Rootcrops as Food, Feed and Industrial Materials: The Challenge to Address Their Production and Post-harvest Needs

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Abstract

The objective of this paper is twofold: first, to introduce the group of starchy underground storage organ-producing crops known as root and tuber crops or simply rootcrops, whose importance and prospects are not yet fully understood; and second, to pose a challenge to all concerned in the global agricultural science community, particularly those from the Graduate School of Bioagricultural Sciences of Nagoya University, to give attention to research on these crops in order to contribute fully in securing food supply for scores of millions of people the world over. Suggestions are, likewise presented on how the concerned scientists and experts could respond to the call for action, as well as, the essential changes that need to be in place in order for them to have relevant contributions in increasing regional and global food supply. Generally, the world food situation is abating and the picture for Asia is not different. Agricultural science education failed to bolster sustainable agriculture and food security measures because it could not respond well to the needs and expectations of the farmers since it either lagged behind in the developing countries or it advanced too much in the developed ones. A number of physical factors, however, contribute to this food supply shortfall. One of these is the continuing reduction in the supply of water in many areas of the world. Rootcrops grow and produce economic yield where other crops may fail; hence these crops are expected to play a key role in reducing hunger and poverty. The task to increase and sustain rootcrop production is rather a tall order. There are simply a lot of things to consider and many main and sub research avenues to be attended to. Involvement of as many players as possible is therefore required, and participatory research or collaborative undertaking is seen as the best possible approach at the moment. Scientists and researchers in the developed countries like Japan are looked up to engage in this concerted activity. However, certain adjustments have to be instituted so that relevant interventions could be extended from their end. Foremost of this is a paradigm shift to be followed by changes in outlook and approaches in the way research is conceptualized and undertaken, giving way for some freedom and flexibility.

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Introduction

The significance of rootcrops

Rootcrops, in layman's terms, mean the group of crops, otherwise known as root and tuber crops, which produce underground tubers or corms. Common among these crops are cassava (*Manihot esculenta*); sweetpotato (*Ipomoea batatas*); potato (*Solanum tuberusum*); and yams (*Dioscorea esculenta*), which constitute the so-called major rootcrops. Others, which are classified as minor rootcrops are the edible aroids (taro, *Colocasia esculenta*; yautia, *Xanthosoma sagittifolium*; giant taro, *Alocasia macrorrhiza*; swamp taro, *Cyrtosperma chamissonis*; elephant foot yam, *Amophophallus campanulatus*) and the lesser yams (*Dioscorea alata, D. bulbifera, D. hispida*).

While the major rootcrops are cultivated in a large extent globally, occupying around 50 million hectares (Scott et al., 2000), the edible aroids and the lesser yams are considered minor rootcrops chiefly because they are of lesser importance in terms of total production and commercial demand. However, some of these crops may have a special function in the food system in certain countries or regions so that they are produced in greater extent than those identified as major rootcrops. A good example of this is taro, which is planted in large scale in many South Pacific countries, being a staple food and an export item (Iosefa and Rogers, 1999).

In 1995-97 farmers produce 639 million tons of cassava, potato, sweet potato and yams annually which was valued more than US$41 billion or about one-fourth that of the value of the major cereals (Scott et al., 2000). The production of these crops is mostly in Asia, Africa and Latin America where the greater demand is for food. It is a fact that where poverty is prevalent, rootcrops are widely planted though production efficiency in these areas may be low. In the Philippines alone, rootcrops, which are grown in a broad range of agro-ecological condition, have a significant function in providing food security and livelihood among the resource poor people living in fragile upland environment, which comprise about 65% of the total agricultural land in the country (Pardales and Roa, 2001). In the global scene, the picture is not different at all, in that rootcrops are typically a small farmer crops and are the basic sources of their food and cash resource (Alexandratos, 1995); the crops being tolerant to adverse growing condition and low input-farming practice compared to other food crops. In relation to this, Scott et al. (2000) had this to say…

"*Root and tubers deserve particular attention because many of the developing world's poorest and most food insecure households look to these crops as a contributing, if not the principal, source of food, nutrition and cash income. Among other things, farm households see the value of roots and tubers in their ability to produce more edible energy per hectare per day than other commodities and in their capacity to generate yields under conditions where other crops may fail.*"

The prospects of rootcrops

The paper containing the above-quoted statements and other information cited earlier, entitled " Roots and tubers in the global food system: A vision statement to the year 2020," provide a very comprehensive picture of the present and the future of root and tuber crops. Ordinarily, however, these crops are grown for household or village-level use where they are utilized as food, feed or processed into starch for domestic needs (Wheatley et al., 1995; Horton, 1988). However, current trends show that what has been a traditional use of root crops, particularly cassava and sweet potato, in the household such as feed for backyard-raised livestock, is expanding and being practiced in a wider scale at present. In China and Vietnam and other parts of the world sweet potato is becoming a popular crop that is used as pig and other livestock feed, which provides high returns (CIP, 2000; Scott, 1992). In a developed country like Japan sweet potato has been identified to offer an array of utilization possibilities such as source of starch, flour, food colorants, and protein and enzyme which have high potential as ingredient for medicine (Yamakawa, 1998) while research on processing the crop into novel products is ongoing in some research centers (Tamaru, 1998).

Cassava, on the other hand, had become a vital export commodity of Thailand to the European Union (EU) as animal feed besides being processed into the global market, the starch in many other parts of the world. In demand for cassava chips (*tapioca*) in 1999 was about 6 million tons (ASEAN, 2000).

