Priorities for Potato Research in Developing Countries: Results of a Survey

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ABSTRACT

International institutions such as the International Potato Center (CIP) strive to provide "global public goods" in the form of improved technologies applicable to large regions of the developing world. To identify priorities for potato improvement, CIP conducted a survey of knowledgeable potato scientists in developing countries to elicit their perspectives on the most important constraints facing poor and small-scale potato growers in their countries. Respondents scored productivity or other constraints according to their importance in the region or country where they worked. Mean and weighted mean scores were estimated to provide a group judgment of the most important constraints facing potato farmers in developing countries. The five highest-ranking needs described by the survey respondents are: (1) control of late blight fungal disease (through varietal resistance and crop management); (2) improved genetic material for high and stable yield potential, suitable for consumption (new cultivars and prebreeding); (3) improved supply of quality potato seed (seed systems management and seed production); (4) control of viruses and their vectors (through varietal resistance, seed production and crop management); and (5) control of bacterial wilt (through varietal resistance and crop management). These five needs were ranked high in all or most of the potato-growing regions of Asia, Africa and Latin America. Exceptions were bacterial wilt control, which was a top-ranked need primarily in sub-Saharan Africa and east and southeast Asia, and virus control, which scored relatively low in Latin America. Priority rankings did not change when survey responses were weighted by potato area and poverty incidence of the country for which respondents reported.

RESUMEN

Instituciones internacionales tales como el Centro Internacional de la Papa (CIP) se esfuerzan en proveer "bienes públicos globales" en forma de tecnologías mejoradas aplicables a bastas regiones del mundo en desarrollo. Para identificar las prioridades para el mejoramiento de la papa, el CIP realizó una encuesta entre los científicos en papa de los países en desarrollo para conocer su opinión sobre los problemas más importantes que tienen que encarar los productores de papa pobres y en pequeña escala en sus respectivos países. Los entrevistados señalaron la productividad y otros inconvenientes de acuerdo a su importancia en la región o país. El promedio y peso de las respuestas fueron estimados para proporcionar un grupo de los problemas más importantes a los que tiene que enfrentarse el productor de papa en los países en desarrollo. Los que obtuvieron mayores puntajes de acuerdo a los que respondieron la encuesta son: (1) control de tizón tardío (por medio de resistencia varietal y manejo del cultivo); (2) material genético mejorado para el rendimiento potencial estable, apropiado para consumo (cultivares nuevos y pre-mejoramiento); (3) abastecimiento de semilla de papa de calidad (manejo de sistemas de semilla y su producción); (4) control de los virus y sus vectores (por medio de resistencia varietal, producción de semilla y manejo del cultivo); y (5) control de la marchitez bacteriana (a través de resistencia varietal y manejo del cultivo). Estos cinco necesidades

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fueron consideradas principales en todas o la mayoría de las regiones de cultivo de papa en Asia, África y América Latina. La excepción fue el control de la marchitez bacteriana, la cual alcanzó un alto puntaje principalmente en África subSahara y el este y sudeste asiático y el control de virus que alcanzó puntaje bajo en América Latina. El puntaje de prioridades no cambió cuando las respuestas se sopesaron en función de las respuestas por área de papa e incidencia de la pobreza en el país para el cual fueron las respuestas.

INTRODUCTION

As an international agricultural research center, the International Potato Center (CIP)[1] strives to provide global public goods in the form of improved agricultural technologies.[2] To help identify research priorities, CIP has periodically conducted surveys of persons knowledgeable about the constraints limiting potato productivity and value in developing countries (CIP 1984; Herrera and Scott 1992/93; Maldonado 1998; CIP 2004b). However, no comprehensive survey of potato productivity constraints in developing countries has been conducted since 1990[3], even though the role of the potato in developing countries has changed significantly over the past 15 years. China, already the largest producer in 1990, saw its annual production double during the 1990s, as did Sub-Saharan Africa. Even in Peru, the origin of the cultivated potato, two decades of declining potato cultivation was reversed during the 1990s, which saw that nation's potato crop nearly doubling as well.[4] Moreover, advances in biological and informational technologies have enhanced the prospects of using agricultural research as a means of improving potato productivity. In addition, with agreement on the Millennium Development Goals by the United Nations, the international community has given renewed emphasis to alleviating poverty, hunger, malnutrition, disease, and other dimensions of underdevelopment. Improving agricultural productivity in developing countries is an important part of this undertaking. For these reasons, in 2005 CIP launched a strategic planning exercise to revisit its priorities for potato research and development. As part of that exercise, CIP conducted a survey of knowledgeable potato scientists in developing countries to elicit their perspectives on the most important constraints facing poor and small-scale potato growers in their countries. The survey is an example of a "scoring model" for assessing research priorities (Ruttan 1982). In this approach, scientists score productivity and other constraints according to their importance in the region or country where they work. Scores are then averaged (with the option of assigning different weights to each response) and compared to get a group judgment of the most important priority ranking of constraints. Other approaches to research priority setting include quantitative models like yield gap assessment and economic welfare analysis (Ruttan 1982; Alston et al. 1995). The advantage of a qualitative scoring model is that its simplicity allows for wide participation by scientists with diverse backgrounds. In CIP's case, it was used to provide a "check" against an internal quantitative assessment of potato research priorities (Fuglie 2007) and a way for scientists from developing countries to weigh in on CIP's strategic planning process.

This paper reports the results of this survey and discusses implications for international potato research and development targeted for developing countries.

[1]CIP is a non-profit institution that conducts agricultural research, including potato improvement, to address food security, poverty, and sustainability of natural resources for developing countries. It was established in 1971 in Lima, Peru, and is supported by the Consultative Group for International Agricultural Research (CGIAR).

