AVRDC
The World Vegetable Center

REPORT OF THE 8th EXTERNAL PROGRAM AND MANAGEMENT REVIEW (EPMR)

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8th External Program and Management Review

(EPMR)

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FOREWORD

To: Dr. Y. T. Huang
Chair, Board of Directors, AVRDC – The World Vegetable Center

On behalf of the Panel of the 8th External Program and Management Review (EPMR) of AVRDC – The World Vegetable Center, it is my pleasure to transmit to you the following report. The proper purpose of such an EPMR report is to provide forward-looking guidance from the perspective of recent experience, in this case covering 2009-2014.

The Panel appreciates the trust that AVRDC Board and Management placed in this autonomous process. The Panel acknowledges and thanks the broad array of partners, stakeholders, and staff who gave so freely of their time and frankly of their views. Any success coming from this report is due to your efforts.

The Panel is impressed by AVRDC's compelling mission and unique role. The Panel recommends that AVRDC better align its actions around development outcomes while sharpening research priorities with an increased focus on human nutrition. The Panel endorses the strategy of working across the entire vegetable value chain, from genetic resources through production, marketing and consumption. Progress on such a broad front depends critically on partnerships, and the Panel recommends enhancing key partnerships, especially with member countries.

The Panel commends the recent strategy of decentralization to four main regional centers (India, Mali, Tanzania, Thailand), and encourages further evolution of this process. The Panel observed impressive science, notably in breeding, and offers recommendations to further improve science quality.

The Panel supports AVRDC's commitment to converting scientific advances into development outcomes. The Panel believes that research has to remain the main component in the balance with development, and that AVRDC should reassess how to best achieve its development objectives. The Panel notes signs that significant impact is being achieved, and recent increased efforts to document these impacts have to be further intensified.

The Panel finds AVRDC finances sound, management strong, and governance effective. The Panel recommends a proactive strategy to mobilize additional resources; changes in management to meet new challenges; and mechanisms to strengthen Board oversight.

Recommendations are new actions the Panel is convinced must be taken.

Commendations are ongoing actions the Panel is convinced must be continued.

Suggestions are new actions the Panel believes may be helpful.

Douglas Pachico
Chair, EPMR Panel

Report of the
8th External Program and Management Review

(EPMR)

EXECUTIVE SUMMARY

Context and Mission

During 2009-2014, the period covered by this 8th External Program and Management Review, AVRDC-The World Vegetable Center implemented major strategic changes to better position itself to realize the immense potential that increasing the production and consumption of vegetables in developing countries can have to alleviate poverty and reduce malnutrition.

In this report, the External Program and Management Review (EPMR) Panel highlights what it believes to be notable achievements, but more importantly, the Panel has also formulated a number of recommendations calling for further strategic and operational adjustments and changes that, if properly implemented, should enhance AVRDC's performance.

Vegetable production presents small farmers with exceptional opportunities for increasing their incomes. Vegetables generate higher values of production per unit area than grain or legume field crops, create more employment for rural laborers, and present market opportunities with faster growing demand. The market value of tomatoes alone exceeds that of any crops researched by international centers except rice and wheat. (http://faostat3.fao.org/browse/rankings/commodities_by_regions/E).

Vegetables can make huge contributions to overcoming several forms of malnutrition: iron deficiency causes the deaths of 50,000 women a year and impairs the mental development of about half the children in the developing world; folate (vitamin B9) deficiency causes approximately 200,000 severe birth defects annually; Vitamin A deficiency leads to the early deaths of an estimated one million children each year. Increased vegetable consumption is also crucial to those with rising incomes whose health is jeopardized by over-nutrition.

Diversity is one of the strengths of vegetables. A diversity of vegetables contributes to variety in the diet, appeals to consumers, and provides a source of numerous nutrients and health-promoting phytochemicals. Diversity among vegetables offers growers an array of options for different seasons and different climates.

The EPMR Panel endorses AVRDC's critically important and unique mission to conduct research that increases production of an array of vegetables to improve nutrition, and the Panel commends AVRDC for its determination that its research results yield real development outcomes and impact.

Strategy, Planning, and Priorities

AVRDC's research strategy spans the entire range of the vegetable value chain, from conserving genetic resources, to breeding, enhancing production systems, improving postharvest processing and marketing, and finally, to increasing vegetable consumption for better human health. AVRDC rightly sees the need to be able to intervene at any stage in the vegetable value chain. Although AVRDC recognizes that it cannot act alone but must complement the efforts of partners, AVRDC has to have the capacity to interact with and work with partners at all stages in the vegetable value chain. **The Panel**

commends the breadth of AVRDC research, spanning the entire vegetable system, from germplasm and breeding, through production and consumption.

From its origins 40 years ago as a center devoted to East and Southeast Asia, AVRDC – The World Vegetable Center has rightly extended the scope of its action to place priority on sub-Saharan Africa and South Asia, the regions where poverty is most intense. During the period covered by this review, AVRDC has established a new regional research center for West and Central Africa in Mali; dramatically increased activities in South Asia; and decentralized large parts of its breeding program to regional centers. **The Panel recommends that AVRDC continue to decentralize its work to regional research centers while building a coherent global research program.**

AVRDC clearly gives priority to work in its regional centers—Thailand, India, Tanzania and Mali—but where vegetables can make a real difference and there is stakeholder and partner commitment, AVRDC correctly is willing to join common efforts, for example, joining with partners in new projects in Oceania and Central Asia. However, to avoid dispersing its efforts, **the Panel cautions that AVRDC should strictly adhere to the current policy of not engaging where effective partnerships are lacking**, for example in West Asia or South America.

AVRDC currently organizes its work around four Themes: genetic conservation, breeding, production, and consumption. Rather than framing its work around the production of outputs and the implementation of activities by different competency areas, **the Panel recommends that AVRDC orient its strategy around a long-term vision of its contribution to development goals.** AVRDC should transform from a supply-driven approach to become a demand-driven source of solutions to major development issues.

The panel accepts that the AVRDC research agenda is complex, spanning the entire vegetable chain from breeding to consumption; covering large swathes of the world; and stretching across multiple species. However, to guide its own resource allocation decisions and to clarify its communication to potential donors and partners, more systematic and explicitly formulated planning is called for. **The Panel recommends that AVRDC undertake regionally based planning to construct global priorities for crops, production systems and constraints.**

Research Program

Recognizing the importance to health of vegetables as the richest sources of micronutrients, including vitamins, minerals and phytochemicals, **the Panel recommends that AVRDC work in human nutrition and health be significantly expanded.** This should include several important lines of research:

- Community nutrition studies to understand food preferences, dietary patterns, food availability and nutrition gaps.

- Nutritional quality studies in close collaboration with germplasm conservation and breeding to understand variability in nutritional quality and its inheritance; to develop molecular markers; and to introduce genes for nutritional quality in suitable agronomic backgrounds.

- Food safety studies to understand the effect of postharvest handling, food processing and preparation on nutritional quality and health risks.

Understanding and monitoring health impacts are outside AVRDC's scope but AVRDC can play a niche role by bringing an agricultural dimension to research efforts typically led by health science partners,

The AVRDC genebank is one of the world's largest international public genebanks and understanding its tremendous inter- and intraspecific diversity gives AVRDC a major comparative advantage. The genebank is well managed, efficient, reliable and fair in its distribution of germplasm. **The Panel commends AVRDC for its role in conserving and characterizing the world's largest public collection of vegetable genetic resources.**

Biotechnology research at AVRDC assists the genebank and breeders by developing genomic resources for vegetable crops; performing wide crosses and regeneration of hybrids to introgress traits from wild species into cultivated relatives; and exploring, adapting and implementing technologies for trait mapping and marker-assisted selection in major vegetable crops. This is an impressive program of work that will provide valuable material for breeding efforts. **The Panel commends AVRDC's successful integration of new molecular methods with conventional breeding**.

In breeding, few alternative suppliers are working at a similar level with tropical vegetables to develop new inbred line cultivars for heat tolerance, multiple disease resistance, and improved nutritional characteristics. AVRDC has effectively mobilized multidisciplinary teams and has taken advantage of global partnerships and networks involving collaborators in the public and private sector.

Pepper breeding is top class and probably as good as any in the world. The tomato breeding program is excellent with few competitors as able to use wild relatives. Greater future use of MAS will maintain its position. Breeding programs with legumes, especially mungbean and vegetable soybean, are of high quality, and AVRDC has good location advantage and a strong germplasm base to make significant progress with bitter gourd and pumpkin. The overall quality of breeding at AVRDC is equal to or better than most and there are few alternative suppliers in the same niche.

Decentralization of breeding has been one of the major achievements during the period of this review. In 2009 legume and cucurbit breeding were relocated to India and Thailand, respectively. The allium breeding program was transferred from Taiwan to Mali in 2012. Okra breeding was established in Niger in 2007 and moved to Cameroon in 2014. **The Panel commends the decentralization of AVRDC breeding to the regions.**

During the period of this review, production research has focused largely on biotic constraints. Many vegetable pests and diseases are regionally or globally important. Moreover, through natural evolution, climate change and the wide dissemination of invasive pests and diseases, the pests and diseases that plague a farmer or a country today will be different tomorrow. Research is required to keep abreast of these rapid changes. AVRDC has an unusual capacity to study widespread diseases and pests of vegetables in the tropics, to characterize their populations, and to monitor changes. This may be one

of the strongest comparative advantages of AVRDC research. **The Panel commends AVRDC's priority on plant protection research and sees this work as a nearly unique role**.

AVRDC efforts in marketing and postharvest management are conditioned by an ongoing process of transformation in the vegetable sector, from subsistence home or community gardens on through small-scale vegetable enterprises in mixed farming systems to intensive specialized fully commercialized systems. AVRDC strives to ensure that through these transformations, small farmers and other disadvantaged groups like women farmers or traders can better participate in the value chain and claim a greater share of the increased value that is being created. AVRDC work in this area has concentrated on adaptive research and development activities including training rather than strategic upstream research on food processing or food technology.

Because most of AVRDC's work on postharvest and marketing is right on the cutting edge of rural transformation, development-oriented donors strongly support this work. AVRDC needs to avoid the mere implementation of a disconnected set of development projects tailored to the regional priorities of particular donors. AVRDC must consistently look for opportunities for cumulative cross learning among different restricted projects.