However, with food shortages common in many parts of the world, the future of cassava lies on the fact that it is identified by the Food and Agriculture Organization (FAO) and the International Fund for Agricultural Development (IFAD) as a crop that can help reduce hunger and poverty in many parts of the developing world. The crop is a basic staple to 500 million people in the tropics and sub-tropics besides being a source of livelihood to millions of farmers, processors and traders around the world (FAO, 2000a).

Of the potential of root and tubers in the years to come, Scott et al. (2000) said the following:

"Root and tuber crops have myriad and complex roles to play in feeding the world in the coming decades. Far from being one sort of crop that serves one specific purpose, they will be many things to many – very many people. By 2020, roots and tubers will be integrated into emerging markets through the efficient and environmentally sound production of a diversified range of high-quality, competitive products for food, feed and industry. These crops' adaptation to marginal environments, their contribution to household food security, and their great flexibility in mixed farming systems make them an important component of a targeted strategy that seeks to improve the welfare of the rural poor and to link smallholder farmers with these emerging growth markets. We estimate that by 2020 well over two billion people in Asia, Africa and Latin America will use root and tubers for food, feed and income. Many of these people will be among the poorest of the poor."

Rootcrops Production System

Being generally associated with poverty, rootcrops are therefore customarily planted as subsistent crops in many parts of the world. The subsistent rootcrops growers are smallholder and resource-poor farmers who grow the crops principally for food. They utilize degraded upland areas that are usually not their own, and normally of less than 0.25 hectare. Subsistent rootcrop production system is devoid of technological applications utilizing only traditional varieties of rootcrops and simple crop care and management practices (Pardales et al. 2001). On one hand, this is primarily because they do not have the resources to comply with what is required for intensive rootcrop cultivation. On the other hand, to some extent, they are being taken for granted, including their indigenous knowledge system, by scientists and extension workers (Pardales et al., 2001). For many years, institutional scientists thought that the small, economically deprived farmers readily embrace whatever production technology is introduced to them. This high-minded attitude had resulted in the introduction of crop production technologies that were not suitable to the environmental and biophysical condition of a certain area, as well as to the socio-cultural mind set of the local people (Pardales and Yamauchi, 1999; Pardales et al., 2001). In one way or another, this also solidified the farmers' hesitation against subsequent external intervention.

The other production systems in which rootcrops are grown are semi-commercial and commercial. In the former, rootcrops are planted in larger tracts of land, usually ranging from 0.25-0.50 hectare, which are commonly situated in sloping to hilly areas (Pardales and Roa, 2001). Semi-commercial rootcrop production is established principally with two intentions, that is, for food and income. Much importance is given to the food requirement of the household while the desire for income is only subsidiary and realized only if crop yield is more than what the household could consume. The farmers engaged in semi-commercial rootcrop farming are normally a bit sophisticated than the subsistent ones, in that, they experiment on the use of some technological innovations like growing recommended varieties and using certain crop care and management practices but almost always in comparison with their customary varieties and cultivation procedures (Pardales and de Guzman, 2001). In relation with the subsistent farmers, the semi-commercial rootcrop growers have likewise a system of knowledge, which may not differ at all from that of their subsistent counterparts. Their production systems have a lot of things in common like the location and characteristics of their farms (terrain and ecological condition), cropping system involving the use of other crops, use of their proceeds, etc. Their social interaction is frequent considering the fact that they both go to the same local market where they sell their products and derive their household needs.

The commercial rootcrop production, on the other hand, is almost 100% for the industry although in the Philippines this may also be 100% for the fresh market in metropolitan areas (Data et al., 1997). The farmers attending to this production system are usually resource-rich and are profit oriented. They are highly dependent on technological innovations and interventions for increased field output (Pardales et al., 2001), hence, their need for technical backstopping from research institutions. Pardales and Roa (2001) mentioned that commercial rootcrop production system is high on application of new technological innovations and interventions where the complete package of recommended cultural management practices for the crops are keenly followed.

World Food Situation and the Role of Rootcrops in Meeting Food Demand

The current condition

Pinstrup-Andersen and co-workers (1997) in their food policy report presented their assessment of the prospects for global food security in the next quarter century. Among the important things they emphasized was the following…

"Between 1993 and 2020, global demand for cereals is projected to increase by 41% and for meat by 63%. Most of the increase in demand is expected to occur in the developing countries. In many of these countries, however, food production is unlikely to keep the pace with the jumps in demand. The "food gap" – the difference between production and demand for food – could more than double in the developing world in the next 25 years. This food gap will have to be filled through increased imports. This should not be case for alarm for the higher-income developing countries, but the poorer countries might not be able to import food in needed quantities. Likewise, even when the low-priced food is available in the marketplace, many poor people might not be able to afford the food they need."

FAO (2000b) estimated that 826 million people around the world still do not have enough food to eat even at the present time when there is said to be an abundance. This FAO report also cites that 792 million in developing nations and another 34 million in industrialized countries were undernourished during the period 1996-98. Singh (2000) reported that the Asia-Pacific region alone is home to two-thirds of the world's undernourished people and in terms of real number this is a staggering 515.2 million. In a separate communiqué, FAO (FAO, 2002a) reported that the food production in Asia is indeed declining. In January 2002 the estimated drop in cereal production (rice, wheat and coarse grains) was 989.3 million tons based on what had been realized during the preceding year. This shortfall in food production was attributed to adverse weather conditions and economic decline in many developing countries.