[2]The concept of a public good is one that could not be expected to be provided by the private sector. It is a good that is *freely available to all* and, as in the case of knowledge, *would not be diminished by use.* Therefore, the provision of public goods is usually the purview of government. However, many important social problems extended beyond national borders, and single nations may be unwilling or unable to provide such assistance in sufficient quantity. The CGIAR is an example of an international consortium being formed to address such a cross-national problem, in this case the under-supply of improved agricultural technology to developing countries (Gardner and Lesser 2003).

[3]The results of CIP's 1990 potato survey were partially reported in Herrera and Scott (1992/93) for Latin America and by Maldonado et al. (1998) for Asia. In 2004, CIP conducted a web-based survey on priorities for potato breeding and germplasm (CIP 2004b). Responses to the 2004 survey included breeders from both developed and developing countries, with few responses from Asia (although Asia accounts for about 80 percent of potato area in developing countries). Thus, this is the first survey of global potato research priorities for developing countries conducted since 1990.

[4]The reasons for the increasing importance of potato in developing countries are complex and varied. For discussions of factors behind the growth in potato production in developing countries, see Walker et al. (1999) and FAO (1995).

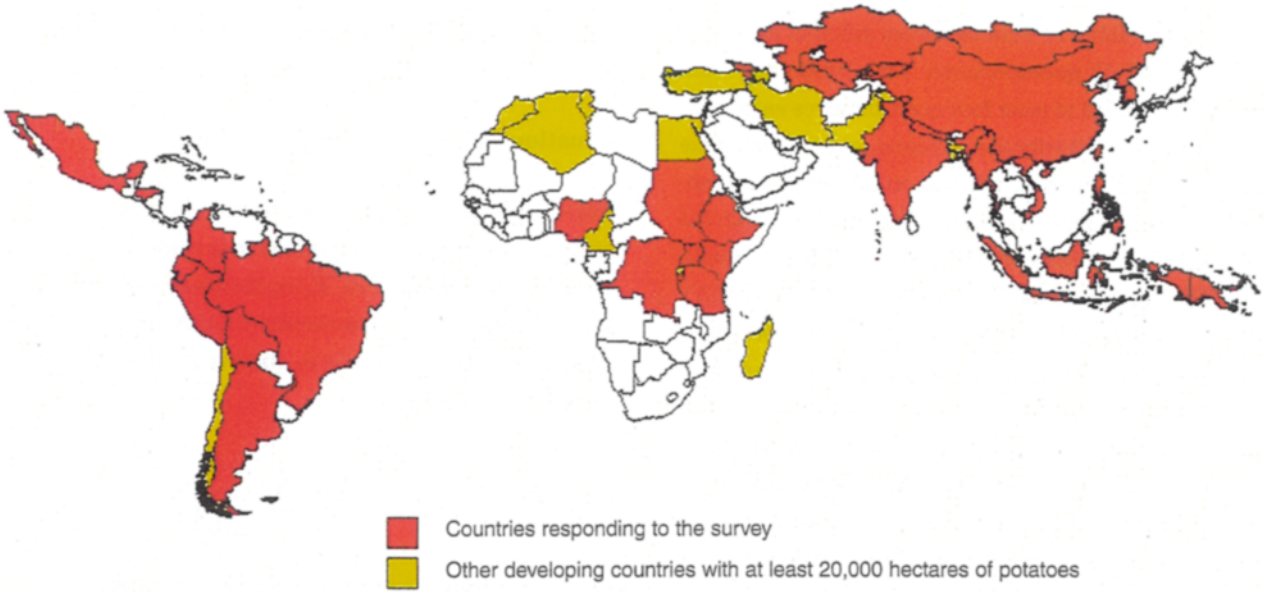

FIGURE 1.
Survey of priority needs of potato farmers in developing countries.

MATERIALS AND METHODS

Between September and November 2005, CIP sent 87 questionnaires to agricultural scientists in 46 developing countries to elicit their opinions on the most important constraints to productivity and value facing poor, small-scale farmers in their countries. The countries correspond to the regions where CIP is most active in collaborative research on potato improvement and include most developing countries where potato is an important crop, with the exception of North Africa and the Middle East.[5] The non-random sample was selected based on CIP's long history of collaboration with these countries. In each country, we at CIP attempted to identify the leading potato researchers and research institutions. In most cases they came from national research programs, although some were employed at agricultural universities, provincial research institutes, or in the private sector. For China, given the size and diversity of the country, questionnaires were sent to a number of provincial research institutes engaged in potato improvement. Survey respondents were also invited to pass on the questionnaire to other persons with extensive knowledge of potato in their country.

The questionnaire included sections for describing priority needs for crop improvement (breeding), vegetative propagation (seed), crop management (including pests, disease, soil and water), germplasm conservation, post-harvest utilization and marketing, impact assessment, and information technology. The survey questions refer to constraints on both farm productivity and crop value, as well as needs of the local potato research community (such as for improved access to potato germplasm and scientific information) for the region or country where the respondent was working. Respondents were asked to rank needs using a score of 1 (not important) to 4 (very important). In addition, respondents were asked to rank the role of CIP in addressing this constraint from 1 (not relevant) to 4 (very relevant). In the great majority of cases the scores for "importance" and "relevance" were similar, so only the scores for "importance" are reported here.

The questionnaire was translated into English, Spanish, Chinese and Russian and distributed by email. By the end of January 2006, 55 responses had been received from 33 countries (Figure 1). Twelve completed questionnaires were

[5]CIP had active research collaboration with North African and Middle Eastern countries throughout the 1970s and 1980s, but gradually reduced this work in the 1990s in order to concentrate more fully on poorer regions of the world. Following the breakup of the Soviet Union in 1989, CIP initiated research collaboration with some former Soviet Socialist Republics in Central Asia and the Caucasus.

received from Latin America, eight from Sub-Saharan Africa, and 35 from Asia (Table 1). Scientists from different provinces in China returned 12 questionnaires, while responses from other countries totaled at most four questionnaires each.