While most AVRDC research on germplasm and breeding and some of the work on production consist of advanced research leading to significant innovation, most of the work on marketing and postharvest management as well as much of the work on production is downstream adaptive research on well-established technologies, testing best-bet technologies or evaluating techniques developed elsewhere. While such work has some value, the Panel believes there is a higher priority need for a pipeline of novel production technologies, unique to the Center, coming from the upstream research and feeding into adaptive research in the regions. **The Panel recommends that AVRDC ensure that its elite upstream research delivers significant innovations in vegetable production.**

AVRDC has a strong record of disaster recovery work with communities after natural disasters and in post-conflict situations, for example in Fiji, Haiti, India, Indonesia and Mali. The work primarily involves the provision of vegetable seed kits. There has been limited research into the effectiveness of short- and long-term impacts of disaster interventions, and little is known of the positive and negative effects of AVRDC's efforts in disaster relief. Understanding this better could represent a niche area of research and development for AVRDC where it has a head start and comparative advantage. **The Panel strongly suggests that AVRDC commission a review into its role in disaster management.**

Elevating research quality to an even higher standard is of particular importance to AVRDC's future, so the EPMR Panel makes three recommendations and two suggestions to sustain and improve research quality.

- The Panel recommends that AVRDC ensure its development work is maintained at a level and scale that does not detract from its essential research program.

- The Panel recommends that AVRDC make adequate investment to maintain state-of-the-art laboratory facilities.

- The Panel recommends that external in-depth scientific reviews of AVRDC research programs be regularly commissioned to provide feedback and monitor research quality.

- The Panel strongly suggests that AVRDC further strengthen its collaboration with academia and research institutes.

- The Panel strongly suggests that the Innovation Fund become a regular part of budgeting.

Regions

Although AVRDC reports working in over 40 countries, its efforts are focused through four regional centers where it is seeking to form inter-disciplinary teams supported by research infrastructure. Developments of these four regional centers have been generally positive, and with strong leadership in place in all regions, the future looks promising.

Work in Thailand for Southeast Asia has been the longest running regional program. AVRDC's global cucurbit breeding is hosted in Thailand. This region includes both impoverished countries with poorly developed vegetable sectors (e.g. Burma, Cambodia, Laos), and more prosperous countries with more dynamic vegetable sectors (e.g. Indonesia, Thailand). While the level of activities in this region has declined during the period of this review, there are opportunities to reinvigorate efforts.

In Eastern and Southern Africa, a full multi-disciplinary team backed by good infrastructure has been established in Arusha, Tanzania. Global leadership for the Consumption Theme operates from Arusha, where AVRDC's work on breeding indigenous African vegetables is also based. This region is on the cusp of an immense increase in the market demand for vegetables, driven by urbanization and economic growth. Among the many opportunities in this region, prospects are promising for expanding work in other countries besides Tanzania.

South Asia has over one-fifth of the world's population and more malnourished people than sub-Saharan Africa. AVRDC has assembled a multi-disciplinary team hosted by ICRISAT in Hyderabad, India. AVRDC's global mungbean breeding is based there, and the team works extensively in Bangladesh, Bhutan, Nepal and Pakistan. AVRDC remains undersized in comparison to the scale of regional challenges and opportunities in vegetable improvement in South Asia even though restricted funding in the region has doubled since 2012.

Vegetable consumption is generally inadequate to meet the nutritional needs of the 300 million people of West and Central Africa. The newest AVRDC regional center was established in Mali only in 2014, although AVRDC has been active in the region for over a decade. The global okra breeding program is based in the region, as is allium (onion) breeding. While still in the early stages of development, regional partnerships, resource mobilization and the establishment of a full interdisciplinary team are all progressing.

Partnerships

Partnerships are essential for AVRDC to make effective progress in research and development across the entire vegetable value chains of a variety of species across wide expanses of Asia and Africa. It is not a job that can be done alone. Consequently, AVRDC is a leading voice advocating for vegetables in global forums like the CGIAR, the Association for International Research and Development Centers for Agriculture (AIRCA) and the Global Horticultural Initiative. **The Panel commends AVRDC, in particular the Director General, for compelling and tireless advocacy for the vegetable agenda.**

Taiwan's support of AVRDC both as host country and as leading donor has been wholehearted and absolutely vital. **The Panel commends AVRDC for its outstanding partnership with its host country.**

AVRDC's relevance to some of its original Asian member countries (Philippines, South Korea, Taiwan, and Thailand) has eroded. As AVRDC has broadened its scope to work for the needs of low-income countries in Africa and South Asia, its original member countries have achieved notable economic growth, transformed their vegetable sectors, and built up their research capacity. Research capacity in South Korea, Taiwan and Thailand as well as in countries like India and South Africa is as good as or better than AVRDC in some areas. New partnership arrangements based on the co-generation of innovations, can leverage the scientific capacity and financial resources of middle-income countries to address issues that low-income countries face. **The Panel recommends that AVRDC pay greater attention to partnership opportunities with middle-income countries, especially among its members.**

Private sector partnerships are an important mechanism through which the outputs of AVRDC breeding work can reach a much greater number of farmers. AVRDC sends large numbers of both bred and genebank materials to seed companies. Many small and medium sized seed companies lack their own breeding programs, so AVRDC lines are often commercialized as varieties without further improvement. Although AVRDC distributes its materials without charge, the Asia and Pacific Seed Association contributed more than $US 1.1 million in unrestricted funds to AVRDC over the period 2006-2014.

Institutional Framework

The Board of Directors that governs AVRDC is composed in roughly equal numbers of appointed country representatives and elected members. The Board has an appropriate composition; ordered and systematic procedures; healthy relations with management; and sound procedures for self-governance. The Board is active, its members largely committed, and it oversees the research programs, finances, and management performance with due attention. To further strengthen Board effectiveness **the Panel recommends that the Internal Auditor report directly to the Board of Directors** and **the Panel recommends that the Board regularly commission external in-depth scientific reviews of AVRDC research programs.**

AVRDC is well managed with a healthy culture. Scientists work smoothly together across themes and regions without impediments of rigid organizational boundaries.

Reporting and control processes for finances, human resources, proposal development, and donor reporting, are systematic and adhered to. Administrative procedures are strong. Senior Management resolves appropriate issues decisively and advocates strongly for AVRDC's mission in international forums.

However, AVRDC is becoming more complex and more geographically distributed, involving more partners, donors, and contracts in more varied activities, thus making adjustments in roles and responsibilities essential. Practices that have been successful in a smaller organization working mostly in a single location cannot be simply extended across a larger more complex organization. Moreover, Senior Management has to take on new challenges: leading the engagement with the nutrition and health sector, nurturing scientific capacity in a technologically dynamic vegetable sector, engaging more with new partners in middle-income countries, and operating in an ever more complex environment of international agricultural research. Therefore, **the Panel recommends that management lead through greater emphasis on teamwork, communication, delegation and coaching.**

Despite a highly variable funding environment, AVRDC is in a sound financial state. AVRDC has controlled expenditures to keep them below revenue every year since 2009, and AVRDC's financial position exceeds commonly accepted indicators of financial health. **The Panel commends AVRDC's prudent financial management in a turbulent funding environment**.

The funding base for AVRDC appears reasonably stable, but it is narrow, being heavily dependent on Taiwan and a few other funding sources. Moreover, with the resources it has now, AVRDC cannot, even in alliance with its current partners, fully implement its strategy. Without increased funding, the fixed costs of maintaining its administrative and research infrastructure will become an ever heavier burden. To be viable and effective, AVRDC needs to grow and to diversify its funding sources. To gradually double in size is a realistic objective. **The Panel recommends that AVRDC expand and diversify its donor base while exercising caution not to be diverted from its strategy.** Prospects for increased restricted project income appear particularly promising in Africa and South Asia and in nutrition-related research.

Support Functions

AVRDC rightly places great emphasis on development activities that convert its research outputs into outcomes that produce positive impacts on human welfare. This is the focus of a significant share of work in the regions, supported by headquarters-based Global Technology Dissemination (GTD). Since GTD does not deliver or have oversight of all the Center's dissemination activities in the regions, it correctly aims to promote Center-wide sharing of experiences rather than to impose a uniform orthodoxy. Management might consider whether a tighter organizational connection could be drawn between GTD and the regional programs. More cross learning could enhance institutional learning and even constitute a research opportunity. **The Panel strongly suggests that strategy, relationship with the regions, and portfolio of responsibilities of Global Technology Dissemination be reassessed.**

While formerly weak, the monitoring and evaluation capacity of AVRDC has recently been significantly strengthened. The number of scientists conducting impact assessment

research has doubled, and now constitutes about 10% of total internationally recruited scientists. More importantly, both the quality and the quantity of evaluation research have increased impressively with the initiation of two multi-country studies using randomized control designs. To promote institutional learning—the main purpose of assessing impact—a variety of research methods should be used. Monitoring and evaluation should be strongly forward looking. For example, when evidence is found of impact, it often points to huge opportunities for scaling out. **The Panel recommends that continued emphasis be given to impact assessment so that it becomes integrated into a continuous learning cycle of innovation, dissemination, and evaluation.**

Measured by the competence, motivation and commitment of staff, the human resource function at AVRDC has had outstanding success. In particular, **the Panel commends the performance of nationally recruited staff, both scientific and administrative, both in the regions and headquarters.** Their names do not appear on all publications, but their efforts are critical to all that AVRDC achieves.

The Panel detected that some perceptions of NRS staff at HQ contrast with those of Management. **The Panel strongly suggests that an elected national staff committee be formed at headquarters to periodically meet with Senior Management to widen communication channels.** Such a committee would give Management an additional opportunity to clarify policies and resolve misunderstandings as well as to become more aware of staff concerns. Since matters of interest vary between HQ and among the various regions, an integrated center-wide NRS representation is not called for. Face-to-face communication is more feasible with the smaller number of staff in the regions and Panel interviews with NRS in the regions did not uncover any indications of a pressing need for more formal structures to complement current interactions.

The challenge facing Communications is to position AVRDC as the international expert on vegetable research for development or risk losing ground to larger agricultural research institutions that are adding vegetables to their portfolios to take advantage of growing donor interest. Social and interactive media are gaining prominence and reach, and Communications needs to be empowered to move AVRDC forward in this arena. To express appreciation and to help insure continuation of its generous support, communication with various audiences in Taiwan is essential. **The Panel recommends that further efforts be made to promote public awareness in Taiwan.** This is a responsibility of Senior Management as much as it is of Communications.