Drought is probably the most serious factor affecting crop production among the stresses related to weather condition. FAO (2000b) had in fact launched several initiatives to help the Near East countries (e.g. Iran, Iraq, Jordan, Syria, Pakistan, etc.) fight drought and desertification. FAO (2000c) had therefore cautioned all concerned that the great global challenge for the coming years will be on how to produce more food with less water. In recent years many parts of the world have experienced long-term dry spells, the most popular of which is the one being brought about by the El Niño phenomenon, which takes place in almost regular occurrence. Probably because of the crops' known ability to tolerate adverse growing condition (Cock, 1985) IFAD and FAO (FAO, 2000a) organized a forum on tropical rootcrops, which approved a global action plan and a cassava development strategy, basically to position the crop as a key commodity in reducing hunger and poverty. Kim et al., (2002) pointed out that cassava has many advantages over cereal crops in that it is tolerant to drought, pests and degraded soils. On a broader context, however, Scott et al (2000b) had these to say:

"Future prospects for the role of roots and tubers in the global food system will be greatly influenced by various demographic, economic, political and environmental trends." "Our analysis suggests that many of these trends will stimulate growers and consumers to produce and consume more root and tubers in new ways, for new uses, and using new technology."

"The largest absolute increase in root and tuber production will take place in Sub-Saharan Africa (cassava and yam, primarily) under both scenarios. China will account for the bulk of additional sweet potato output, and both China and India are projected to harvest two-thirds or more of the additional potatoes produced. Furthermore, increases in root and tuber production will be driven by demand for food in the case of potato (both fresh and processed) and yam. Processed food products such as noodles made from starch and non-food uses such as feed will be much more important for cassava and sweet potato."

Food security and sustainable agriculture: What now?

The decade of the 1980s ushered hopes to the millions of food hungry people in the world through unprecedented initiatives of many institutions, which were indications then that great things were forthcoming. One of the ideas that surfaced and was well received by people of different walks of life, i.e., farmers, policy makers, experts, consumers, and others was sustainable agriculture. This concept rested on the principle that the needs of the present generation must be met without compromising the ability of future generations to meet their own needs (Feenstra et al., 1997). Hence, the matter of cooperation of all people concerned including those in the academe is a prime imperative. Simply put, sustainable agriculture is the responsibility of all participants in the whole agriculture system. While this concept or practice may have brought dividends in economically commercial crops, in rootcrops and other crops of less economic value for that matter, this concept until now is still a much talked about issue but seemed unrealizable. More often than not, each player is to his own and the focus is diffused. In the developing world sustainable agriculture is far from reach. In the developed one it rests in the theoretical minds.

In the middle of the 1980s, the food security idea sprung up and lots of definition were coined. The implication was that all people should have access to food at all times not just for survival but also for continued active participation in the society. In a commissioned paper, Hall (non-dated) mentioned that:

"A country and people are food secure when their food system operates in such a way as to remove the fear that there will not be enough to eat. In particular, food security will be achieved when the poor and vulnerable, particularly the women and children and those living in marginal areas, have access to the food they want."

What happened? FAO (2000b) clearly stated that the food insecurity in the world shows no progress towards world food summit target. Taking away physical reasons aside like changing climatic patterns, it is believed that one of the reasons for the failure of sustainable agriculture and food security measures in much of the developing world is that agricultural science education could not fully respond to the current needs and expectations of the agricultural producers. Either it lagged behind in the developing countries or it advanced rigidly too far in the developed ones that researchers became inconsiderate of anything less challenging and non-popular. In addition, Atchoarena and Gasperini (2002) had the opinion that the contents and delivery process of agricultural education have been generally isolated from other ongoing processes of education and training within the rural environment.

Elements and Process of Mitigation On the Food Production and Utilization Problems

Pardales and Yamauchi (1999) presented a so called "domain interaction approach" in developing technologies or finding solution to nagging agricultural production problems in the field. Basically, this idea came about as experiences of technology failures of PhilRootcrops, a government research institution in the Philippines, came one after another with the farmers, the so-called "end users of technology," passively complaining of the non-practicability and non-usefulness of the technologies introduced to them. Pardales et al. (2001) pointed out that the basic reason why recommended technologies did not work out well with the farmers was that they were not involved in the development of the technologies. In the case of the sweet potato varieties developed through conventional breeding by PhilRootcrops scientists and introduced into a certain locality, these varieties did not last long in the farmers field because they were too sweet and watery, bushy in growth stature so that they were prone to weed competition, and not tolerant to limited water supply, pest infestation and degraded soil condition. Pardales et al. (2001) had this observation:

"Experiences with rootcrop production technology failures across practically all classes of rootcrop farmers brought up the following points which necessarily call for alternative ways of developing technologies and introducing them to end users:

- *Researchers/scientists have no monopoly on technological ideas and innovative practices. They cannot impose something on farmers because in the end it is the farmers themselves that determine what is best for them.*
- *Merely letting the farmers view and make judgment on introduced technologies or innovations is not sufficient and does not guarantee adoption of technologies.*
- *Unless the farmers clearly understand the principles behind a certain technology they cannot appreciate the need for its methodological application."*

Having the ways and means of producing crops as the focus of attention in increasing food availability, it becomes imperative that all involved players of the agricultural activity (i.e., the scientists, extension workers farmers) have to consider the element of participation or collaboration as pivotal point in the technology development – technology transfer – technology adoption cycle. Nevertheless, it should be taken into account that the whole process has to be viewed by all players from the same vantage point to cultivate a sense of sensibility towards interdependence and cooperation.

