (Bolivia), the National Potato Program of the INIAP (Ecuador) and the INCOPA Project (Peru), and in coordination with public and private actors of the sector in each country. This process underwent the following steps: i) execution of an international diagnosis; ii) implementation of national surveys and analyses in Peru, Bolivia and Ecuador; iii) implementation of workshops to build up a joint strategic vision for the potato in each of the countries with the participation of the public and private actors within the potato production chain.

The partners in each country are using these results to support concrete undertakings for the development of the sector. In Peru, there have been promotional policies and technical regulation for the potato with an ample commitment from the public and private sectors. In Ecuador, as a main result of the strategic vision, a public fund of US $ 32 millions was approved by the Ministry of Agriculture to strengthen the potato sector. Bolivia is analyzing the development of a strategic vision as a methodological tool to support the development of the sector.

Keywords: production systems, strategic vision, potato value chain, native potatoes, policy incidence, Andes.

Introduction

Potato, and particularly its highland native varieties, is a central element to families' and national economies in Bolivia, Ecuador and Peru. The Swiss Agency for Development and Cooperation (SDC) and the International Potato Center (CIP), with the participation of national organizations of the potato sector in the three countries, have supported potato producers in the Andes for several years, with very encouraging results obtained, such as better income for producers through access to dynamic markets and a more equal participation in the market chain. In commercial terms, the first native potato based products have started to reach national and international markets.

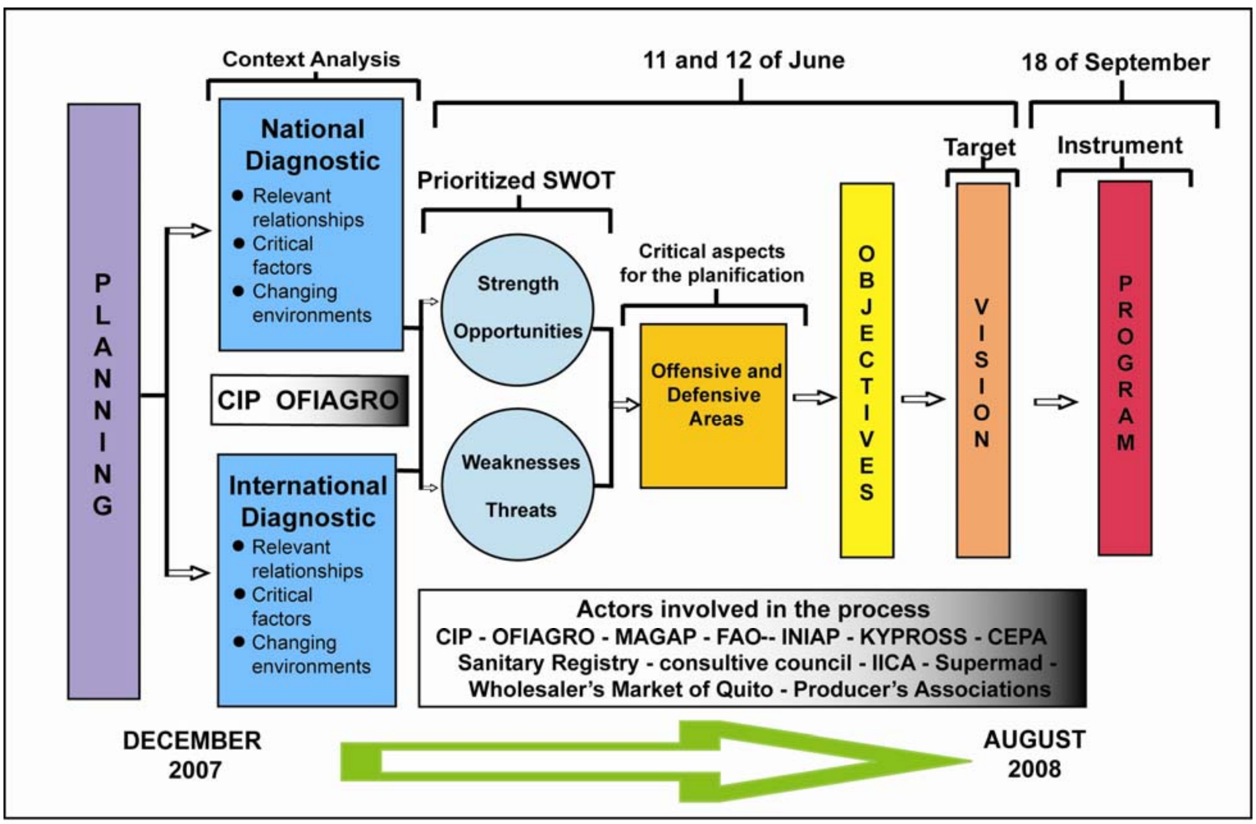
SDC has taken advantage of the celebration of the International Year of the Potato 2008 (AIP 2008) to promote, along with CIP, the potato sector in different areas, nationally as well as internationally. The CIP based Papa Andina Initiative and its partners (Proyecto *Innovación y Competitividad de la Papa*, INCOPA, from Perú; *Fundación para la Promo*ción e Investigación de Productos Andinos, PROINPA, from Bolivia; y el Instituto Nacional *Autónomo de Investigación Agropecuaria*, INIAP, from Ecuador) worked together to implement the project called "*Celebration of the International Year of the Potato (AIP) in the Andean Region*" with two objectives: (1) to implement a diagnostic of the potato sector in Boliva, Ecuador and Peru; support the participative development of a strategic vision for this sector and define priorities of action to strengthen it, and (2) to create and promote regionally, nationally and internationally, awareness about native potatoes and their culinary, cultural and economical potential for promoting development in the Andean region. This project was integrated to the strategy of Papa Andina Initiative, which is oriented to linking research with pro-poor innovation systems and making use of results and impacts to influence policy and set potato on the political agenda (Devaux et al., 2009)