We tabulated the distribution of scores and calculated the mean score for each question using the entire sample and subsamples from four major regions: Latin America and the Caribbean (LAC), Sub-Saharan Africa (SSA), East and Southeast Asia (ESEA), and South, West and Central Asia (SWCA). In addition to simple mean scores, we estimated a weighted mean score by first calculating the mean score per country (in cases where multiple responses were received from a country) and then weighting each country mean score by the potato crop area and by a measure of the prevalence of poverty in that country. Potato crop area is the average annual area harvested between 2001 and 2003 (2005 FAOSTAT database, http://faostat.fao.org). Since we have a particular interest in identifying priority needs of potato growers living in regions with greatest poverty, we also estimated a weighted average score using crop area multiplied by the proportion of a country's population in extreme poverty (earning less than $1/capita/day). Poverty statistics are from the World Bank (2005 WDI On Line, https://publications.worldbank.org). The area x poverty rate weighted mean gives greater importance to countries with greater numbers of people growing potato and living in extreme poverty. Therefore, mean scores will be higher for constraints that are important in a large number of countries, and weighted mean scores will be higher for constraints that are important in large potato-producing countries with high incidences of poverty. While individual responses may well reflect priorities for a single region or country, the mean and weighted mean scores are meant to reflect priorities for international research organizations like CIP and the CGIAR, which seek to address common problems facing many countries or regions.

The formulas for calculating the mean and weighted-mean scores are as follows. The global mean score to question j, for example, is simply

Equation 1 $$\overline{X_j} = \sum_{i=1}^{N_j} \frac{X_{ij}}{N_j}$$

where Nj is the number of responses received to question j. Mean scores were also calculated for all responses received by country and by region. Let $\overline{X_{cj}}$ be the mean score to question j from all respondents from country c. Let A_c be the potato area and P_c be the poverty rate in country c. The area-weighted mean score is given by

Equation 2 $$\overline{X_j^a} = \sum_c \frac{A_c \overline{X_{cj}}}{\sum_c A_c},$$

and the (poverty x area)-weighted mean score is

Equation 3 $$\overline{X_j^{pa}} = \sum_c \frac{P_c A_c \overline{X_{cj}}}{\sum_c P_c A_c}$$

Again, weighted-mean scores were also calculated for each region.

Since the responses are categorical data, mean scores range from a possible minimum of 1.00 to a maximum of 4.00, with a higher score implying greater importance. Response rates varied by question since not all respondents answered all questions. Further, for several questions, such as on the importance of pests and diseases, respondents were asked to name the particular species important to potato farmers in their country. When several respondents mentioned a particular pest or disease, we report the mean score for those responses. We also calculated the standard error of the means. For most questions, standard errors are around 0.1, implying a 95% confidence interval around the mean score of 0.2. As a general rule of thumb, we view mean scores differing by more than 0.2 to be significantly apart. We grouped the needs into three broad categories (with about one-third of the survey questions in each group) depending on their overall ranking.

TABLE 1—*Questionnaires sent and received from potato scientists in developing countries.*

Region	Questionnaires sent	Countries sent	Questionnaires received	Countries received
Latin America and Caribbean (LAC)	18	12	12	8
Sub-Saharan Africa (SSA)	18	9	8	7
East and Southeast Asia (ESEA)	31	10	26	9
South, West and Central Asia (SWCA)	20	15	9	9
All	87	46	55	33

High priority needs are those that received a mean score of at least 3.40, medium priority needs are those with mean scores between 3.00 and 3.39, and relatively low priority needs are those with mean scores below 3.00.

RESULTS

We report the results from our survey in five sections. The first four sections report the unweighted rankings for priority needs by the entire sample and by respondents from each region. The fifth section examines how weighting the survey responses by national crop area and poverty rate affect the rankings for potato research priorities in these developing countries.

Priority Needs for Potato Crop Improvement

Table 2 shows the priority needs for potato crop improvement (breeding) reported by the survey respondents. The constraints are divided into separate categories for Yield and Quality, Biotic Stresses, Abiotic Stresses, and Environmental Adaptation. The first five columns of figures show the distribution of rankings given to each productivity constraint as well as the total number of responses to this question (out of a maximum of 55). This is followed by the mean score and its standard error for all responses and for each region separately.

Among all the listed needs for yield and quality, the need for stable and high-yielding varieties acceptable for the fresh market ranked first (mean score of 3.77 out of a maximum score of 4.00) and was indicated as a high priority in all regions. Prebreeding (genetic enhancement of parent material for use in national breeding programs) was also ranked relatively high in all regions. Many survey respondents also expressed a strong need for improved processing varieties, although this was generally lower than the need for varieties for direct consumption. Furthermore, improved varieties for processing appeared to be in greater demand from the LAC and ESEA regions than from SSA or SWCA regions, which corresponds to our knowledge of the relative maturity of the potato processing industry in these regions. Needs for high starch varieties and improved TPS progenies were ranked considerably less in importance compared with other needs for potato crop improvement.