AVRDC has clear policies on biosafety and a code of ethics. It is committed to abide by international norms and protocols, as well as the rules of its partners and countries of operation. It has an effective proposal approval process that provides a robust scrutiny of projects. However, it considers only genetically modified organisms, and animal and human trials. Increasingly universities and international research centres have recognised the need for a more formal consideration of research projects across a wider range of ethical risk categories. **The Panel recommends that AVRDC revise its policies and project approval process in the areas of biosafety and research ethics.**

1. OPERATING CONTEXT

AVRDC operates in a context where it aims to contribute to human welfare through improved access to vegetables. Both its efforts and its achievements are conditioned by important external issues. These issues shape the operational objectives of AVRDC, its outputs, and their impacts on human welfare. This introductory section examines eight important issues and trends that are especially relevant to AVRDC. As argued below in the report (Section 2.2), AVRDC has to think about the implications of these issues to clarify the development objectives towards which AVRDC's work is oriented and how AVRDC is best positioned to respond. This introductory section focuses principally on describing these issues and trends, but it also includes some preliminary comments on how AVRDC is addressing or could address them.

1.1 Malnutrition and Improving Human Health

Globally almost one billion people are undernourished, almost two billion are overweight or obese, and micronutrient malnutrition affects more than two billion people. Human health is significantly impacted by malnutrition. Iron deficiency causes the deaths of an estimated 50,000 young women a year and impairs the mental development of about half the children in the developing world. Folate (vitamin B9) deficiency causes approximately 200,000 severe birth defects every year and is associated with approximately one in every ten adult deaths from heart disease. Vitamin A deficiency compromises the immune systems of approximately 40% of the children under five years old in developing countries and leads to the early deaths of an estimated one million young children each year.

Clearly good health is not only a matter of food security or a sufficiency of calories. It is critically dependent on the consumption of a varied set of nutrients such as are supplied by diverse diets rich in vegetables. Different vegetables have different nutrient profiles and they are typically more readily available during different seasons. Dietary supplements, fortification of food products, biofortification and assuring a diversity of vegetables and fruit in the diet are possible ways forward to ensure nutritional security. Of these alternatives, often the easiest way to enhance the quality of nutritionally deficient diets is for the poor to consume more nutritious foods including vegetables, either grown in home gardens or affordably available in local markets.

Even where there is relative affluence, food choices are often badly made from the nutritional point of view, resulting in another extreme of imbalanced diets leading to obesity and the associated health problems. This is no longer a health problem only in high-income countries, but is of increasing importance in Latin America and Asia, and undoubtedly will become so soon in urban Africa. Again, increased consumption of vegetables can be an important part of dietary enhancement for the calorically over-nourished as much as they can be for the undernourished.

1.2 Increasing Small Farmer Incomes

Vegetable production offers especially good prospects for providing opportunities for increased income for small farmers. Compared to staple field crops like cereals, pulses and root crops, vegetables can generate more income per unit area. Vegetable prices are typically higher than field crops. Furthermore, yields can also be relatively high, and

cropping seasons are often short, permitting multiple crops annually. Labor requirements for vegetable production are generally higher than for field crops and this too favors small farmers who often have relatively abundant labor compared to land. Vegetables can, therefore, generate good incomes on small land holdings through multiple harvests of high yielding high value crops. There are few better alternatives for small farmers.

Seizing the opportunities of high productivity, high value vegetable crops with a growing market is not, though, without obstacles for some small farmers. To be cost competitive in production, small farmers have to intensify. As discussed below (Section 3.4), higher input, more intensive production systems are the future of vegetable production. Many small farmers face serious constraints in making this transition. Probably most limiting is land, or more broadly natural resource quality. Small farmers without irrigation, on poor soils, and with poor access to major markets are less likely to find vegetables an attractive option. Research and development by AVRDC and its partners can to some extent ameliorate these constraints by improving soil fertility and widening access to irrigation, yet farmers in the most disadvantageous situations will not always be able to overcome these limitations.

Intensification of production is also going to be knowledge and management intensive. Again, simply by virtue of managing smaller land areas, small farmers will often be well positioned for intensified management, for example, thorough weed control or integrated pest management (IPM). However, more sophisticated production systems require greater knowledge, for example, of pests and diseases. AVRDC and its partners can help small farmers by generating new knowledge and making it widely available, but in many situations small farmers are at educational and social disadvantages that impede their ability to access and process new knowledge. This constraint is probably more amenable to being overcome than poor natural resource quality, and to enable small farmers to successfully transition into ever more intensive production systems. Knowledge generation and dissemination are areas where attention from AVRDC and its partners may be especially valuable.

Besides being typically labor and knowledge intensive, vegetable production is also generally capital intensive. Because they are high value crops, it is worthwhile to invest in plant protection inputs, and farmers frequently are willing not just to apply chemical pesticides, but to apply them in excess. Similarly, because they are such valuable crops and because seeds are not usually the harvestable product in vegetable production, even cash constrained small farmers are often willing to invest in high quality planting material—open pollinated or hybrid seed, and simple or grafted seedlings. Likewise, the returns to investing in soil fertility and irrigation for vegetables are also often good.

However, the sum of all these inputs—crop protection, quality planting materials, soil amendments, irrigation and in some cases hired labor to supplement family labor—makes vegetable production capital intensive. Thus, while vegetables may be profitable, their production requires more capital per unit area than most field crops. This can generate problems for small farmers who often are as capital constrained as they are land constrained. Research, for example on improved varieties or grafting, can improve the efficiency of capital inputs and in some cases might even reduce total investment. Still, some small farmers will find it difficult to make the capital investments that vegetables require. In this context, AVRDC's strategy of working on the entire vegetable chain (Section 2.1) is highly relevant. Strengthening the seed sector; promoting integrated

value chains that extend to postharvest handling and market structure (Section 1.3); and even linking with credit schemes can all add leverage to the work of AVRDC and its partners in technology development. Without such intervention, socio-economic forces do not make it automatic that small farmers will be able to take advantage of the opportunities offered by vegetable production, but the active efforts of AVRDC and partners can make a big difference.

1.3 Promoting Market-Led Growth

The market prospects for vegetables are favorable. The rapid urbanization characteristic of the developing world provides a growing market demand for vegetables. Economic growth accelerates increases in the demand for vegetables since the demand for vegetables is more elastic than for food staples—as income increases the demand for vegetables also increases much more than for food staples. The high perishability of fresh vegetables also gives farmers some protection against imports. Overall, vegetables offer a relatively promising market that can be an attractive instrument for linking small farmers to markets.

However, while facing good growth prospects, vegetable markets are highly variable due to seasonality in production and high perishability. Vegetable markets can tend to vary between gluts and scarcity with consequent wide swings in prices. To some extent improved production technology can ease this problem by extending the growing season or allowing off-season production, and this has long been a focus of AVRDC research. Improved postharvest handling can also help small farmers cope better with the marketing of perishable vegetables, and this too is a subject of AVRDC effort (Section 3.6).

More generally, though, with urbanization and economic growth market chains in low-income countries will change substantially. Food processing will become more important and this could contribute to greater price stability as well as a wider market. Likewise, retailing is changing with larger scale retailers and supermarkets becoming more important. This process is already well advanced in Latin America and is spreading in Asia and coming to Africa. Large retailers can, through contract farming or other modalities, provide a steady market with less price uncertainty. However, these changes in vegetable value chains are not without complications for small farmers.

Small farmers face new product quality standards in the shift from traditional local markets to supplying food processors and supermarkets. Market channels will change as retailers and processors need assured volumes of vegetables.

Individual small farmers risk exclusion from these opportunities if they are unable to meet new product quality standards and because of diseconomies of scale in dealing with large numbers of small farmers. Large buyers cannot deal with numerous small-scale suppliers; market organization will change with large-scale food processing and retailing. Whether small farmers can best integrate with these new systems through organizing into farmer associations or if this can be done through market intermediaries depends upon particular circumstances. What is clear is that without explicit action, small farmers can easily miss the chance for the growth market opportunities that vegetables present. Consequently, AVRDC makes a major effort in research and development on market chains and postharvest management (Section 3.6).

Indigenous traditional vegetables are particularly prone to losing out with the urban transformation in marketing channels. The nutrients in some traditional species are considerably higher than in global species, which have often been bred for commercial qualities such as long shelf life at the expense of taste and nutrition. Many indigenous traditional vegetables are not only unfamiliar to large scale retailers that are often international in scope, but they also may not be familiar to urban consumers who are migrants from many regions of a country. Efforts on developing marketing channels, devising postharvest handling practices and creating consumer awareness may be even more important than improved production technology for preserving the dietary diversity and richness that traditional vegetables can bring.

1.4 Enhancing Women's Welfare

Women are often closely involved in vegetable-related activities. Changes in the vegetable sector thus might have a more powerful positive impact on women's welfare than other changes in agriculture. Of course women's welfare depends much more on social norms and structures than the means of agricultural production, and new vegetable production technology alone cannot overcome the many forms of socio-economic disadvantage that ensnare women. Nonetheless, because women are so involved in vegetables in so many ways, vegetables may provide some useful leverage to improve their welfare.

Women are much more likely to control vegetable activities than field crops. Home gardening for subsistence consumption is frequently mainly a female activity, and this can carry over to small-scale marketing of surplus vegetable production. In much of Africa and parts of South Asia, women are important traders of vegetables in local markets. Women are also often a key part of the labor force in vegetable production; expansion of the sector could create additional employment opportunities for women. Generally women are key decision makers in household food consumption, making women's choices critical in achieving better health outcomes and nutrition from increased vegetable consumption.

It is attractive, therefore, to think of improvements in vegetables as an especially good instrument for promoting the welfare of women. AVRDC has begun to address these issues. AVRDC has conducted an internal sensitization workshop to better equip AVRDC scientists to be alert to these opportunities. AVRDC seeks actively to include women in its development activities, including training and participation in project activities, and monitors its performance in this regard. An AVRDC study has found evidence indicating that even in a highly gendered social system disadvantageous to female equality, promotion of home gardens can lead to at least modest gains in female empowerment.

From this solid base AVRDC has the opportunity to conduct research directly aimed at understanding how change in the vegetable sector affects women. Such research could include topics such as studies of women's roles in the vegetable value chain as producers and market participants; women's roles in home gardens and the contribution of home gardens to welfare and nutrition; and enhancing women's knowledge as decision makers in vegetable consumption. Employment creation in vegetable production and marketing, for example in the grafting industry in Vietnam, can also create important opportunities for women that deserve study. There is little doubt that the future of vegetables in low-

income countries is going to involve the intensification of vegetable production (Section 3.4) and the greater commercialization of output (Section 3.6). How these changes are affecting women's welfare, and how they could be channeled to ensure that women benefit from these changes, are important issues.