Methodology

The work has been done according to a plan of action and a methodology devised by a regional consultancy firm, OFIAGRO. A strategic vision was developed in line with the following steps:

5. Implementation of an international diagnosis and analysis of the potato sector and its market development in the international context. The main idea was to show and analyze world trends in potato production and trade, and relate them to the Andean region context proposing possible implications for the development of the potato sector in this region.
6. As a second stage, national diagnostics of the potato sector in Peru, Bolivia and Ecuador were performed.
7. Finally, workshops were implemented with the participation of the potato sector's public and private stakeholders, supporting organizations and public entities such as the Ministry of Agriculture, in order to build a strategic vision.

The methodological process was adapted in each country according to the local context, local public policies and requirements that arose from participants during the participative process. But a general common methodology was adopted containing the following elements: A SWOT analysis (strengths, weaknesses, opportunities, and threats) was carried out and the strategic vision was formulated, including offensive and defensive issues, strategic areas to be worked out, and strategic objectives. A summary of the general methodology based upon the Ecuadorian experience is shown in the following graphic. The main strength was the participative approach that allowed working with a wide range of public and private partners.



Source: Rubén Flores (2008). OFIAGRO, Quito – Ecuador

Results

The potato in the Andean region

The potato crop contributes 7.4%, 11.0% and 10.0% of the agricultural Gross Domestic Product (GDP) in Ecuador, Peru and Bolivia respectively, equivalent to a total added value of 1 055.6 million US$ in 2006. It is estimated that there are more than 820,000 potato producers in the three countries, representing around 5% of the agricultural Economically Active Population, and more than 52 million workdays generated each year. In this sense, the potato is without a doubt one of the main labor and income sources in the rural Andes.

Regarding the production in these three countries during the period of 2002-2006, even if Peru fully exceeds both Boliva and Ecuador's production with 3,248,000 TM/per year, its rate seems to remain at this level while Ecuador's production continues growing at an annual rate of 2.0% and Bolivia's farming area cultivated with potato increases 1.5% annually. Although they represent the centre of origin of the potato, the three Andean countries together represent today only 1.38% of the world production and less than 2.3% of farmed area. In the same period, 2002-2006, 82.3% of the potato's world production was concentrated in Asia and Europe; with only five countries (China, Russia, India, the USA and Ukraine) representing 53.3% of world production. However, while the industrialized countries' production has fallen to -2.4% annually, developing countries' production has increased by 8.4% per year, with China and India as leaders. Potato yields in Bolivia, Ecuador and Peru are well under the world average (17.6 t/ha) and very far behind countries like New Zealand (45.7 t/ha), Belgium (43.9 t/ha) or the Netherlands (43.2 t/ha). There are many reasons –agronomical, climatic, socio-economical, and institutional- that may explain those differences.

The primary production of these three Andean countries is characterized by a great dispersion of agricultural areas and a great variability in production systems due to various factors: type of producers, ecological area, farming season, altitude, rural and urban consumers' preferences, weather conditions, access to technological innovation, types of organizations, training and access to credit. At the same time, the major proportion of potato production (90% or more in the three countries) is consumed unprocessed, which is why fresh potatoes are still a basic staple for the great majority of the poor population, particularly in the rural areas of the Andes, where there is no adequate infrastructure to store or process it. Fresh potato consumption per capita for the period of 2002-2006 was 31.8, 43.3 and 68.4 kg/per year in Ecuador, Bolivia and Peru, respectively, which exceeded the world average (36.5 kg/per year).