Participatory research is one area where the traditional players in the technology continuum could come together for a more meaningful and shared undertakings in looking for a solution of a certain field crop production problem. As a research approach, participatory research is a methodological strategy, which recognizes the critical contributions (i.e., practices, attitudes, skills, knowledge, motivations) of the different stakeholders of an undertaking (Pardales et al., 2001). Furthermore, it is a process that is highly dependent on skills of facilitation and an open mind-set of those involved. Out of their experiences in piloting a farmer field school on sweet potato integrated crop management, the same workers (Pardales et al., 2000) presented the beneficial outcomes of participatory research with farmers as follows:

- *Saving on resources. Whether participation is among technical researchers or between researchers and farmers or processors, financial, material or physical resources can be shared.*
- *Enriched knowledge system. The blend or integration of indigenous or local knowledge and the technical or scientific knowledge brings about sustainability in the application of a certain technology. This is because the farmers develop a sense of co-ownership of the ideas or technology.*
- *Immediate application of developed or improved technology. Because the farmers are partners in technology development or improvement they need no further convincing as to the appropriateness, practicality or efficiency of a certain agricultural practice. Being key players in the innovation process, others in the locality look up to them as authoritative example of*

development, thus, adopting any agricultural intervention easily.

- *Capacity building. In participatory research the farmers gain skill and knowledge in comparing and evaluating different ideas or practices themselves. This process of judging out ideas or practices which include seeing, discovering and reasoning develops the farmers capacity to analyze, thereby making them capacitated to solve field problems effectively. On the part of the researchers, working in partnership with farmers introduces them to action research, which give them broader perspective of the real condition in the field and the need to consider various issues in working out technological interventions and innovative systems. Furthermore, participatory research or extension enriches the technical or academic preparations of a researcher for formal instruction and training.*
- *Scaling up. That participatory research is one good approach to solve local field problems with local people being part of the problem-solving process has the potential of becoming a participatory community development. The practice could be adopted through an experienced and capacitated local farmer who can lead others to be engaged in participatory diagnosis and analysis of certain problems.*

While scientist-farmer participatory activity may be considered a vital relationship to bring a change in the way agriculture related field problems are studied, scientist-scientist technical collaboration also brings positive dividends. The paper of Pardales and Yamauchi (1999) also cites the fact that collaborative undertaking on certain area of research, no matter how small the fund or short the duration is, could lead to the discovery of many things – simple scientific explanations they may be. These facts could then pave the way for broader scientific understanding and technology development. Basic research information could lead to the formulation of recommended practices or development of novel technologies. To alleviate the abating food production elsewhere in the world, it is suggested that an elemental framework of intervention by all concerned be followed, taking into account the domain interaction approach of technology development brought up by Pardales and Yamauchi (1999) (Fig. 1).

In other words, the critical strategic element in attempting to alleviate an alarming declining world food situation is establishing an atmosphere of participative or collaborative undertakings among the concerned. For rootcrops whose versatility, significance and potential in many aspects is well recognized (Scott et al. 2000a; Scott et al., 2000b), there is a need for greater interest and attention from various sectors in the scientific and agriculture community to critically study their production, storage, processing, utilization, status and problem

(Wheatley et al., 1995). Rice is one crop whose production capacity had been pushed up because of scientific breakthroughs as a result of heightened collaborative interest of many international, national and local institutions and researchers (Pardales and Yamauchi, 1999).

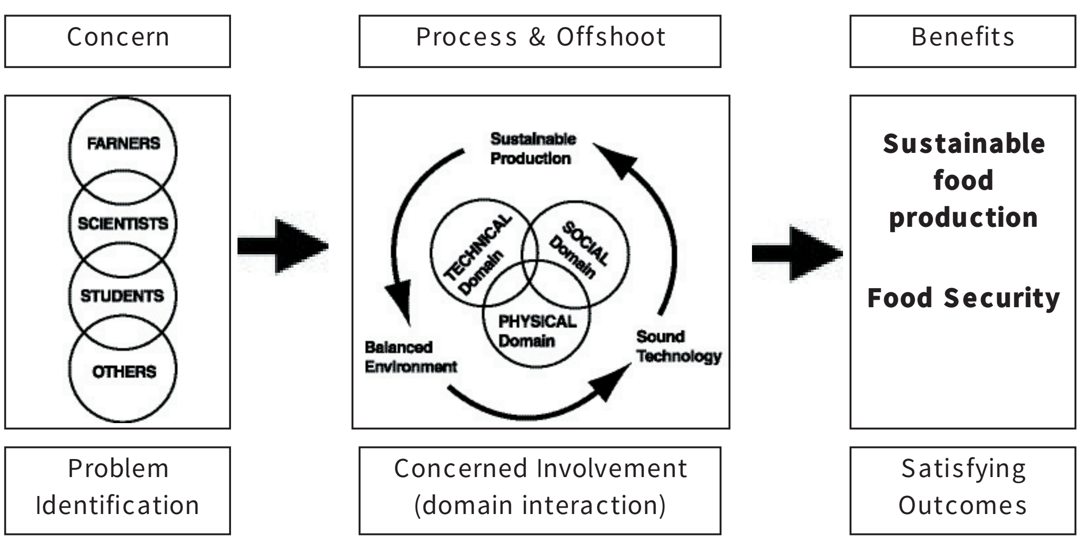

Fig 1. Elemental framework of intervention in mitigating the problem of declining regional and global food production adopting the domain interaction approach of technology development as the process.