TABLE 2—*Priority needs for potato crop improvement (breeding).*

	All Responses: Number of responses ranking importance (1 to 4)					All Regions		LAC	SSA	ESEA	SWCA
	1 Not important	2 Low importance	3 Important	4 Very important	Total responses	Mean rank	s.e. (mean)	Mean rank	Mean rank	Mean rank	Mean rank
YIELD and QUALITY											
Stable and high yield, consumer acceptance	0	0	12	41	53	3.77	0.06	3.70	4.00	3.73	3.78
Prebreeding	0	5	16	25	46	3.43	0.10	3.75	3.43	3.35	3.38
Processing quality	1	4	22	24	51	3.35	0.10	3.60	3.13	3.48	2.88
Starch or flour yield	5	17	14	14	50	2.74	0.14	2.11	2.38	3.12	2.63
TPS progenies	6	15	22	10	53	2.68	0.13	2.45	2.38	2.68	3.22
BIOTIC STRESSES											
Late blight	1	2	8	43	54	3.72	0.09	3.82	3.88	3.81	3.22
Viruses	0	5	19	27	51	3.43	0.09	2.89	3.25	3.52	3.89
Bacteria	1	7	19	23	50	3.28	0.11	2.60	3.71	3.58	2.89
Insects	1	10	18	24	53	3.23	0.12	3.67	3.14	3.08	3.11
Nematodes	13	13	12	9	47	2.36	0.16	3.00	1.71	2.45	1.88
Other biotic stresses	1	5	3	7	16	3.00	0.26				
ABIOTIC STRESSES											
Drought	5	8	14	24	51	3.12	0.14	3.20	2.67	3.15	3.22
Heat	6	14	14	16	50	2.80	0.15	2.70	2.67	2.69	3.38
Cold	8	14	18	9	49	2.57	0.14	3.00	1.83	2.54	2.67
Marginal soils	10	14	18	8	50	2.48	0.14	2.90	2.57	2.21	2.67
Other abiotic stresses	0	0	4	4	8	3.50	0.19				
ENVIRONMENTAL ADAPTATION											
Earliness	0	2	24	27	53	3.47	0.08	3.80	3.50	3.38	3.33
Seed dormancy	0	9	28	14	51	3.10	0.09	3.25	3.38	3.04	2.89
Long days	8	16	16	6	46	2.43	0.14	2.25	1.50	2.70	2.56

Source: Author's survey

Late blight (*Phytophtora infestans*) ranked as the highest priority biotic stress limiting potato productivity throughout the developing world. In fact, this need scored only slightly below the need for varieties with stable and high yield potential. Viruses were indicated as the second most important biotic stress. Viruses were especially important in Asia, although they did not appear to be a major constraint in Latin America. The most economically significant potato viruses in developing countries are thought to be PVY and the Potato Leaf Roll Virus (PLRV), while PVX is generally not important alone but very important in co-infection with PVY (Solomon-Blackburn and Barker 2001). Bacterial constraints ranked high in the SSA and ESEA regions and significantly lower in the LAC and SWCA regions. By far the most frequently named bacterial constraint was wilt (*Ralstonia solanacearum*) followed by soft rot (*Erwinia*). Bacterial wilt is a soil- and seed-borne disease that has proven difficult to control in developing countries. It was ranked as an especially important constraint in Sub-Saharan Africa. Recently, some new sources of resistance to bacterial wilt were discovered in CIP's germplasm collection (Priou et al. 2005), although breeding this resistance into cultivated varieties will likely take several years. Insect pests ranked above 3.00 in all four regions and were especially important in Latin America. However, there was considerable variation in the importance of pest species regionally. The potato tuber moth (*Phthorimaea operculella*, *Symmetrischema tangolias*, *Tecia solanivora* — the particular species varied by country) was the one insect pest named by respondents from all four regions. In the Andes countries (Colombia, Ecuador, Bolivia and Peru), the Andean potato weevil (*Premnotrypes spp.* Andean) was most highly ranked pest. Other insect pests named by several respondents included the leaf miner fly (*Liriomyza huidobrensis*) in Southeast Asia and Brazil, aphids (*Aphidoidae spp*) in Sub-Saharan Africa and Central Asia, and the Colorado potato beetle (*Leptinotarsa decemlineata*) in Central Asia and the Caucasus. Need for nematode-resistant varieties ranked relatively low in all regions except Latin America.

While growing concerns about climate change may be expected to give increased attention to abiotic stresses, our survey respondents generally gave lower scores to these stress compared with biotic stresses and the need for yield and quality. Across all countries in the survey, drought stress ranked the highest in this category (3.20), although heat stress ranked higher in South Asia. In South Asia, most potato is grown on the low-lying IndoGangetic plain during the cool season (November to March). An analysis of potential impacts of climate change found that this region was the most vulnerable potato-growing region in developing countries to a rise in global temperature (Hijmans 2003). Cold stress was indicated as an important constraint in some of the high-altitude Andes countries of Latin America. Drought stress was ranked high in China and Mongolia. Breeding varieties tolerant to marginal soils scored relatively low in importance.

For environmental adaptation, survey respondents from all regions expressed a strong need for earliness in potato varieties, which we interpret as early bulking. Earliness serves several purposes, including allowing for increases in cropping intensity, reducing the crop's exposure to pests and diseases, and in some cases allowing a farm family to harvest a crop during a "hungry period" in the seasonal crop cycle. Seed dormancy to fit the local cropping calendar was another important need expressed by survey respondents. The need for long-day adapted varieties was generally not important except in the southern cone countries of Latin America and in central and northern Asia and the Caucasus.

TABLE 3—*Priority needs for potato seed improvement.*

	All Responses										
	Number of responses ranking importance (1 to 4)										
	1	2	3	4		All Regions		LAC	SSA	ESEA	SWCA
	Not important	Low importance	Important	Very important	Total responses	Mean rank	s.e. (mean)	Mean rank	Mean rank	Mean rank	Mean rank
Seed production management	0	0	13	40	53	3.75	0.06	3.64	4.00	3.84	3.44
Seed systems management and policy	0	1	14	36	51	3.69	0.07	3.88	3.75	3.65	3.56
Seed storage	1	7	22	23	53	3.26	0.10	2.82	3.50	3.36	3.33
TPS propagation	5	12	24	11	52	2.79	0.12	2.40	2.38	2.84	3.44
Other	0	1	1	2	4	3.25	0.48				

Source: Author's survey

Priority Needs for Potato Propagation (Seed)

As a vegetatively reproduced crop, seed availability and seed quality inevitably rank high on the list of priority needs for the potato crop. The lack of appropriate seed management methods or access to improved seed is often particularly severe for poor, small-scale farmers in developing countries. In our survey, respondents were asked to score the importance of four different types of seed needs: (a) seed production, which includes technologies for rapid multiplication and disease elimination as well as farm production and management of retained seed, (b) seed systems management and policy, such as seed certification and distribution systems, (c) the use of TPS as an alternative to clonal seed, and (d) seed storage.