At this point AVRDC can move from assertions about women's role in vegetables, which is true enough, to actively researching how these roles can be enhanced to improve women's welfare. This could be a major research area for AVRDC. There is great interest in these topics not just from development donors but also from specialized agencies in many low-income countries that could be new partners beyond traditional partnerships with agricultural researchers. Other international agricultural research institutes have yet to take the issue of women in agriculture seriously. Vegetables may offer a unique chance that could enable AVRDC to establish a leading role for itself on this topic.

The first step has to be to lay out the important issues at a strategic level and then identify where and how AVRDC is going to tackle them with as much specificity as possible. Social science input will be critical to get this done. Developing a gender research strategy does not necessarily require someone to be full time, a new hire, or female. A short-term consultancy could be an effective way to move forward quickly on this.

As an indicator of AVRDC seriousness, AVRDC could consider reporting to stakeholders how much is being invested to support the implementation of the gender research strategy. This does not have to be new money, unrestricted funds, or earmarked as such in the original project budget. For example, a project that looked at women's roles in postharvest handling could attribute a corresponding part of its budget to gender research.

The facts are clear that vegetables generally involve women more than field crops. Enhancing the roles of women in vegetable production and marketing could make a significant contribution to their welfare. This is an important issue that is not being aggressively taken up by other international agricultural research centers, and it could attract partner and donor support. Of course, AVRDC resources, financial and human, are limited and it cannot undertake every attractive research opportunity. Nevertheless, this does seem like an area to which AVRDC would be wise to give even greater attention.

1.5 Pesticide Abuse and Human Health

Globally, the use of pesticides is widespread and increasing. It has been estimated that annual use has increased fifty-fold since the advent of the modern era of pesticide manufacture in the 1940s. The promotion of good agricultural practices and the strict enforcement of regulations controlling the production, sale and use of pesticides, along with stringent quality control of residues in products, has ensured very safe pesticide use for vegetables produced in, or exported to, many high-income countries. However, the situation is less satisfactory in many low- and middle-income countries where pesticide use is often high and typically poorly regulated.

Vegetable production in tropical countries is especially subject to severe yield losses from insect pests and diseases. Pesticides are widely available but integrated control practices are rarely available to small vegetable farmers in low-income countries. Overall pesticide use in sub-Saharan Africa remains low but is increasing rapidly. Pesticide use

is excessive in many parts of South and Southeast Asia, where pesticides use may account for more than a third of input costs in vegetable production.

A healthy diet requires that the food ingested by consumers not only has positive nutritional and other health qualities but also an absence of toxic or anti-nutritional factors. Important in this goal is ensuring the absence, or safe level, of residues of the wide range of pesticides used in horticulture. Equally important to community health is the safety of agricultural workers using pesticides in vegetable production and the avoidance of accidental exposure of people to pesticides by contamination of air and drinking water. Misuse of pesticides can also have negative effects on the productivity of vegetable systems and the environment more widely leading to a reduction of beneficial organisms, a resurgence of secondary pests, and the development of pesticide resistance. AVRDC recognizes the importance of this and cites, as one of its strategic advantages, its work to reduce pesticide abuse by finding alternatives to pesticides that can have an impact on community health.

Unfortunately, the intensification of vegetable production in many low- and middle-income countries is often accompanied by pesticide overuse and misuse. In some cases, pesticides banned in high-income countries are still used throughout low- and middle-income countries because they are highly effective and cheap to produce. Policies in developing countries have often been supportive of pesticide use, offering cheap credits to buy inputs, tax exemptions for agricultural pesticide imports, or even free distribution of pesticides during major pest outbreaks driven by the need to ensure local food security.

Excessive pesticide residues in food are a major problem, for example in South Asia where it is estimated that 50-70% of vegetables are contaminated with insecticide. The World Health Organization, in conjunction with the United Nations Environment Programme, has estimated that annually around 3 million agricultural workers worldwide suffer from acute pesticide poisoning resulting in up to 20,000 deaths, with 99% of these in low- and middle-income countries.

Farmers and consumers in poor developing countries are at particular health risk from the overuse of pesticides. This problem is exacerbated by a lack of knowledge about safe use and lack of understanding of the impact of pesticides on human health and the environment. Pesticides are often used without protective equipment. There are also many examples of farmers using pesticides provided for field or cash crops on vegetables for which they have not been tested or approved.

AVRDC is well-placed to make a significant contribution to reducing pesticide use and misuse. Included in its research programs are breeding projects to increase pest and disease resistance in vegetables; projects on grafting and protected cropping to provide cultural rather than chemical pest control; and projects on biological control, biopesticides and safe, simple inorganic chemicals. The breeding programs are undoubtedly a great success and the Center's integrated pest management strategies have proven effective in, for example, reducing pesticide spraying for eggplant fruit and shoot borer in trials in Bangladesh and India by 65–75%, cutting production costs by 30%, and increasing farmers' incomes by 60%.

Within its development projects AVRDC has the opportunity in farmer field schools, best practice hubs and community based education programs to transfer knowledge and

technologies for safe use of hazardous pesticides and to identify local pesticide reduction strategies. Where there is market demand, AVRDC could also contribute to a reduction in pesticide use by promoting organic agriculture or other schemes with a price premium for pesticide-safe produce. Internationally, AVRDC should maintain an advocacy role for best practice in pesticide use and regulation.

1.6 Climate Change

The anthropogenic emission of greenhouse gases continues to drive increased global temperatures resulting in increased climatic variability, especially of temperature, precipitation and tropical cyclone activity. Higher temperatures and increased precipitation may increase crop yield in some areas but overall, excessive rainfall, sea level rise, salinization of ground and irrigation waters and drought mean that in many regions, especially in the tropics, climate change will result in decreased agricultural productivity, decreased food insecurity, poorer diets and increased malnutrition. IFPRI (2010) predict that the area of land suitable for crop production will fall by 0.3% and world food production will fall by 2.7% by 2050 under a scenario of moderate climate change.

Geographically, the worst effects of climate change will be experienced in many of the areas where AVRDC is most active, including the drier areas of Africa and parts of South Asia where very large numbers of people rely on rainfed agriculture. In coastal Asia rising sea levels and flooding represent major challenges. The adverse effects of climate change are likely to be felt most by the poorest and most vulnerable members of society, the focus of AVRDC's mission. The poor often depend on agriculture for subsistence and almost invariably have limited resources and ability to adapt. More widely, the impact of climate change on the availability and distribution of productive land, water and food has a serious potential to initiate or exacerbate conflict between individuals, groups and states, and to encourage migration to cities or between regions and countries.

The abiotic stresses of climate change detailed above will deeply affect the biological components of natural and agricultural ecosystems with a general loss of biodiversity and an increasing mismatch between the adaptive range of crops and varieties and the prevailing climatic conditions. At the same time, there are likely to be changes, mostly adverse, in the incidence, severity, and geographic range of pests and diseases.

AVRDC is well-placed to contribute to aspects of the global response to climate change; for example, to the general priorities listed by DFID (2005) as "increased knowledge and application of new irrigation technologies, water conservation measures, drought resistant varieties, new cropping patterns, improved management of pests and diseases through integrated pest management, and crop diversification particularly with alternative crops". AVRDC is uniquely able to focus on the special implications of climate change for vegetable diversity, production and consumption. On the one hand, vegetable production, in some cases with protected cropping and irrigation, might be less vulnerable to climate-induced stresses than staple crops. On the other hand, where vegetable production is less insulated from climate effects, its high value, smaller scale, polyculture and crop diversity make it particularly amenable to climate change mitigation technologies and approaches.

AVRDC has a leading role to play in monitoring climate change to evaluate the risks for vegetable production, and to advocate actions that reduce risk and maintain or increase production, especially in rural smallholder agricultural systems. The core function of AVRDC to preserve and characterize a wide range of vegetable biodiversity will be vital in meeting the challenges of climate change, not only to preserve threatened diversity, but also to provide the species and varieties, including many locally important indigenous vegetables, needed to allow flexibility of production systems in response to climate change. It would appear desirable to increase the germplasm collection to preserve materials that might otherwise be lost due to climate change. However, within the framework of the Convention on Biological Diversity, national policy in most countries severely constrains AVRDC's ability to undertake any new collections.

The climate of a location has a profound role in determining which crops are grown, the seasonal agricultural cycle, rotations and the optimum practices for crop production and protection, all researchable issues for AVRDC. Changes to traditional crop mixtures or varieties, whether by design or enforced by climate change, will, of course, bring challenges of marketing and consumption that will need to be addressed by AVRDC. Where climate change causes natural disasters such as drought and flooding, or man-made emergencies resulting from conflict or migration, AVRDC's disaster recovery program could provide important support to vulnerable groups and communities.

AVRDC is already active, highly successful and well-placed to expand its activities in breeding for biotic and abiotic stress. Breeding for heat, salinity and flooding tolerance, already a priority, is likely to become even more important. Similarly, breeding for pest and disease resistance will become even more important as climate change drives increased pest and disease spread, diversity and severity.

The Panel believes that AVRDC has a significant role to play in the global response to climate change. Many of its core activities across all of its themes and regions have clear and immediate value to this global response. For this reason, the Panel suggest elsewhere in this report that "adapting to climate change" should be one of the development goals providing the axis for AVRDC effort, with a clear message to donors and the public of how the wide-ranging activities of the Center fit together as a coherent climate change response strategy.

1.7 Cutting-Edge Vegetable Systems

The world population is predicted to increase for the next 40-50 years before peaking at around 9 billion largely urban dwellers. Producing sufficient food for this population will be a major challenge for agriculture and horticulture has an important role to play in contributing high quality, nutrient-dense products to ensure healthy diets. At the same time, patterns of consumption will continue to change with rising household incomes. As incomes increase, there is increased demand for off-season, year-round vegetables, and for greater product diversity and quality. This brings increased market opportunities for vegetables farmers but presents a number of challenges. Growing off-season vegetables often requires new approaches to managing the crop growing environment and pest problems. To these are added the medium-term challenges of coping with climate change, and the pressing need to develop horticultural systems that are water, energy and labor efficient. Not surprisingly, the horticultural sector in high-income countries, while not

abandoning traditional field vegetable cultivation, has also turned to technology to deliver the levels of control and efficiency necessary to meet these challenges.