Academic Adjustments to Meet Challenges in Securing Regional and Global Food Supply

The case of Nagoya University: Previous observation

Observation and experience had it that many, if not all, academic laboratories in the former School of Agriculture in Nagoya University (presently the School of Agricultural Sciences) undertake research on certain crops or animals based on either of the two considerations: interest of the professors-scientists, or interest of the agency giving funds for the research. The crop of interest by the professors-scientists is studied in the laboratory by the scientists themselves and their students if the source of research fund gives freedom to the researchers in terms of the crop that they could work on. On the other hand, the latter is pursued if the agency giving research funds has the say on the crop that the laboratory has to particularly deal with. At present the way the object (plant or animal) of the study is selected in the different laboratories of the School of Agricultural Sciences may not actually deviate much from the old custom since the long established system of research funding remains practically the same.

Basically, there is nothing wrong with the system, which has been the tradition for scores of years now, but the practice portrays a strictly limited or restricted view of looking at underlying problems or issues having to do with food supply problem mitigation. This is duly because the conduct of research by academic laboratories hinges solely on either the personal academic interest of scientists or the corporate concern of the funding institutions rather than giving some degree of attention to the interest of farmers and other agricultural players. More often than not, research results and concomitant information are especially packaged to fill pages of technical journals to satisfy high-end consumers who themselves are scientists and academicians who may have very limited contact likewise with farmers, food processors, etc. The present situation of declining food production right in Asia (FAO, 2000a) should be a cause for alarm so that research attention and efforts should be directed towards the prevailing factors that constrain sufficient and sustainable food production (Pardales and Yamauchi, 1999).

The need for a paradigm shift: A suggestion

Significant contribution to improve the world food situation warrants that resources, interest and outlook be shared among agricultural stakeholders wherever they may come from. This could mean that the well-funded, laboratory-entrenched agricultural scientists in developed countries like Japan have to reconsider their way (objective and method) of pursuing research - from being personally motivated, academically driven, passive and single-minded into problem-based, broadminded, proactive and forward looking kind of researcher. The paradigm shift that is advocated in this paper is the change from the long established tradition of carrying out experiments based on one's personal desire for enlightenment on certain scientific riddles to engaging in collaborative or participative research with partners from outside his normal domain, be they from other countries or regions. This could only be done if scientists reach out to others (scientists, extension workers, farmers, etc) to engage in discussion and exchange of ideas on certain pervading issues affecting regional or global agriculture, if only to alleviate the economic condition, improve the production system, and secure the food supply base of the greater majority of the people in the long run, who are resource poor, vulnerable, and food insecure. Furthermore, the paradigm shift here could also mean adjustments in ones interest, say from rice to rootcrops, from soil fertility to natural resources, etc. The whole thing calls for flexibility and openness of everyone involved.

A paper by Nabangchang (2001) classified agricultural research into *supply-driven* and *demand-driven*. The former kind of research, which is the conventional approach, identifies the research agenda based on pre-conceived notions of scientists as to what is needed by farmers or technology users. Pardales and Yamauchi (1999) considered this as a "know it all" attitude of scientists. In contrast, the latter kind of research, necessitates that research agenda be identified by the end users of the technology themselves (the farmers commonly) since they are the ones who know what they need to understand or have. In his attempt to present the merits of the demand-driven research, Nabangchang (2001) stated the following in furtherance:

"The desirability of the shift from supply-driven to demand-driven research is based on observed shortcomings of the former in four main aspects, namely: (i) the tendency to extract the research

activities from social, physical and environmental context into a more laboratory-controlled environment, (ii) the monopoly of research by scientists, specialists, academics at the expense of the exclusion of the farmers who, in many respects, are the most experienced field experts and are therefore prime resource persons, (iii) the probability of the incompatibility of research results and the physical environment, (iv) the tendency of treat of adoption of technology as given through failure to recognize the farmers' economic perspectives as he weighs and balances the costs and benefits and all risk factors involved in adoption of new technology."

Other adjustments to be done: A view from outside

The intrinsic system in typical Japanese academic laboratories is the seeming lack of flexibility of the students to work something out on their own. It is a common practice that professors decide on what research problem their students would pursue. By and large, this kind of arrangement is not a problem with the students. Besides the fact that this is customary, students enjoy the privilege of having their laboratory and related needs covered by the research fund of their professors. This system may be ideal in developed countries where the applied technological needs of its agricultural producers are taken care of by the governmental research institutions and the academe covers the basic aspects of scientific investigations. In a way, however, this is being centrist and without regard for what is happening around, and what the needs of the people are in the region or other parts of the globe. This may be viewed as *self preservation* or *academic survivalist* on the part of the resource-rich scientist by their counterparts in the developing countries who are vulnerable to food insecurities simply because they cannot do so much for reason of lack of necessary resources and technical capabilities to some extent (Pardales and Yamauchi, 1999).

The staggering situation of the world food supply (FAO, 2000b; 2002a) and the opportunities and prospects that other crops like rootcrops could offer (FAO, 2000a; Scott et al, 2000a; 2000b) therefore calls for the agricultural scientists and students in developed countries to be *sensitive* to explicitly consider the problems of food production especially in countries having poor and erratic food production performance. Academics and students must be keen of what is happening in the global or regional agriculture arena. They must both be observant of the issues and concerns of agriculture for the rest of the world. They must be flexible and bold to venture into different realms of research. They must be ready to leave their laboratories occasionally to work with partners (not as subordinates, not as mere recipient of technical aids, but as equals) in foreign lands where the greater food production problems are usually realized.