The need for improved seed production methods was expressed as an important or very important need by all of our survey respondents (Table 3). This need received the maximum possible score of 4.00 from all of the respondents from Sub-Saharan African countries. It was also the highest-ranked need among all questions in the survey in the ESEA region, where it received a score of 3.84. These two regions have also experienced the most rapid growth in potato planting area over the past 15 years, which could partly explain why quality planting material appears to be in especially high demand in these regions. But improving potato seed quality and quantity are not only about improving techniques in seed production. Survey respondents ranked high the need for better management of the entire seed system, including improving seed policy and regulation. The lack of seed storage methods suitable for small-scale farmers was indicated as an important constraint in Sub-Saharan Africa and Asia. The need for better TPS propagation methods ranked lowest among the seed questions, although it scored relatively high in the SWCA countries. I return to the seed question again in the crop management section below.

Priority Needs for Potato Crop Management

Closely related to crop and seed improvement, but encompassing a broader set of technology options, are needs for improved management of soils, pests and diseases. This could include new methods of field cultivation, tillage and application of fertilizer and pesticide as well as the use of improved seed and varieties. Our survey focused on identifying the key productivity constraints that respondents thought could be addressed through research on improved crop man-

TABLE 4—*Priority needs for potato crop management.*

	All Responses: Number of responses ranking importance (1 to 4)					All Regions		LAC	SSA	ESEA	SWCA
	1 Not important	2 Low importance	3 Important	4 Very important	Total responses	Mean rank	s.e. (mean)	Mean rank	Mean rank	Mean rank	Mean rank
DISEASE CONTROL AND MANAGEMENT											
Late blight	2	0	7	44	53	3.75	0.09	3.80	4.00	3.81	3.33
Viruses	1	3	19	29	52	3.46	0.10	2.89	3.50	3.58	3.67
Bacteria	1	4	15	28	48	3.46	0.11	3.11	3.88	3.68	2.89
Bacterial wilt	1	4	16	27	48	3.44	0.11	3.11	3.88	3.64	2.89
Other fungal diseases	4	6	26	9	45	2.89	0.12	3.38	3.00	2.77	2.67
PEST CONTROL AND MANAGEMENT											
Insects	0	4	16	33	53	3.55	0.09	3.64	3.38	3.48	3.78
Aphids	0	3	26	18	47	3.32	0.09	2.75	3.38	3.48	3.38
Potato tuber moths	7	10	17	16	50	2.84	0.15	3.50	2.88	2.50	3.00
Leaf miner fly	11	14	16	7	48	2.40	0.15	2.67	1.50	2.54	2.57
Colorado potato beetle	21	13	5	7	46	1.96	0.16	2.11	1.63	1.50	3.11
Andean potato weevil	26	9	6	6	47	1.83	0.16	3.00	1.13	1.62	1.63
Nematodes	11	13	14	12	50	2.54	0.15	3.30	1.71	2.50	2.44
PRODUCTION AND RESOURCE MANAGEMENT											
Soil fertility	0	3	17	32	52	3.56	0.08	3.64	3.88	3.50	3.33
Cropping systems	1	8	22	22	53	3.23	0.11	3.27	3.38	3.31	2.75
Soil erosion	1	7	24	20	52	3.21	0.10	3.60	2.75	3.24	3.11
Water management	2	5	33	13	53	3.08	0.10	3.30	2.75	3.12	3.00
Harvesting methods	3	24	11	13	51	2.67	0.13	3.13	2.63	2.65	2.33
Soil salinity	3	11	11	2	27	2.44	0.15	2.33	1.00	2.63	2.00
Soil acidity	7	20	22	3	52	2.40	0.11	2.50	2.63	2.40	2.11
Other	1	1	1	3	6	3.00	0.52				

Source: Author's survey

agement, but not on identifying the specific components of those technologies per se. The priority rankings for three crop management categories (Disease Control and Management, Pest Control and Management, and Production and Resource Management) are shown in Table 4.

Improved management of late blight again ranked as the overall greatest need in potato crop management by survey respondents. It also ranked as the most important need in each region except SWCA, where it was ranked second behind the need for improved management of potato viruses and aphids, an important virus vector. The need for improved control of virus diseases and aphid pests also ranked high in Sub-Saharan Africa and Asia but was not indicated as a major problem in Latin America. Improved control of bacterial wilt ranked only slightly behind viruses. But bacterial wilt was primarily viewed as a problem in SSA and ESEA and not as a major problem in the other regions. Other bacterial and fungal diseases mentioned as important in some countries include early blight (*Alternaria sp.*) especially in SSA, bacterial soft rot (*Erwinia*) in Southeast Asia and LAC, and *Fusarium* primarily in SSA and LAC.