Over many decades there have been major advances in the technologies for integrated pest management, fertigation, mulching, micro- and drip irrigation, mechanization, precision farming, greenhouse and other protected cultivation, and hydroponics. Many of these developments have been enabled by advances in information technology with new sensors and scanners giving the ability to collect and collate weather and soil data, and control climate, water and energy use. Protected cropping, in particular, has proved highly effective in high-income countries and is increasingly spreading as a cost effective production system though upper- and lower-middle income countries.

At least part of the horticulture sector in the more advanced high-income countries has become very technology-based with the entire cultivation cycle from seeding to harvesting conducted in a controlled and fully automated environment. Soilless, hydroponic cultivation is common and there is increasing mechanization with 'self-drive' tractors for precision cultivations and precision robots to do tasks from planting to individual fruit picking. Although not yet widespread there is serious interest, for example in Japan, Singapore and the Gulf States, for fully automated 'vegetable factories' and vertical farming growing vegetables vertically in towers.

AVRDC has a global remit but its commitment to alleviating poverty and malnutrition in the developing world through improved varieties and production methods means much of its work is in developing countries with more traditional vegetable production systems. New varieties, IPM and grafting technologies, and low cost drip-irrigation and fertilization systems can all be suited to smallholders. However, AVRDC also does some research with interested member countries on more advanced technologies including a project to compare computerized greenhouse fertigation systems for cost-effectiveness.

Globally there is a wide polarization between the hi-tech vegetable production systems prevalent in high-income countries and low input traditional systems in low-income countries. As countries develop, there are increased demands and opportunities to develop more advanced vegetable systems. AVRDC's own publications speculate that, in Asia at least, the next decades will see considerable expansion and mechanization of protected agriculture and an increase in artificial or sterilized peat/compost based alternatives to soil for better climate, fertigation, and pest control. The extent to which AVRDC should devote its resources to more advanced and possibly 'blue sky' research in addition to improving food security by small incremental advances using limited and locally appropriate low-cost technology merits consideration.

It is unlikely that AVRDC will ever be in a position, or face the need, to compete with industry in developing cutting-edge, hi-tech vegetable production systems alone. However, with partners in high- and middle-income countries, including in the private sector, AVRDC does have the possibility of participating in the development of new technologies that meet its objectives. Also, importantly, with an eye to medium-term changes expected in the production / marketing / consumption patterns in, for example, Africa, over the next 40 years, AVRDC can play an important role in transferring existing production technologies from more to less advanced countries where demand and opportunities for 'leapfrogging' innovations can be identified.

1.8 Organic Agriculture

A commonly used definition by the USDA in 1980 is that organic agriculture is, "A production system which avoids or largely excludes the use of synthetic compounded fertilizers, pesticides, growth regulators, and livestock feed additives. To the maximum extent feasible, organic farming systems rely upon crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes, and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients, and to control insects, weeds, and other pests."

The term "non-certified organic agriculture" is applied by FAO and others to farming systems that follow the basic production principles of organic agriculture but do so for home consumption or local markets where there is no distinction between organic and conventional produce. For the most part, however, organic agriculture means "certified organic agriculture" with defined production standards, inspection by a third party or other means of ensuring compliance, and certification of production as a consumer guarantee. Internationally, and in most individual developed countries, certified organic agriculture is legally defined and regulated. In some countries less formal 'participatory guarantee schemes' allow a lighter touch in application compliance processes.

Worldwide, in 2011, 162 countries and territories reported data for certified organic agricultural production (Willer et al. 2013) and 86 countries had regulations in place to govern production. Around 1.8 million producers farmed 37.2 million hectares of certified organic land, up from 11 million hectares in 1999. This still represents less than 1% of agricultural land. The world organic market has expanded dramatically in recent decades and was estimated in 2011 to be worth $US 62.9 billion, compared to $US 15.2 billion in 1999.

The principles of organic agriculture, as articulated by the International Federation of Organic Agriculture Movements, are in close alignment with AVRDC's own commitment to promote health, environment, livelihoods and sustainability. Thus, organic agriculture addresses issues related to environmental protection, animal welfare and social justice as well as the more traditional farm sustainability. Fresh organic fruit and vegetables have traditionally been the entry point for new organic consumers and, while there has been a trend from fresh to more processed products in the mature organic markets of Europe and North America, fresh vegetables remain an important organic sector. Vegetable production is often seen as particularly amenable to organic production, owing to its high value, relatively smaller scale, higher labor demand and more direct marketing opportunities.

There is strong complementarity between organic agriculture and the research of AVRDC. The majority of individual technologies developed and promoted by AVRDC, including resistant varieties, biological control, crop diversification, grafting, protected cropping, and aspects of soil and water management, while not developed for, or within, organic systems are equally applicable to them. Conversely, many of the advances made by organic researchers in non-chemical weed control, agroecological approaches to pest control, use of traps and barriers, mulching, cover crops and green manures, and companion planting may also be of value in the lower input systems where AVRDC is active, such as in home gardens.

This cross-fertilization of ideas can be achieved without AVRDC carrying out research within a holistic organic system. On the other hand, if there was a strong interest from partners or donors for more specific organic vegetable production research, perhaps to support locally emerging organic markets or export potential in AVRDC target countries, AVRDC might be able to respond. Since a conversion period of two or three years is required to convert land from conventional to organic, and the plots at AVRDC headquarters are unlikely to be fully certifiable as organic due to high levels of naturally occurring heavy metals, any short-term move for AVRDC to carry out organic research would require access to third-party certified land.

Even in Europe and North America, the market for organic vegetables is still small relative to that for conventional produce, and in most countries where AVRDC is active, organic food represents a tiny market niche. However, if opportunities are perceived to exist because of donor interest and local demand there is no reason why AVRDC's work on market chains and postharvest development could not take this into account.

In conclusion, it would not be advisable or possible for AVRDC unilaterally to set its research in an exclusively organic context. AVRDC does not need to adopt an official position on organic agriculture nor on the nutritional value of organic versus conventional food, for which the evidence is mixed and inconclusive. However, at the level of individual technologies, AVRDC has much to offer the organic sector while at the same time having the prospect of 'mainstreaming' some organic technologies.

Willer H, Lernoud J, Kilcher L. 2013. The World of Organic Agriculture. Statistics and Emerging Trends 2013-14 edition. Research Institute of Organic Agriculture (FiBL) and International Federation of Organic Agriculture Movements, Frick and Bonn.

2. STRATEGY AND PLANNING

2.1 Mission and Recent Strategic Evolution

AVRDC has a clear and attractive mission:

> ***The World Vegetable Center, an international nonprofit research and development institute, is committed to alleviating poverty and malnutrition in the developing world through the increased production and consumption of nutritious and health-promoting vegetables.***

AVRDC is a non-profit organization, depending for its income on the generosity of donors committed, like itself, to alleviating poverty and malnutrition in the developing world. To this end, AVRDC works closely with public research and development agencies in developing countries, but it also partners with the private sector including seed companies and vegetable farmers. Through public-private partnerships AVRDC aims to better reach its ultimate beneficiaries, consumers and vegetable growers. While AVRDC encourages cost sharing with private sector actors whenever possible, its objective is not to seek commercial revenue but rather to promote the widest possible access to the international public goods which are the result of its work.

As discussed above in Section 1 on the AVRDC operating context, vegetables are well-placed to be an engine of growing incomes for small farmers while being critical to a nutritious and healthy diet. Increased production and consumption of vegetables can indeed contribute to alleviating poverty and malnutrition in the developing world. **The EPMR Panel endorses AVRDC's critically important and unique mission.**

AVRDC pursues its goals through a combination of research and development activities. While research to generate improved vegetable production technologies constitutes the heart of AVRDC's work, it is the only international agricultural research center with development explicitly as part of its mission. AVRDC is committed to seeing through the entire innovation process to ensure that the advances coming from its research do not remain in the academic literature, howsoever important that may be, but rather that the products of its research are taken up by users and ultimately have impacts on human welfare and nutrition. Without abandoning its vocation for research by becoming principally a development agency, AVRDC does see working on the innovation frontier between research and development as a key part of its effectiveness. **The EPMR Panel commends AVRDC for its determination that its research results yield real development outcomes and impact.**

Due to this appreciation of the need to link research to development, AVRDC's research strategy is to span the entire range of the vegetable value chain, from conserving priceless vegetable genetic resources, to the genetic improvement of priority species, the enhancement of production systems, improved postharvest processing and marketing, and finally, to increased vegetable consumption and better human health. To achieve its ultimate goals of prosperity and health, AVRDC rightly sees the need to be able to intervene at any stage in the vegetable value chain. Although, as discussed in more detail below in Section 5, AVRDC recognizes that it cannot act alone but must leverage the efforts of many partners to reach common goals, AVRDC has to have the capacity to interact with and work with partners at various stages in the vegetable value chain.

Breeding better vegetable varieties, for example, will not alone guarantee attaining AVRDC objectives of prosperity and health. Varieties have to be integrated into efficient and sustainable production systems, meet postharvest handling and marketing requirements, and satisfy consumer preferences. Research may be able to overcome constraints at any of these steps in the vegetable value chain. **The EPMR Panel commends the breadth of AVRDC research, spanning the entire vegetable system, from germplasm and breeding, through production and consumption.**

Although initially founded with a focus on East and Southeast Asia, AVRDC has had regional programs in Africa for two decades. Over time, AVRDC has expanded its range of action to serve more people in more countries. To best reach its overarching goals of alleviating poverty and reducing malnutrition, AVRDC has to address these problems where they are the most widespread, with particular attention to Africa and South Asia. During the period covered by this review, AVRDC has moved proactively to intensify its work more globally. A new regional office for West and Central Africa has been established in Mali. Activities in South Asia have increased dramatically. New projects are underway in Oceania and Central Asia and are under discussion in Central America. While the strategy for globalization is discussed in more detail below, nonetheless **the EPMR Panel commends the vision and persistence of AVRDC in its determination that its work extend beyond the original member states to reach the malnourished throughout Asia and Africa.**

2.2 Strategic Orientation by Development Goals

Although AVRDC has a Strategic Plan 2011-2015 that gives an overall view of the center's aspirations, the Medium Term Plan (MTP) is currently the principle guide giving structure to AVRDC's work. The annually produced three-year MTP is framed around themes which are in essence competency areas that supply different types of technology or other outputs. AVRDC should orient its work around achieving development impacts rather than the production of outputs and the implementation of activities by different thematic areas. Focus on impacts has several advantages:

- it mobilizes staff energy around an inspiring vision
- it insures that a clear path to impact always drives research
- it shapes planning and prioritization around higher level objectives
- it communicates AVRDC alignment with the goals of development donors

A variety of development goals could provide the axes of AVRDC effort:

- Improving human nutrition and health
- Increasing small farmer incomes
- Empowering women
- Adapting to climate change
- Promoting market-led growth
- Protecting the environment by reducing pesticide abuse

AVRDC cannot treat all these goals as primary objectives since achieving the various goals requires different combinations of skill sets and research infrastructure. For example, improving nutrition would require more capacity in nutrition, while

empowering women more social science capacity, and adapting to climate change probably more modelling capacity. Even though some outputs can contribute to multiple development goals, given inevitable resource limitations, serious pursuit of these goals requires making choices among them. The selection of its priority development goals is a strategic decision for the Board and Management.