Academics must also be more vocal in rationalizing the necessity that research-funding agencies give funds for studies on crops other than what are considered economic priority crops of Japan. It is a great relief though that the way of thinking of some funding agencies is slowly changing towards the positive side of this.

For instance, the Japanese Ministry of Education, Science and Culture (Monbusho), has started a few years ago in approving research grants to the Laboratory of Crops Science, and presently the Bioresources Cycling Laboratory (BCL) of the Graduate School of Bioagricultural Sciences for studies centered on rootcrops. These grants paved the way for certain Japanese scientists to engage in collaborative work with some foreign researchers. The case in focus could be the latter laboratory's (BCL) collaboration with the Philippine Root Crop Research and Training Center (PhilRootcrops) in studying the drought resistant mechanisms of rootcrops, which is in accordance with FAO's challenge to combat drought and produce more food with less water (FAO, 2002b; 2002c).

Research Avenues on Rootcrops to Bolster its Role as Food, Feed and Industrial Materials

While limiting their viewpoint on participatory research with farmers in developing agricultural technology, Pardales et al., (2001) included some activities where participatory research may have greater application. Considering the greater challenge of the present in the light of food security apprehensions, the same activities could be considered as the avenues over which participatory research or collaborative works on rootcrops could be made to strengthen their position in meeting the demand for food, feed and industrial raw materials. These research avenues are as follows:

- *Development of new rootcrop varieties.*

While the farmers as producers and consumers at the same time have their specific requirements in a variety of certain rootcrops, the needs of the greater majority of the people and the industry on a global context may be entirely different. In view of this, breeding strategies may need to be an issue for participative discussion by as many stakeholders as possible especially if the breeding process requires techniques beyond conventional methods or support activities that are not within the means of one laboratory or institution. An example of this could be the breeding for high anthocyanin content in sweet potato for the food coloring industry (Odake, 1998) or for the emerging health food business (Kays and Kays, 1998), or simply to improve the nourishment of the greater majority of the people who are resource poor and depend on sweetpotato as primary food item for their households (Scott et al., 2000a).

The fact that rootcrops is eaten by scores of millions of people around the world and the greater number of this are from Asia, the bigger challenge in tailoring new rootcrop varieties is in improving their nutritive content since rootcrops are normally low in basic nutritional composition (Bradbury, 1988; Wheatley et al., 1995). Basically, this is a research area that necessitates the use of advance tools in biotechnology so as to shorten the breeding process and to win the race against time to avert undernourishment of some 515.2 million people in Asia-Pacific alone (Singh, 2000).

The other areas whereby specific participatory or collaborative research may be done along this main research avenue are as follows:

- o Genetic resources evaluation.
- o High starch content.
- o Resistance to pests and disease organisms.
- o Resistance to environmental stress factors.
- o Early maturation.
- o Resistance to post-harvest deterioration.
- o Non-conventional breeding approaches.

• *Improvement and/or development of production and post-harvest practices.*

Rootcrops are generally known as hardy crops that grow in adverse condition, yet they are found to be sensitive in many extents to unfavorable environmental factors (Pardales et al., 1999; Pardales et al., 2000; Pardales, et al., 2001; Pardales and Esquibel, 1996; Agili and Pardales, 1997, etc) which ultimately reduce their economic yield. The underlying reasons for environmental stress sensitivity and yield reduction in rootcrops is not thoroughly understood yet, so that, there is a great need for in depth studies on the eco-physiology of these crops right in the place where they are commonly grown so as to increase, stabilize, and sustain if possible, their production levels on a unit area basis. Traits that confer resistance or tolerance to certain adverse factors are still to be clearly identified so as to feedback plant breeders with the appropriate characters for inclusion in their design for an improved variety.

Furthermore, rootcrops tubers or corms are highly perishable (Scott et al., 2000a; Scott et al., 2000b; NAS, 1978) so that losses are great if they are not handled well after harvest. Hirose and Data (1983) and Uritani and Data (1983) have elucidated the physiology and biochemistry of deterioration in cassava, but there could be more new insights that could be discovered in the light of today's novel technological tools, which may help prevent rapid deterioration of fresh rootcrops produce.

Along this line, the following are some examples of the areas that need focused research attention:

- o New production practices and techniques.
- o Non-chemical based weed control.
- o Non-chemical based production and postharvest pest control.
- o Physiological response to various environmental stress factors such as limited water supply, high soil temperature, soil acidity, shade, etc. to develop mitigating interventions.
- o Novel handling and storage techniques to check physical, physiological and biochemical deteriorations.

• *Improvement and/or development of production and processing tools and equipment.*

Rootcrops production may be the least automated venture among the economic crops grown for whatever purpose. This is because most of its production areas are in marginal locations and the common systems of production are mostly subsistent and semi-commercial. To some extent even those considered commercial farms in developing countries mostly resort to draft animals for land preparation and other cultivation activities. Because of this, the efficiency of rootcrop production is very low. In terms of processing, starch mills, for example, in many countries employ the antiquated machines that are inefficient and cost ineffective. Village level processing are mostly manual. The following should be the subjects of attention by concerned researches with advanced know-how and fundamentals:

- o Low cost draft animal-drawn tillage and cultivation implements.
- o Functionally designed lightweight and low cost production and processing tools and simple machines for women and children.
- o Novel commercial production, post-harvest and processing machines.

• *Development of new products*.