For crop pests, improved management of aphids was ranked as the most important need in all regions except Latin America. In developing countries, aphids are primarily a vector for spreading viruses like PLRV but do not cause much crop damage directly. Thus, the high ranking given for improved aphid control should be considered together with the high importance given to virus-resistant varieties in the first section and to disease-free quality seed in the second section above. Survey respondents appear to be expressing two or three different strategies for reducing yield losses from viruses. One strategy is through resistant varieties, another is through formal seed systems providing virus-free seed, and perhaps a third is a way for farmers to better manage their own seed production. In developed countries, effective certified

TABLE 5—*Other priority needs for potato development.*

	All Responses: Number of responses ranking importance (1 to 4)					All Regions		LAC	SSA	ESEA	SWCA
	1 Not important	2 Low importance	3 Important	4 Very important	Total responses	Mean rank	s.e. (mean)	Mean rank	Mean rank	Mean rank	Mean rank
GENETIC RESOURCES											
Characterization	0	3	24	26	53	3.43	0.08	3.55	3.50	3.48	3.11
Ex situ conservation	1	1	26	23	51	3.39	0.09	3.45	3.50	3.46	3.00
Intellectual Property Rights management	0	8	24	18	50	3.20	0.10	3.40	2.86	3.17	3.33
In situ conservation	0	0	8	6	14	3.43	0.14	3.56		3.25	
Other	0	0	3	2	5	3.40	0.24				
POST-HARVEST AND MARKETING											
Marketing systems	0	4	21	26	51	3.43	0.09	3.70	3.38	3.36	3.38
New product development	1	6	24	19	50	3.22	0.10	3.50	3.13	3.21	3.00
Ware storage	2	6	23	20	51	3.20	0.11	2.67	3.38	3.32	3.22
Reforming food and agricultural policy	0	9	24	16	49	3.14	0.10	3.30	3.29	3.13	2.88
Other	0	1	0	2	3	3.33	0.67				
IMPACT ASSESSMENT											
Technology impact on poverty	1	2	22	23	48	3.40	0.10	3.55	3.29	3.38	3.33
Health and environmental risk of pesticides	1	5	21	20	47	3.28	0.11	3.20	3.00	3.38	3.33
Economic returns to research	1	7	27	13	48	3.08	0.10	3.36	3.29	2.95	2.89
Other	0	0	1	3	4	3.75	0.25				
INFORMATION AND COMMUNICATION SKILLS											
Capacities in information and communication	0	6	18	22	46	3.35	0.10	3.33	3.67	3.36	3.11
Communicating to target audiences	0	3	26	18	47	3.32	0.09	3.30	3.50	3.36	3.11
Internet-based learning modules	0	8	21	18	47	3.21	0.11	3.00	3.17	3.27	3.33
Other	0	1	0	4	5	3.60	0.40				

Source: Author's survey

seed systems have been developed to eliminate the virus problem from potato production, but for institutional and climatic reasons such systems have proven difficult to establish in developing countries (Crissman 1990; Fuglie et al. 2006). For countries where large-scale production of virus-free seed is not practicable, the development of virus-resistant varieties presents a viable alternative for reducing virus losses (Walker 1994).

Needs for improved management of other insect and nematode pests tended to be regionally specific. The potato tuber moth (*P. operculella*) was the only insect pest mentioned as important in all regions. Nematodes (*Nacobbus aberrans*, *Globodera sp*, and *Meloidogyne*) and potato tuber moths (*P. operculella* and *T. solanivora*) were highly-ranked pests in LAC, as was the Andean potato weevil in Andean mountain countries. The leaf miner fly (*Liriomyza huidobrensi*) was mentioned as an important pest in Indonesia, the Philippines and Brazil. Although the Colorado potato beetle was only an important pest in the Caucasus and Central Asian countries, it will probably migrate into northeastern Asia within the next decade and could become a more significant pest for the millions of potato farmers in that part of the world.

The Production and Resource Management section of the survey included a number of questions on soil and water management, as well as management of cropping systems and harvesting methods. Improved management of soil fertility to optimize potato production was identified as a high priority by survey respondents from all regions in our survey. Improved management of potato cropping systems was ranked relatively high in all regions except SWCA, although the lower ranking in SWCA hides important differences within the region. Respondents from South Asia (India and Nepal) scored the need for improved cropping systems high (3.50 mean score) while respondents from central Asian and Caucasus countries ranked this need lower (2.50 mean score). In many regions of the developing world, potato is grown in multiple cropping systems in rotation with other vegetable or cereal crops. Where farm size is declining with population growth and where irrigation is expanding, cropping systems are often increasing in intensity (more harvests per year), and the survey respondents may be expressing the need for improved management and optimization of these rapidly evolving systems. The third most important need in this section was improved control of soil erosion. This is especially critical for highland potato-growing areas such as in the Andes region and Southeast Asia. Improved water management was important to the LAC Region, where potato is usually grown without irrigation. Improvement in harvesting methods and management of problem soils (high acidity and salinity) were indicated as having relatively minor importance in the survey.

Other Priorities for Potato Improvement

In the survey we asked respondents to rank a number of other issues related to improvement of potato productivity in their countries, including genetic resource management, post-harvest crop utilization and marketing constraints, the need for evidence of impact of potato technology and research investments, and the need for strengthening the capacity of potato research and extension organizations in information and communication technologies and methods. Responses to these questions are summarized in Table 5.

Improved characterization and *ex situ* conservation of potato genetic resources were ranked as an important needs in every region. Strengthening the capacity to manage Intellectual Property Rights to national potato genetic resources was important, especially in Latin America, the origin of the potato, as was *in situ* conservation. *In situ* conservation was also mentioned as important by respondents from northern China but was ranked low by respondents from other areas.