Orienting its research around development goals provides a framework for planning and communication and is not intended to be a recommendation for organizational structure. Themes would continue as competency areas that deliver outputs in AVRDC priority regions. Planning, though, would proceed by determining first what outputs are needed in different regions to achieve development goals. Based on that, resource inputs from and the activities of the themes in different regions would be derived. Medium Term Plans might usefully be produced on a triennial basis to show AVRDC aspirations while annual workplans and budgets would lay out what AVRDC intends to do given available resources.

Without disturbing a well-functioning organizational structure, AVRDC can go from appearing like a pedestrian supply-driven organization, to being an attractive and vibrant demand-driven source of solutions to major development issues. AVRDC relevance, impact and appeal to funding agencies would be enhanced.

Recommendation No. 1: The Panel recommends that AVRDC orient its strategy around a long-term vision of its contribution to development goals.

2.3 Priority Setting: Crops, Systems and Themes

The panel accepts that the AVRDC research agenda is complex, spanning the entire vegetable chain from breeding to consumption, covering large swathes of the world, and stretching across multiple species. However, to guide its own resource allocation decisions and to clarify its communication to potential donors and partners, more systematic and explicitly formulated planning is called for.

Diversity is one of the strengths of vegetables. A diversity of vegetables contributes to variety in the diet, appeals to consumers, and is a source of numerous nutrients and health-promoting phytochemicals. Diversity among vegetables offers growers an array of options for different seasons and different climates. Despite the fact that diversity is a virtue, AVRDC still has to make choices among all the vegetables that it might work on.

By 1973 AVRDC had decided to focus on a set of six priority vegetables: tomato, mungbean, sweet potato, white potato, soybean and Chinese cabbage. Of these six, tomato and mungbean remain priority crops. Tomato is the eighth most important crop in the world in terms of net value of production, exceeding widespread staples like maize, sugar cane and cassava, and surpassing any pulse or fruit. Mungbean is among the most important pulses in South Asia as well as a major vegetable in the form of bean sprouts in East and Southeast Asia. AVRDC has largely dropped work on sweet and white potato since these crops are handled by the International Potato Center (CIP). Limited work is currently done on vegetable soybean and Chinese cabbage.

By the early 1980s AVRDC had added research on peppers, cauliflower, mustard greens, snap beans and radish, while by the early 1990s onions, cabbage and eggplant had

become priority crops. Today major breeding work is conducted on tomato, mungbean, sweet and chili pepper, onions, leafy crucifers, cucumbers, summer and winter squash, and okra. Major efforts are not ongoing for formerly prioritized crops like cauliflower, snap beans, radish and eggplant. Selection programs are improving the quality of traditional African and Asian vegetables.

Over four decades AVRDC has periodically reviewed its vegetable improvement priorities. While tomato and mungbean have been priorities since the foundation of AVRDC 40 years ago, and the pepper improvement program has had a long and stable trajectory, work on some crops has started then been suspended while other crops have received more attention recently.

Recognizing that diversity is an asset among vegetables, occupying different agro-ecological niches and appealing to a variety of consumer preferences while providing different combinations of nutrients and health-promoting phytochemicals, nonetheless AVRDC inevitably has to make choices among the species it might work on. While the Panel does not specifically contest any AVRDC decisions to work or not on any particular vegetable, there is a notable lack of a clear and systematic rationale for the crop choices that have been made.

There may be good reasons for the crop choice decisions that AVRDC has made, but such reasoning is implicit rather than transparent. There is a similar vagueness about priority production systems that are being researched within the framework of the intensive and extensive systems that guide the work of the production theme (Section 3.4).

Recommendation No. 2: The panel recommends that AVRDC undertake regionally based planning to construct clear global priorities for crops, production systems and constraints.

Such planning would be based first on the expected contribution to AVRDC development goals as proposed above in Recommendation No. 1. For the species and systems of greatest potential impact on these development goals, specific research constraints and opportunities could be identified in each region, and this in turn would help define the relative balance of input needed from different thematic competencies.

Such a resulting three-year planning framework for each region by development objective could be used to assign unrestricted resources and to communicate to donors AVRDC's portfolio of research and development opportunities for which funding is sought. Annual work plans and budgets would reflect the actual resource availabilities and output targets for which AVRDC would hold itself accountable. Following this approach could help reduce the tension between, on the one hand, the need to be strategic and avoid being donor driven and, on the other hand, the reality that AVRDC can only undertake research for which it has funding. The triennial Medium Term Plan would be aspirational, a clear portrayal of what AVRDC would like to do, while the annual workplan and budget would be more for monitoring progress achieved with actual resources.

Prioritization has to be constructed upwards from farming systems and local diets. Consequently, it is envisaged that priorities be assessed first at a regional level, then aggregated into coherent Center-wide priorities.

From its original mandate in tropical Asia, the Center has successfully expanded. Now, in addition to its headquarters in Taiwan, AVRDC is assembling regional research teams in Eastern and Southern Africa; West and Central Africa; East and Southeast Asia; and South Asia. AVRDC should continue with its policy of building regional multidisciplinary teams of sufficient critical mass, backed by strong support functions from HQ. Such critical mass is unlikely to be achieved in Oceania or Central Asia and the Caucasus, which might better be run as sub-networks, respectively from East and Southeast Asia and South Asia.

Recommendation No. 3: The Panel recommends that AVRDC continue to decentralize its work to regional research centers while building a coherent global research program.

Each regional team needs some capacity to identify regional vegetable research and development priorities; to foster local partnerships; mobilize donor resources; implement a relevant research program; and provide adequate administrative support. Although each regional program has to be driven by a regional agenda, partnerships, and financial resources, all regional programs have to be structured around overarching AVRDC strategic objectives, and should operate in the framework of a coherent AVRDC research program.

AVRDC should conduct integrated global research, sharing scientific resources across regions. Headquarters and each region leads breeding in one or more crops: mungbean in South Asia, okra in West Africa, etc. AVRDC could develop a global network of varietal testing through exchange among its regional research stations and headquarters. Shuttle breeding could also be an alternative. Likewise, many vegetable diseases and pests are global or inter-regional in scope. AVRDC has the unique capacity to monitor disease and pest populations at this scale. Such information is essential for deployment not only of genetic resistance in crop breeding programs, but also for biocontrol agents like pheromones.

Expertise in molecular markers and nutrient biochemistry at headquarters can support all regional research teams. Specialized expertise can be shared across regions so that critical mass can be attained without the presence of every discipline at every site. For example, postharvest expertise in Tanzania could support West Africa, while agronomy expertise in Mali could support East Africa.

While the Panel endorses AVRDC's global aspirations, it cautions that AVRDC should not expand where its effectiveness is compromised by lack of funds or critical mass of staff, as might be the case in Central America or West Asia/North Africa.

All projects in a region should be managed within the region rather than from headquarters. Inter-regional projects require case-by-case treatment, but the principle should remain that all activities in a region are subject to oversight by the Regional Director.

3. RESEARCH PROGRAMS

3.1 Overview

To fulfil its mission of alleviating poverty and malnutrition in the developing world, AVRDC undertakes both research and development activities. Its research spans the whole value chain from crop breeding and production, through postharvest and marketing issues, consumption and beyond to human nutrition and health. AVRDC also has a strong regional focus to its research and it is essential that its research underpin its wider development objectives. The complex overlap and interactions between subject-specific, regional and development objective dimensions of its work present the Center with a challenge in determining the most effective and manageable structure for its programs. For many years the Center has organized its research and development into global themes. These are not only for management and administrative convenience, but also serve as a signal to the outside world of the importance of different aspects of the work, and most importantly enhance collaboration and coherence among staff working in common competency areas.

At the time of the 7th EPMR in 2008, five global research themes were operating:

- Germplasm, comprising the genebank activities, the development of molecular markers and transgenics
- Breeding, developing improved varieties
- Production Systems, including plant protection, integrated crop and soil management, seed systems, dissemination methods and varietal release
- Postharvest Research, covering market characterization, supply chain analysis, and postharvest processing and packaging
- Nutrition and Biostatistics, maximizing the nutritional benefit of increased consumption of vegetables. The Nutrition theme had evolved from 'Chemistry' (1972-1989); 'Analytical Laboratory' (1989-1996); 'Nutrition and Analytical Laboratory' (1996-2002) and 'Nutrition Unit' (2003)

A number of changes have been enacted since 2008, some in response to the recommendations of the 7th EPMR. Biostatistics was separated from Nutrition into an independent Biometrics Unit; dissemination methods separated from Production to become the Global Technology Dissemination Unit; and varietal release from Production moved mainly to Breeding. In 2009-10 Postharvest and Nutrition were merged to form the Consumption Theme. However, it is not clear that AVRDC has vigorously responded to the 7th EPMR view that AVRDC's focus on nutrition be widened and deepened.

At the time of the 8th EPMR in 2014, the Center's research and development activities are organized under four themes:

- Germplasm, to preserve and utilize the biodiversity of vegetable genetic resources
- Breeding, to develop varieties with potential to expand opportunities in tropical vegetable production
- Production, to develop safe and sustainable vegetable production
- Consumption, to improve consumer health by increased consumption of nutritious vegetables

Notwithstanding its recommendation that AVRDC's research should be oriented around development goals (Recommendation 1, Section 2.2), the Panel does not call for changing the current organization of research and development into broad global themes as competency areas that deliver outputs in AVRDC priority regions. There is probably no perfect organization into research themes and the Panel considered several options. Scientifically, Theme Germplasm and Theme Breeding are closely related and could form a coherent whole; however, they would form a very large group and the Panel found no evidence that maintaining these as two groups adversely affected performance. The Panel also considered whether the various elements merged into Theme Consumption might be better off de-merged.