Wheatley et al. (1995) mentioned that the sizable potential of rootcrops for contributing to socioeconomic development in rural areas requires a combination of efficient, sustainable crop production with new or improved products and markets. Because the products have to be competitive, product development has to consider identification of product ideas, research, piloting and commercialization. This line of activities seemingly appears simple but is actually intricate for ordinary players since a number of considerations like local market situation, constraints and opportunities have to be viewed with clear focus. Again, concerted efforts from various players have to take center stage if rootcrop production is to be boosted by strong value adding up through processed product development. Basically, the studies that may need to be conducted in this area should be as follows:

- o Market survey techniques to identify new products with high market potential.
- o Product development
- o Piloting techniques
- o Market sensitivity
- o Commercialization
- o Management techniques.

Conclusion

Rootcrops are an acknowledged bunch of crops the world over with great potentials, foremost of which is its promise to offer food security to scores of millions of vulnerable resource limited people. Although these crops are generally associated with poverty, their prospects do not end with the poor. The developed world receive benefits from these crops, unknowingly probably to most policy experts, and scientific people because of the different forms by which they may be traded, e.g., starch, chips, frozen items, etc. Yet, in spite of this, rootcrops are not being given much research attention to fully exploit their uses, which have been proven to some extent to even go beyond the traditional like as source of medical remedies, etc.

Critical evaluations of the potential of root and tuber crops have been published. World bodies like CGIAR and FAO have acknowledged these crops to provide food security in the light of an increasing world population, getting adverse climatic condition, depleting natural resources and worsening livelihoods among the disadvantaged sectors of society. The scientific community is therefore challenged to respond, and the act of doing so is not that difficult. This is because the nature and background of the crops are known, the system of their production is understood, their uses are made clear, the element of mitigation is suggested and the necessary adjustments to react to the challenge is given, and so as the main and tributary avenues of research. If there is a need for more understanding to affect a more thorough intervention along these areas, it is just a matter of reaching out to the farmers, researchers and other players in the agricultural arena of the less developed world. Sensitivity is key.

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References

Agili, S.M. and Pardales, J.R. Jr. 1997. Influence of moisture and allelopathic regimes in the soil on the development of cassava and mycorrhizal infection of its roots during establishment period. Phil. J. Crop Sci. 22:99-105.

Alexandratos, N. 1995. World Agriculture: Towards 2010. An FAO Study. New York.

John Wiley and Sons.

ASEAN. 20021. Cassava. In: Strengthening ASEAN cooperation in canned pineapple,canned tuna, tapioca, frozen chicken and frozen shrimp. Bangkok, Thailand. p.17-25.

Atchoarena, D. and L. Gasperini. 2002. From agricultural education to education for rural development and food security: new perspective for the international community. http://www.fao.org/sd/2002/KN0504_en.htm. (Accessed June 2002)

Bradbury, J. H. 1988. Chemical composition of tropical rootcrops and its implications for nutrition. In: Proc. 8th Symp. Int. Soc. Tropical Root Crops. Bangkok, Thailand. p.159-178.

CIP (International Potato Center). 2000. Stories from the field – CIP Annual Report 2000. http://www.cipotato.org. (Accessed May 2002).

Cock, J. H. 1985. Cassava: New potential for a neglected crop. Westview Press, London. 191 p.

Data, E. S., J. R. Roa and P. G. Tangonan. 1997. Sweetpotato food systems in Central Luzon, Philippines. UPWARD Working Paper Series No. 3. UPWARD, Los Baños, Laguna. 30 p.

FAO (Food and Agriculture Organization). 2000a. Cassava can play a key role in reducing hunger. Press Release 00/25. http://www.fao.org. (Accessed May 2002).

FAO (Food and Agriculture Organization). 2000b. The state of food insecurity in the world shows no progress towards world food summit target. Press Release 00/56.

http://www.fao.org. (Accessed May 2002).

FAO (Food and Agriculture Organization). 2002a. Food production declining in Asia. http://www.fao.org/WAICENT/faoinfo/economic/giews/english/fo/fotoc.htm. (Accessed May 2002).

FAO (Food and Agriculture Organization). 2002b. Combating drought, a top priority for Near East countries. Press Release 02/25.

http://www.fao.org/WAICENT/OIS/PRESS_NE/english/2002/3084-en.html. (Accessed May 2002).

FAO (Food and Agriculture Organization). 2002c. Agriculture needs to produce more food with less water. Press Release 01/33.

http://www.fao.org/WAICENT/OIS/PRESS_NE/english/2002/340-en.html. (Accessed May 2002).

Feenstra, G., D. Campbell, D. Chaney, Mr. George and E. Bradford. 1997. What is sustainable agriculture? http://www.sarep.ucdavis.edu/production/index.htm. (Accessed June 2002).

Hall, D. O. (non-dated). Food security: what have sciences to offer? http://www.icsu.org/Publications/FoodSci/sec2/cha2.html. (Accessed June 2002)

Hirose, S. and E.S. Data. 1983. Physiology of the storage and deterioration of cassava. In: Proc. of Int. Sem. on Root Crops in Southeast Asia: Production and utilization (E. D. Reyes, L. B. Flores and R. G. Gabatin, eds.). Baybay and Los Baños, Philippines. p. 143-166.

Horton, D. 1988. Underground crops: Long term trends in production of roots and tubers. Winrock International. Morrilton, AR. 22 p.

Iosefa, T. and S. Rogers. 1999. The multiplication, growth and use of introduced taro cultivars in Samoa. Pacific Regional Agricultural Programme.

Kays, S. J. and S. E. Kays. 1998. Sweetpotato chemistry in relation to health. In: Proceedings of international workshop on sweetpotato production system toward the 21st century (D. R. La Bonte, M. Yamashita and H. Mochida, eds.). p. 231-272..