Improvement in potato marketing systems was the most important post-harvest need. Marketing margins and seasonal price fluctuations are generally high for potatoes in developing countries, especially in regions with poorly developed farm-to-market infrastructure. Research on potato marketing in developing countries has found that high marketing margins are more often the result of high marketing costs rather than high profits of market traders (Scott [1981] has provided a classic study of potato marketing in Peru). High seasonal price fluctuations are closely related to lack of timely market information and poor storage conditions (Fuglie 2002). Poorly functioning marketing systems were an especially important concern in Latin America, as was the need for developing new potato products. Given historically high per capita potato consumption in Latin America, especially in the Andes countries, the need for new products may reflect a stronger demand-side constraint relative to other parts of the developing world. Other important post-harvest needs included improved methods for ware storage, and in some countries, policy reform.

Most survey respondents felt a need for more evidence of impact of potato technology adoption on poverty alleviation.

While there have been a number of case studies documenting high economic returns to public investments in potato research in developing countries (Walker and Crissman 1996; Walker et al. 2003), the evidence of impact on poverty alleviation is weaker. A recent review of the impact of CIP-related potato technology in Asia suggested that the effects on poverty are likely to have been significant, especially in interior provinces of China where there has been significant adoption of modern varieties and where poverty rates have historically been high (Fuglie 2006). Survey respondents also viewed as important the need for more impact assessment of the health and environmental risks of pesticide use on potatoes. The potato crop is among the highest user of pesticides of any food crop in developing countries, and research in Ecuador has shown that health and environmental risks of pesticide exposure can be significant (Crissman et al. 1994).

Survey respondents expressed general needs for upgrading the skills of the potato research and development community in utilizing information and communication technology (ICT). The highest rankings for ICT needs were given by respondents from Sub-Saharan Africa. Stronger capacity to use internet-based learning modules was important, but ranked lower than the need for more general training in ICT in all regions except SWCA.

Effect of Weighting Survey Responses by National Crop Area and Poverty on Ranking Priorities

The renewed emphasis given to poverty reduction by the international community (expressed, for example, in the United Nations declaration of the Millennium Development Goals to halve the world's poverty rate by 2020) has led the international agricultural research community to search for ways to bring the benefits of agricultural science more directly to the very poor (e.g., CIP 2004a). But is there a "pro-poor" research strategy specifically focused on the needs of low-income potato farmers? One way to try to identify a "pro-poor" research strategy is to give priority attention to the constraints faced by large numbers of small-scale farmers in very poor countries or regions. Thus, weighting the country-average responses by the potato area and poverty rate of that country may give different global mean rankings of farmer needs than would the simple average scores reported above. In Table 6, we list the priorities of small-scale farmers according to the weighted and unweighted mean scores assigned by survey respondents to each constraint. Due to space constraints, only the needs with at least one mean score at or above 3.00 are included in Table 6.

Introducing area and poverty weights in calculating the mean scores for priority rankings did not have much effect on the priority rankings for all developing countries. Weighting the scores mainly tended to result in even higher scores to the already top-ranked needs. Regardless of the weighting scheme, the need for higher and stable yielding varieties, the need for technologies to control and manage late blight and viruses, and the need for improvements to potato seed systems ranked as most important in our survey. There were a few issues, however, that received a significantly different score when weighted by poverty x area. The needs that increased the most in importance using weighted mean scores were variety resistance to bacterial disease (especially *Ralstonia solanacearum*), potato ware storage, management of viruses, and drought tolerance. Issues that fell significantly in importance using weighted means included cold tolerance and nematode resistance, which were already scored relatively low. The poverty x area weighting tended to give somewhat stronger importance to priorities identified for Asia and Africa and less importance to priorities in Latin America, due to the greater potato area and poverty incidence in the former regions.

What does this suggest for the content of a "pro-poor" development agenda for potato? One issue is whether or not the technologies to address these needs are accessible to farmers who may have few financial resources and only grow potato on very small plots. Most of the technologies identified in the survey appear to be scale-neutral, meaning that they could be profitably adopted by farmers growing very small potato plots as well as by large-scale potato growers. While the high input cost associated with growing potato is often expressed as a constraint facing poor farm households, in fact potato is widely grown by very poor households throughout the developing world, if only on a very small scale. Scale-neutral technologies that further reduce those costs (e.g., by increasing yield per unit of input applied) are likely to make potato even more profitable for such farmers. Another issue is whether or not increases in farm productivity would actually translate into higher incomes for farmers. There is the possibility that increases in productivity, if adopted widely, could lead to over-supply and a corresponding fall in market price, thereby reducing income benefits of new technologies to farm-

ers. However, in most developing countries potato is considered a high-value and high-profit crop with strong and elastic market demand. The relatively low rankings given to needs for post-harvest value addition suggest that survey respondents saw increasing the productivity of low-income potato farmers as a viable pathway out of poverty. Nevertheless, formal economic models are probably necessary to examine linkages between increased potato productivity and poverty alleviation with more rigor. A recent attempt has been made to develop such a model for potato in developing countries (Fuglie 2007). Survey respondents expressed an important need for more formal studies on the effects of adoption of improved potato technology on poverty reduction.

TABLE 6—*Priority needs for potato research for poverty reduction in developing countries.*