Recognizing the importance to health of vegetables as the richest sources of micronutrients, including vitamins, minerals and phytochemicals, the Panel considers that nutrition and health research should be elevated from being part of Consumption to become one of AVRDC's main research themes. A specific Theme Nutrition and Health would encompass various components:

- Community nutrition studies to understand food preferences, dietary patterns, food availability and nutrition gaps.
- Nutritional quality studies conducted in close collaboration with Germplasm and Breeding to understand variability in nutritional quality and its inheritance; to develop molecular markers; and to introduce genes for nutritional quality in suitable agronomic backgrounds.
- Food safety studies to understand the effect of postharvest handling, food processing and preparation on nutritional quality and health risks.

Increasing the emphasis on nutrition and reinforcing the link between nutrition and health will both require, and provide opportunities for, AVRDC to forge new strong partnerships with public health and health sciences institutions. Understanding and monitoring health impacts are outside AVRDC's scope but AVRDC can play a niche role by bringing an agricultural dimension to research efforts typically led by health science partners, potentially unlocking resources in the health field, which dwarf those available for agricultural research.

Recommendation No. 4: The Panel recommends that AVRDC work in human nutrition and health be significantly expanded and treated as one of AVRDC's main research themes.

Therefore the Panel proposes that, without too much disruption to the current organizational structure, which functions well, the Center establish the following five research themes; Germplasm, Breeding, Production, Nutrition and Health and Market Chains & Postharvest Management. These are discussed separately below. Although the Panel does not consider Disaster Management as a separate theme, it has elements that set it apart from the other work and it is treated as a separate section for discussion.

3.2 Germplasm

Main Activities

The Germplasm Research Theme at AVRDC is concerned with the conservation and utilization of vegetable biodiversity including landraces, crop wild relatives and undomesticated wild species. In practice, the work currently falls into three closely interlinked areas: the Genetic Resources and Seed Unit (GRSU), including the AVRDC Genebank; the Biotechnology group; and a project on grafting.

The biodiversity conserved in the genebank is a valuable source of material, including wild relatives of crops, for breeders at AVRDC and elsewhere to use in breeding programs with internationally important species, including, currently, tomato and pepper. It also maintains a considerable diversity of material of regionally important crops, such as okra and bitter gourd, also subject to AVRDC breeding programs. The genebank has a wide range of other species, including many indigenous vegetables with future potential for breeding advances or further domestication. The policy for germplasm storage is for long-term storage at HQ and shorter-term storage in the regions. Transfer of material is subject to international protocols and agreements.

In accord with the recommendation of the 7th EMPR, emphasis is on conservation and characterization of existing material, and its utilization, rather than further systematic collection, although the facilities exist to add accessions or widen the species or geographic remit if AVRDC research requires this. Irrespective of the need for AVRDC to have a clear, well-justified focus on a limited number of crops (discussed elsewhere in sections 2.3 and 3.3), the genebank should continue to conserve as wide a range of species as possible to allow future flexibility in developing crops for diverse agricultural systems and climate change scenarios.

To safeguard AVRDC's germplasm, the Center has formal storage arrangements with the Svalbard Global Seed Vault in Norway and the National Agrobiodiversity Center of the Rural Development Administration in South Korea. There is also significant duplication of AVRDC's genebank collection at the National Plant Genetic Resources Center of the Taiwan Agricultural Research Institute. Each of these currently conserves a little over 20% of AVRDC accessions. There is an on-going program of regeneration of the Center's germplasm based on established criteria of need, and as part of this, samples of regenerated material are added annually to the collections in Norway and South Korea. Alongside regeneration there is a program of morphological characterization, molecular trait screening and agronomic evaluation of accessions used by the breeders. Nearly 27,000 accessions are overdue for regeneration and characterization. The Center aims to reduce this regeneration and characterization backlog as soon as possible to make most of the germplasm available.

GRSU is a vital source of material for the AVRDC biotechnology and plant breeding programs and distributes seed of accessions and breeding lines worldwide. Recipients of germplasm include international, regional and national genebanks, universities, NARES and private seed companies, with 25-30% going to the private sector.

A key role of the Biotechnology group is molecular characterization of the germplasm collection to mobilize valuable traits. These pre-breeding activities include the

introgression of traits from wild species into cultivated crops and tagging these traits with selectable molecular markers to facilitate more efficient and rapid production of improved varieties. Focus of the pre-breeding activities is determined by the priorities of the breeding programs and includes resistance to a wide range of pests and diseases, and abiotic stresses, and to some extent nutritional quality traits. Clearly this is a long-term and evolving process as breeding crop focus and trait priorities change, driven partly by the continuing evolution and spread of new pathogen types, and increased severity and distribution of abiotic stresses aggravated by climate change.

To remain at the forefront of molecular plant breeding, the Biotechnology group is going beyond its earlier use of simple sequence repeat markers for characterization and trait mapping and has started to apply genotyping by sequencing methods on vegetables. Together with the use of open source bioinformatics programs that can process sequence data and identify useful markers for downstream application, and phenotypic, geographical and ecological information, these molecular approaches will fast-track vegetable breeding, making it more efficient and cheaper.

AVRDC currently maintains a laboratory facility, containment greenhouses and dedicated field plots suitable and licensed for work on genetically modified organisms. This is in line with its stated support in principle for 'the application of genetic modification (GM) technology to the enhancement of vegetable varieties' and 'consideration of genetically modified vegetables as part of an integrated agricultural strategy to alleviate poverty and malnutrition'. Since 2008, the Institutional Biosafety Committee, renamed as Institutional Biosafety and Ethics Committee from May 2011, has given approval to a small number of projects on genetic engineering of tomato.

The Panel encountered mixed views among management and staff regarding the future opportunities for, and desirability of, the application of GM technologies. On the one hand, there is a "wait and see" policy which favors learning the lessons of current attempts to establish GM vegetable varieties such as Bt eggplant in Bangladesh. If this is successful and gains consumer acceptance, and concerns environmental and food safety risks of GM foods prove to be overstated, other opportunities for GM vegetables may arise including crops engineered for improved nutrition or even edible vaccines. If it is not successful, GM vegetables may become even less acceptable than they are now. However, to keep its options open, AVRDC is faced with the decision of whether to maintain its GM facilities and level of staff expertise or face re-establishing them and seeking new approval at a later date.

The arguments against AVRDC involvement in GM developments, other than as an experimental laboratory tool for scientific investigation, include little or no perceived demand from AVRDC's clients for genetically modified varieties not least due to the limited opportunity for selling GM vegetables. In the short-term, the technologies that are most likely to achieve GM advances, such as Bt insect resistance and RNAi virus resistance, are already heavily patented, limiting AVRDC's opportunities to use them. In the medium-term, other less contentious technologies such as targeted gene editing may well replace the current GM approach.

Theme Germplasm has a small program on grafting. Grafting has been promoted by AVRDC as a mature technology particularly to address soil-borne diseases and abiotic stress. The impact of AVRDC's tomato grafting technology applied to tomato in Vietnam

has been evaluated and the study indicates a very high adoption rate and an estimated 31% increase in tomato yields. The work is currently focused on interspecific grafting in tomato, which has the potential to yield significant further advances in developing soil-borne disease and abiotic stress tolerant rootstock/scion combinations. By exploiting AVRDC's germplasm collection fully, and linking the grafting work closely to the breeding program, AVRDC can continue to make important advances in this area.

Advances and Changes since 2008

The 7th EMPR made a number of recommendations related to the germplasm research theme, including importantly:

(1) Strengthening and expansion of the scope of its Material Transfer Agreement (MTA) both for the public and private sectors, to obtain feedback for impact assessment. To achieve this AVRDC has revised, adapted and extended the scope of its MTA and more explicitly built-in feedback. In 2013, AVRDC adopted the Standard Material Transfer Agreement (SMTA) of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) for the distribution of all genebank accessions. In 2014, it adopted the 'Easy SMTA', which includes an automatic SMTA creation and reporting mechanism. It remains difficult, however, on a voluntary basis, to obtain feedback and a response rate of only about 25% has been achieved. Details of performance of transferred materials from replicated trials is particularly difficult to obtain. Similarly, tracing and monitoring onward use of AVRDC materials is difficult, though a wide ranging retrospective review of this will help. This is recognized as an important task and it is suggested that Regional Directors have more responsibility to follow this up.

(2) Completion of the nutritional audit of accessions to facilitate the Center's nutritional research. Nutritional characterization remains an ongoing process on a project basis with selected crops. However, research in Theme Consumption suggests that there is greater difference in nutritional quality within crops due to environment, including seasonality, than between accessions, suggesting that a simple one-off nutritional characterization would be of limited value.

(3) Exploration of the scope to generate funds through involvement of the biotech sector or large food companies. This remains an unresolved challenge with limited restricted project funds of commercial income available to the Theme and a continuing heavy reliance on core funding.

(4) Priority given to completing the characterization, evaluation and documentation of existing accessions, their inclusion in AVGRIS and availability via the web. Characterization and evaluation are ongoing and among the priorities of the group. AVGRIS has been fully implemented and there is very positive feedback from users. In 2011 the passport data on AVRDC's germplasm holdings were updated on SINGER (System-wide information network for genetic resources of crop, forage and tree germplasm of the CGIAR) and linked with GENESYS – the Global Portal for Information about Plant Genetic Resources for Food and Agriculture. In 2014 AVRDC partnered with the DivSeek (Diversity Seek) Initiative. DivSeek aims to unlock the potential of crop diversity stored in genebanks around the globe and make it available to all so that it can be utilized to enhance the productivity, sustainability and resilience of crops and agricultural systems. DivSeek aims to help bridge the gap between the

information requirements of genebank curators, plant breeders and more targeted upstream biological researchers, to support applied germplasm curation, forward-looking breeding programs and strategic research. The DivSeek initiative will work to characterize crop diversity and develop a unified, coordinated and cohesive information management platform to provide easy access to genotypic and phenotypic data associated with genebank germplasm.

(5) A special initiative should be considered to explore germplasm for sources of resistance to drought, heat, salinity, acidity and other abiotic stresses. Since 2008 there have been several projects evaluating material for heat, drought and salt tolerance, including using molecular approaches. Abiotic stress tolerance has been identified and successfully utilized in breeding programs.

(6) Further collection and evaluation of local and indigenous vegetables by AVRDC Regional Research Stations in Southeast Asia, South Asia, and Africa should be regarded as a priority. Indigenous vegetable programs are a significant focus of the regional work, with most countries sharing material with AVRDC HQ. The Panel consider it important to distinguish between indigenous vegetables and underutilized crops. The former includes crops such as amaranth and African eggplant, which are geographically limited in their distribution and use but within their region may be economically very important. Underutilized crops tend to be ones that are of limited use at present or scarcely domesticated.