Kim, H., P. Van Bien and R. H. Howeler.2002 . Status of cassava in Vietnam: Implications for future research and development. http://www.globalcassavastrategy.net/Asia/vietnam/v0000e02.htm. (Accessed May 2002).

Nabangchang,O.2001.Demand-driven researches on agricultural production technologies: The paradigm shift in the MOAC's principles and approaches. In: Proceedings of international workshop on participatory technology development and local knowledge for sustainable land use in Southeast Asia p. 1-11.

NAS (National Academy of Sciences). 1978. Postharvest food losses in developing countries. National Research Council, Washington. 205 p.

Odake,K.1998.Characteristics of food color pigments derived from Ayamurasaki. In: Proceedings of international workshop on sweetpotato production system toward the 21st century (D. R. La Bonte, M. Yamashita and H. Mochida, eds.). p. 303-309.

Pardales, J.R. Jr. and C.B. Esquibel. 1996. Effect of drought at different time during establishment period on the root system development of cassava. Jap. J. Crop Sci. 65 : 93-97.

Pardales, J.R. Jr., D.M. Bañoc, A.Yamauchi, M. Iijima and Y. Kono. 1999. Root system development of cassava and sweetpotato during early growth stage as affected by high root zone temperature. Plant Prod. Sci. 2:247-251.

Pardales, J.R. Jr., D.M. Bañoc, A. Yamauchi, M. Iijima and C.B. Esquibel. 2000. The effect of fluctuation of soil moisture on root development during the establishment phase of sweetpotato.

Plant Prod. Sci. 3:134-139.

Pardales, J.R. Jr., M.C. Verutiao, R.F. Sebidos, C.B. Esquibel and D.V. Belmonte Jr. 2001. Waterlogging damage on cassava during plant establishment period.Philipp.Agric.Sci.84:138-140 .

Pardales, J. R. Jr., V. B. Asio, A. B. Tulin and D. M. Campilan. 2001. Indigenous knowledge and practice of nutrient management of farmers growing sweetpotato in the uplands of Pinabacdao, Samar, Philippines. http://www.escap.cipotato.org. (Accessed May 2001).

Pardales, J R. Jr. and J. R. Roa. 2001. Rootcrops Agriculture in the Philippines: The quest for food security and livelihood. In: Secondary crops for secondary farmers: Meta-analysis of women's role in rootcrop livelihood in the Philippines. FAO Publication. Under editing.

Pardales, J. R. Jr. and R. de Guzman. 2001. Role of Genetic Resources Conservation to Rootcrop Livelihood. In: Secondary crops for secondary farmers: Meta-analysis of women's role in rootcrop livelihood in the Philippines. FAO Publication. Under editing.

Pardales, J. R. Jr. J. R. Roa, D. M. Campilan and M. Kadohira. 2001. Institutional experience with participatory research on rootcrops in the Philippines. In: Proceedings of international workshop on participatory technology development and local knowledge for sustainable land use in Southeast Asia p. 245-252.

Pardales, J. R. Jr. 2000. Experiences, concerns and issues about participatory research: The PhilRootcrops experience. In: Proceedings of international workshop on capacity development for participatory research. In preparation.

Pardales, J. R. Jr. and A. Yamauchi. 1999. Factors affecting rootcrop establishment and productivity: An example of the need to consider a new approach in doing research. In: World food security and crop production technologies for tomorrow (T. Horie, S. Geng, T. Amano, T. Inamura and T. Shiraiwa, eds.). Kyoto, Japan. p. 241-246.

Pinstrup-Andersen, P., R. Pandya-lorch and M. V. Rosegrant. 1997. The world food situation: Recent development, emerging issues and long-term prospects. Food Policy Statement No. 26. http://www.ifpri.cgiar.org. (Accessed May 23, 2002)

Scott, G. J., M. W. Rosegrant and C. Ringler.2000a. Root and tuber crops for the 21st century: Trends, projections and policy options. International Food Policy Research Institute. 64 p.

Scott. G. J., R. Best, M. Rosegrant and M. Bokanga. 2000b. Root and tubers in the global food system: A vision statement to the year 2020. Inter CGIAR Center Publication.111 p.

Scott, G. J.1992. Sweetpotato as animal feed in developing countries. CIP Circular 19(1):7-8.

Singh, R. B. 2000. The state of food insecurity in the world (SOFI 2000): Introduction for SOFI 2000 (Bangkok). http://www.fao.or.th. (Accessed May 2002).

Tamaru, H. 1998. Sweetpotato processing research in Kagoshima prefecture. In: Proceedings of international workshop on sweetpotato production system toward the 21st century (D. R. La Bonte, M. Yamashita and H. Mochida, eds.). p. 295-301.

Uritani, I. and E. S. Data. 1983. Biochemistry of the storage and deterioration of cassava. In: Proc. of Int. Sem. on Root Crops in Southeast Asia: Production and utilization (E. D. Reyes, L. B. Flores and R. G. Gabatin, eds.). Baybay and Los Baños, Philippines. p. 167-187.

Wheatley, C., G. J. Scott, R. Best and S. Wiersema. 1995. Adding value to root and tuber crops: A manual for product development. International Center for Tropical Agriculture. Cali, Colombia. 166 p.

Yamakawa, O. 1998. Development of new cultivation and utilization system for sweetpotato toward the 21st century. In: Proceedings of international workshop on sweetpotato production system toward the 21st century (D. R. La Bonte, M. Yamashita and H. Mochida, eds.). p. 1-8.