	Poverty x Area weighted		Area weighted		Unweighted	
Priority	Mean rank	Priority Group	Mean rank	Priority Group	Mean rank	Priority Group
CROP IMPROVEMENT						
Stable & high yield, consumer acceptance	3.90	1	3.87	1	3.77	1
Late blight resistance	3.89	1	3.83	1	3.72	1
Bacterial resistance	3.70	1	3.53	1	3.28	2
Virus resistance	3.61	1	3.61	1	3.43	1
Processing quality	3.60	1	3.58	1	3.35	2
Prebreeding	3.53	1	3.50	1	3.43	1
Insect resistance	3.38	2	3.30	2	3.22	2
Drought tolerance	3.38	2	3.45	1	3.12	2
Earliness	3.26	2	3.35	2	3.47	1
Seed dormancy	3.08	2	3.11	2	3.10	2
Starch or flour yield	2.99	3	3.08	2	2.74	3
SEED & PROPAGATION						
Seed systems management	3.81	1	3.80	1	3.69	1
Seed production management	3.63	1	3.73	1	3.75	1
Seed storage	3.35	2	3.33	2	3.26	2
CROP MANAGEMENT						
Late blight	3.97	1	3.93	1	3.75	1
Viruses	3.78	1	3.77	1	3.46	1
Insects	3.57	1	3.52	1	3.55	1
Cropping systems	3.48	1	3.37	2	3.23	2
Soil fertility	3.44	1	3.48	1	3.56	1
Bacteria	3.43	1	3.41	1	3.46	1
Water management	3.18	2	3.20	2	3.08	2
Other fungal diseases	3.13	2	3.13	2	2.89	3
Soil erosion	3.05	2	3.20	2	3.21	2
GENETIC RESOURCES						
Characterization	3.65	1	3.61	1	3.43	1
Ex situ conservation	3.38	2	3.44	1	3.39	2
Intellectual Property Rights management	3.34	2	3.30	2	3.20	2
POST-HARVEST & MARKETING						
Ware storage	3.50	1	3.35	2	3.20	2
Marketing systems	3.48	1	3.43	1	3.43	1
Reforming food & agricultural policy	3.19	2	3.21	2	3.14	2
New product development	3.03	2	3.09	2	3.22	2
IMPACT ASSESSMENT						
Technology impact on poverty	3.63	1	3.51	1	3.40	1
Health and environmental risk of pesticides	3.26	2	3.39	2	3.28	2
Economic returns to research	3.07	2	3.02	2	3.08	2
INFORMATION & COMMUNICATION TECHNOLOGY						
Capacities in information & communication	3.31	2	3.33	2	3.35	2
Communicating to target audiences	3.26	2	3.30	2	3.32	2
Internet-based learning modules	3.18	2	3.22	2	3.21	2

Source: Author's survey. Crop area harvested from FAO (2005 FAOSTAT database, http://faostat.fao.org); poverty data is from the World Bank (2005 WDI On Line, https://publications.worldbank.org).

CONCLUSIONS

The scoring model used to derive priorities for potato improvement in developing countries proved to be a relatively low-cost method of canvassing a wide spectrum of views from knowledgeable experts of the crop. Response rates were undoubtedly enhanced by the translation of the survey into four major languages and the widespread access to electronic communications by the global agricultural research community.

Using either weighted or unweighted mean scores, the five highest-ranked needs of low-income potato farmers in developing countries as described by the survey respondents were as follows:

1. Control of late blight fungal disease (through varietal resistance and crop management);
2. Improved genetic material, suitable for consumption, with high and stable yield potential (new cultivars and prebreeding);
3. Improved supply of quality potato seed (seed systems management and seed production);
4. Control of viruses and their vectors (through varietal resistance, seed production and crop management);
5. Control of bacterial wilt (through varietal resistance and crop management).

These five needs were ranked high in all or most of the potato-growing regions of Asia, Africa and Latin America. Exceptions included bacterial wilt control, which was a top-ranked need primarily in Sub-Saharan Africa and East and Southeast Asia, and virus control, which scored relatively low in Latin America.

Other high-ranking needs included improved varieties suitable for processing, improved management of insect pests, cropping systems and soil fertility, and improved marketing systems and ware storage methods. Although insect pest management was ranked high generally, the importance of specific species varied considerably from one region to another. Other top-ranked global priorities included supporting the potato research community through improved characterization of potato genetic resources and better evidence of the impact of potato technology adoption on poverty reduction.

The priority needs identified in this survey are largely consistent with results from previous surveys conducted by CIP on potato research priorities as well as economic assessments that estimated potential benefits from research investments. In a web-based survey of potato breeders conducted by CIP in 2004, respondents from developing and developed countries listed yield, late blight resistance and virus resistance as their three top breeding priorities (CIP 2004b). A survey of potato scientists from developing countries conducted by CIP in 1990 found (a) seed, (b) integrated disease management (especially of virus and fungal diseases), (c) integrated pest management, (d) management of cropping systems, and (e) improvement of marketing systems as the highest priority needs of developing countries.[6] Finally, an economic model of potential impacts of potato research on developing countries found that the largest potential benefits are likely to come from improved control of late blight and virus disease and improved supply of quality seed (Fuglie 2007).

Thus, there appears to be a broad consensus on the most important priorities for the potato research community to meet the needs of low-income potato farmers in developing countries. Nevertheless, this should not exclude exploration of new and creative ways for using the tools of agricultural science to address the needs of low-income farming households. One such example was suggested by a survey respondent from China, Dr. Fengyi Wang, who added this comment to his completed questionnaire:

> "In southern China, there is a huge potential of potato production in winter cropping. After late rice, the field is empty during winter season. Before, local farmers used to grow spring wheat, but they stopped because of low market price. However, price of potato is so good in early spring, so farmers like to grow potato after late rice. But lower temperature would come even for a very short period during potato growing. If we have some special varieties that can be tolerant lower temperature, such as 0 or -2 C°, for a short time, it would be helpful for winter cropping of potatoes."

In other words, with further adaptation of the potato to new cropping systems and environments, great potential probably remains for further area expansion. The tremendous growth in potato production that has occurred in recent decades in developing countries attests to the significant role that the potato crop has played in meeting the food and income needs of the world's poorest and fastest-growing populations. Further improvements to the potato made through research to address the needs expressed by the survey respondents will no doubt help this crop continue to make significant

[6] This is based on analysis of unpublished survey responses from 29 countries. Results of this survey from 14 Latin American countries were published in Herrera and Scott (1992/93), and results from 14 Asian and Pacific countries were reported in Maldonado et al. (1998).

contributions to improving the livelihoods of small farm households in developing countries.

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