It should be noted that there are thousands of varieties of native potatoes, traditional and commercial, in the Andean zone of the three countries, the sub-species andigena, Curtilobum and Juzepczukii, being the most important ones, that have been preserved in-situ by small Andean farmers, along with white improved varieties of the sub-specie tuberosum, selected by national and international research programs. Although these native potatoes have a potentially lower yield than the improved white potato, they present several advantages in terms of production (tolerance to low temperatures and resistance to pests and diseases), in terms of processing (high starch content, less consumption of frying oil) and in terms of consumption (color, texture and flavor). These multiple attributes of native potatoes are highly valued by the small producers in the Andes and mitigate the multiple agricultural risks (freezing temperatures, hail and drought), phytosanitary threats and market conditions they face on a daily basis to ensure their food supply. Ultimately, **native potatoes are beginning to position themselves in urban market niches** with high purchasing power, processed as potato chips and snacks, and as ingredients with interesting gastronomic characteristics for gourmet food and "Novo Andina cuisine". This new tendency should benefit small Andean producers who will require better coordination with the market chain actors in order to respond to the interest of the target consumers for their product (and in the preservation of the environment and the biodiversity.)

Building process of the strategic vision performed in Ecuador, Peru and Bolivia

Ecuador. The process was coordinated by OFIAGRO and implemented with CIP-Papa Andina, INIAP, FAO, the Ministry of Agriculture (MAGAP, *Ministerio de Agricultura, Ganadería, Acuacultura y Pesca*), the Consortium of Smallholders Potato Farmers (CONPAPA) and several universities, which formed a committee to organize the IYP in Ecuador.

The strategic vision was based on the diagnostic previously done. The main conclusions of the diagnostic were that it was necessary to carry on several activities: (1) strengthen farmers' organizations; (2) improve access to technologies to reduce production costs, (3) increase productivity and reduce environmental and health impacts; (4) improve the relationships among potato market chain actors to reduce price fluctuations; (5) promote domestic consumption; and (6) consolidate potato supply within the country.

With this information, a workshop to construct the strategic vision for the potato sector in Ecuador was carried out following the methodology mentioned above. Thirty two people representing public and private organizations attended the meeting allowing for the identification of strategic areas to be worked out, and the strategic objectives

The diagnostic and the strategic vision were presented at a public meeting to celebrate the IYP in Ecuador (Quito, June 2008) in a positive political context, as the national government significantly increased its social investment, especially for the poorest sectors of Ecuadorian society. As a result of these efforts, a high official of MAGAP in charge of the highland region where potatoes are grown (*Subsecretaria de la Sierra*) decided to use the strategic vision as the basis for constructing an ambitious initiative: a Program to Strengthen the Potato Sector, focusing on low-resource smallholders. CIP-Papa Andina and OFIAGRO supported this initiative and coordinated its implementation. The public and private partners involved in the development of the strategic vision participated in the construction of this program.

A year later (June 2009), the same MAGAP authorities launched the program under the name "*Programa de Desarrollo Productivo y Fortalecimiento de la Cadena Agroalimentario de la Papa*". This program will be implemented by MAGAP over a period of 60 months, with a budget of US $6,720,630 supported by a complementary budget of $26,222,825 (through credits to smallholders farmers), and support to the following projects: (i) promotion and diffusion of information systems; (ii) promotion of scientific research and diffusion of adequate technologies; (iii) production and use of quality seed; (iv) strengthening the organization capacity and partnerships in the potato sector; (v) strengthening MAGAP's institutional capacity; and (vi) improving the participation of small-scale farmers in the marketing system.

In the case of Peru, the situation of the potato market chain was analyzed from different perspectives and a SWOT analysis carried out. The following themes were identified as requiring policy attention: i) revaluation of potato biodiversity and response to climate change threats; ii) orienting the market according to consumer needs; iii) promoting technological innovation as the basis of competitiveness; iv) implementation of innovative and differentiated strategies for commercial development; v) re-launching the potato's image nationally; vi) promoting different forms of entrepreneurial organizations and public-private alliances focusing on farmers' organizations.

In Peru, the First National Congress of the Potato "Science, art and business" was organized in the context of the International Year of the Potato 2008 in Huancayo. The congress objectives were to promote a process of knowledge sharing about scientific, productive, commercial, industrial and gastronomic experiences with the potato. After the congress, two additional events involving public and private actors of the potato sector were organized in close coordination with the Ministry of Agriculture and with the different institutions that were part of the Multisectoral Commission for the International Year of the Potato (IYP 2008).

The first event was the **"Entrepreneurial Meeting for the Development of the Potato Sector"** conducted in August 2008 calling together all the main entrepreneurial actors of the potato chain to discuss the present state, projections and the necessary policies to develop, from the entrepreneurial point of view, the potato sector in Peru. The Minister of Agriculture and his technical team related to policies of the potato sector attended the meeting, as well as 47 other people, mainly from the entrepreneurial sector.

Some of the most important private companies that are working in the potato sector analyzed the situation according to the following questions: i) what are the main potato products?; ii) what are the main problems facing these products; iii) what are the perspectives in the long term (10 years) for these products?; iv) what policies are considered necessary to stimulate entrepreneurial development for these products? With these inputs it was possible to obtain a matrix of various business plans and identify policies required to support the entrepreneurial sector linked to the potato sector in Peru.

The Workshop **"Elements for the Strategic Vision for the Potato Sector in Peru to 2015"** was the second event that was conducted in August 2008 aimed at defining priorities and strategies for the development of the potato market chain, taking as references the following aspects: production, processing, commercialization, research and development.

This meeting took advantage of the conclusions of the Entrepreneurial Meeting for the Development of the Potato Sector, the conclusions of the First National Congress of the Potato and information from the national and international diagnostics. Sixty three participants representing several organizations working in the potato sector (producers, ONGs, research centers, public institutions and cooking schools among others) attended the meeting. A SWOT exercise was run, defining the strategic vision and identifying strategic working areas, strategic objectives, action plans and budget.

As a result of the previous process, several actions were proposed for the potato sector, differentiating white potato and native ones including the yellow potato. These actions included technological, institutional and commercial areas based on the defined strategic objectives. With this input, the Ministry of Agriculture decided to develop several studies oriented to identify the competitiveness factors in promoting the potato sector: i) key factors to increase potato consumption in Peru; ii) market chains for French fries in Lima; iii) key factors to increase the use of high quality seed; iv) reception centers for potatoes to be marketed to urban markets in the Peruvian highlands and the need to support a new wholesale market in Lima. The details of these studies can be found on the following web page: http://www.minag.gob.pe/congreso-de-la-papa/congreso-de-la-papa/4.html

In **Bolivia**, the national diagnostic was completed with the PROINPA Foundation. It was shared with the *Ministerio de Desarrollo Rural, Agropecuario y Medio Ambiente* (MDRA and MA) for analysis and further comments before initiating the next steps in building and implementing the vision. The Ministry has prioritized the potato sector in the context of the creation of the *Instituto Nacional de Investigación Agraria y Forestal* (INIAF). A strategy to support the potato sector within INIAF based on a strategic vision has still to be defined.

Conclusions

The strategic vision exercise implemented in the Andean region has allowed the proposal of several priority areas requiring action for the development of the potato sector, such as: i) organizing the potato sector, promoting local consortiums that could converge in a national potato council playing a coordination role among the actors of the market chain and organizations supporting the potato sector, ii) developing lobbying abilities at producers, entrepreneurs and businessmen levels for policy influence in favor of the potato sector, iii) defining policies, programs and actions that would contribute to managing the risks generated by significant price fluctuations; iv) developing technologies adapted to the situation of each actor in the market chain to improve the efficiency of the potato production system in both the economic and environmental contexts.

The partners in each country are using the information generated in the process in coordination with the Ministry of Agriculture to propose concrete approaches for the development of the sector. In Peru, promotion policies and technical norms for the potato were promulgated indicating the commitment of the public and private sectors. Private investments were made to develop new potato based products and to build processing plants. In Ecuador, the strategic vision and the priorities identified have contributed to the development of a program supporting potato production and marketing systems with a public funding of $32 million. In Bolivia, building the vision of the potato sector is considered a methodological tool by INIAF to develop its strategy for this commodity.

The success in the case of Ecuador can be explained by the following reasons. First, the context has been favorable for the construction of a strategic vision for the potato sector, and for designing a program to implement it. The government has drastically increased its social investment and has a clear focus towards the poorest sectors of Ecuadorian society, including smallholder potato farmers. Secondly, there has been stability within public institutions, allowing continuity in the initiatives launched by CIP-Papa Andina and its partners. Thirdly, MAGAP has assumed a clear leadership in the process, inviting and stimulating private and public organizations to contribute to this initiative. Finally, small-scale potato farmers organized in the CONPAPA consortium have put pressure on national and local authorities to get tangible support, which shows the capacity of this farmers' organization for advocacy (Cavatassi et al., 2009).

A common factor in the three countries analyzed in this exercise is the instability of the authorities or public leaders who are responsible for making and assuming political decisions. It explains the diverse dynamics and the different levels of progress achieved in building the vision and its implementation in each country. But, undoubtedly, as it is a participative effort, the different actors motivated by this process, who are also the true implementers, are responsible for continuing the promotion and realization of these actions in support of the sector in the medium and long term.

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