(7) Duplicate storage of germplasm, especially the elite lines, should be prioritized. In 2008, 'black-box' arrangements with the Nordic Genetic Resource Center in Norway (Svalbard Global Seed Vault [SGSV]) and with the Agrobiodiversity Center of RDA in South Korea were concluded. This led to a project entitled "Regeneration and safeguard of valuable collections of vegetable germplasm held at AVRDC - The World Vegetable Center", including safety backup at the SGSV; the project was funded by the Global Crop Diversity Trust (2008-2012).

In 2010-11, genebank expansion and renovation work funded by the Taiwan Government doubled the medium- and long-term storage space.

Quality

The AVRDC genebank is one of the world's largest international public genebanks and access to its tremendous inter- and intraspecific diversity gives AVRDC a major comparative advantage and makes it a valuable partner for both the private and public sector. The germplasm collection has been described as AVRDC's "most precious asset and investment in the fight against the global challenges of poverty and malnutrition". The Panel agrees with the importance assigned to this resource. GRSU is well managed, efficient, reliable and fair in its distribution of germplasm. The genebank represents a prudent and value-for-money use of resources underpinning much of AVRDC's work across the research themes.

The quality of the work of Theme Germplasm can be assessed by the quantity and quality of the germplasm collection it maintains and distributes, the scientific advances it makes in molecular biotechnology and grafting as indicated by published outputs, and evidence of uptake and impact, To date AVRDC holds 61,177 germplasm accessions, comprising

172 genera and 440 species from 155 countries. Since its establishment in 1973, AVRDC has distributed about 590,000 seed samples of its vegetable germplasm collection to researchers and breeders in 200 countries.

Each year the Center's GRSU distributes seed samples of 6,000-8,000 accessions and breeding lines. These are invaluable to public and private clients worldwide and lead directly or indirectly to the release of improved varieties. As an example, from a total of 37 new varieties released in Central Asia and the Caucasus region during 2007-2013, 14 new varieties (38% of total) originated directly from AVRDC genebank accessions supplied by GRSU including varieties of tomato (2), hot pepper (4), sweet pepper (1), eggplant (1), vegetable soybean (4), mungbean (1) and yard-long bean (1).

The Biotechnology group comprises well trained and experienced staff with strong capacity for novel approaches to genomic resources development and marker-assisted screening. The work is of a very high standard and is providing the information necessary to allow the breeders to optimize their improvement programmes and more effectively to combine multiple traits. As mentioned elsewhere in this report there will be a need for continuous investment in the equipment and facilities necessary for this work and in training the next generation of staff in next-generation sequencing technologies. **The Panel commends AVRDC for its role in conserving and characterizing the world's largest public collection of vegetable genetic resources.**

Future Opportunities

The Panel echoes previous recommendations that seeds from the germplasm collection continue to be "distributed freely and without charge in order to reach as many poor farmers as quickly as possible". The Panel considers that the genebank will continue to need substantial subsidy from core funding. However, previous suggestions that the commercial possibilities of novel genes of interest to commercial biotechnology companies for crop improvement and for biotherapeutics, nutraceuticals and other health-related products should not be discounted.

The Panel considers that there are unlikely to be radical changes in the nature of the relationship between AVRDC and the end users of its germplasm. Many private seed companies have started to build their own genebanks for long-term germplasm conservation and have asked AVRDC for hands-on training of selected staff in germplasm and genebank management.

The evaluation of vegetable germplasm for selected nutrition-related compounds is considered an important area for germplasm screening. Nutrient databases are planned for Mali, Burkina Faso, Cameroon, Nepal and Bhutan. Information on vegetables at species and cultivar level of popular and underutilized crops will be collected. The nutrient database will be designed to be web-based, interactive, user-friendly and open access.

The Biotechnology group has the opportunity, funds permitting, to extend its work including providing services on molecular genetics, mainly to the genebank and AVRDC breeders by developing genomic resources for vegetable crops; performing wide crosses and regeneration of hybrids to introgress traits from wild species into cultivated relatives; and exploring, adapting and implementing technologies for trait mapping and marker-

assisted selection in major vegetable crops. There is an impressive list of work planned and/or in progress that will provide valuable material to feed into the breeding programs. Among the realistic targets are molecular markers for resistance genes against bacterial, oomycete, fungal and viral diseases of tomato, pepper, mungbean and pumpkin, as well as resistance genes in mungbean against insects.

AVRDC has plans in progress to increase, identify and use the genes for abiotic stress tolerance in its main crops. It plans to apply a combination of different trait mapping methods to salt tolerance genes in wild tomato and transfer these genes into cultivated tomato. Flooding tolerance has been identified in tomato lines in the AVRDC germplasm collection and systematic screening will identify any flooding tolerant lines that can be channeled into breeding programs. Heat stress tolerance genes in tomato have been identified; the tolerance traits will be fine-mapped and new heat tolerant material will be explored for improved heat tolerance traits. There is great demand for these approaches; the focus should remain driven by resources and responsive to demand from AVRDC's own breeding programs at HQ and in the regions, including efforts on local economically important species such as okra.

Collaborations with academic institutions such as Academia Sinica, National Cheng Kung University, and National Taiwan University add basic research aspects to the rather applied research focus of AVRDC, lead to joint publication in higher impact journals, and should be increased, as recommended elsewhere in this report (Section 3.8). There is also the possibility of building sustainable research partnerships with small and medium size private firms by providing molecular tools for vegetable breeding and varietal characterization, which the companies themselves cannot provide.

The work of Theme Germplasm remains central to AVRDC's worldwide operation. It contributes to the outputs of the Center across themes and regions. Elsewhere in this report the Panel argues that the work of the theme could be better presented as an essential component of programs leading to clear development objectives and outcomes (Section 2.2).

3.3 Breeding

Main Activities

Along with its world-class genebank, AVRDC is probably best known internationally for its breeding and the release of improved lines and cultivars of many important vegetables. The introduction of improved vegetable cultivars is one of the cheapest, simplest and most effective ways of improving production, nutrition and livelihoods among AVRDC's target beneficiaries. New cultivars offer the prospect of relatively low-input, environmentally benign, and sustainable improvements in yield, tolerance to abiotic stresses such as heat and salinity, resistance to pests and diseases, postharvest handling qualities, and quality and nutrient contents of the produce.

The remit of AVRDC covers vegetables generally rather than specific mandate crops and over the years it has been able to respond to changes in demand by breeding a wide range of crops (Section 2.3). Although the choice of crop has been dictated to some extent by the availability of funding and expertise, the criteria for selection include economic importance of the crop and potential for income generation; potential crop contribution

to human nutrition; availability of genetic resources for breeding; potential to solve significant problems cost-effectively through breeding; AVRDC's comparative advantage in breeding versus the private sector; ease of seed production and other technical considerations; and costs of research and the likelihood of attracting funding.

To facilitate its breeding and programs, AVRDC has established effective relationships with public and private sector institutions for exchange of breeding lines and breeding material, information sharing, research and discovery of basic information on genetics of important traits, screening protocols, and realizing outcomes from distribution, testing, release, and scaling up of AVRDC improved lines. Direct release of AVRDC breeding lines (inbred lines versus hybrids) takes place through public institutions. Private seed companies are also of particular importance as a route for widespread distribution of the outputs of AVRDC breeding programs. The seed companies have the facilities for large-scale production, marketing and distribution of vegetable seeds and the capacity to reach large numbers of farmers through field days and company technical advisors.

Via both the public and private sectors, the outputs of the AVRDC breeding program undoubtedly have widespread positive outcomes and impact far beyond the initial release. However, AVRDC has limited control over this process after release. Since AVRDC material is freely available, seed companies are able to commercialize AVRDC lines directly or use them as hybrid parents or breeding stocks in their own programs. Public institutions often lack the staff and resources to produce sufficient foundation seed, the capacity to scale up production and the channels to market seed to farmers. Release of a cultivar alone does not guarantee its uptake. Added to this problem is the difficulty faced by AVRDC in tracking the uptake and impact of the breeding lines it releases, let alone its onward utilization in future breeding programs. Although AVRDC's Material Transfer Agreement (MTA) is designed to obtain feedback from both the public and private sectors for impact assessment, the response is variable, especially from smaller seed companies.

Advances and Changes since 2008

The 7th EPMR in 2008 recommended that the Center should continue to re-focus its breeding programs in a regionally appropriate way, with elite-level science and breeding concentrated at headquarters and downstream breeding of locally relevant varieties in the regional offices. Previously, most breeding programs were based at HQ but now only tomato and pepper breeding are. In 2009 legume and cucurbit breeding were relocated to India and Thailand, respectively. The allium breeding program was transferred from Taiwan to Mali in 2012. Okra breeding was established in Niger in 2007 and moved to Cameroon in 2014. The breeding focus in Arusha is mainly on improvement of traditional vegetables. AVRDC has discontinued breeding programs, or will shortly do so, on common cabbage, Chinese cabbage, eggplant, cucumber, broccoli and non-heading leafy crucifers.

Decentralization of breeding has been one of the major achievements during the period of this review and **the Panel commends the decentralization of AVRDC breeding to the regions.**

A second recommendation of the 7th EPMR was that the Center should ensure it maintains an explicitly pro-poor balance in its efforts to develop commercial crop

varieties and also indigenous vegetables and open-pollinated varieties more suited to the needs of poor farmers and households. This has remained a central feature of the Center's work with the provision that in some cases with global varieties, hybrids may be more suitable for the needs of poor farmers, especially if they sell to local or regional markets.

AVRDC has continued with its strategy for tomato and sweet pepper of incorporating heat tolerance and multiple disease resistance traits, and for chili of achieving multiple disease resistance. The tomato breeding program has added a marker-assisted selection (MAS) component to its conventional breeding, which enables pyramiding of disease resistance genes and improved selection efficiency. Major tomato breeding achievements and ongoing activities since 2008 include development of lines combining virus and vector resistances for stable tomato yellow leaf curl virus disease resistance, improved bacterial wilt resistance through MAS, high beta-carotene/high carotenoid content lines, mapping heat tolerance, and introgression of late blight resistance from wild tomato. Major pepper breeding achievements and ongoing activities include identification and introgression of anthracnose and begomovirus resistances, studies of mechanisms of heat tolerance in sweet pepper, and incorporation of cytoplasmic male sterility.

The AVRDC mungbean breeding program has been very successful in combining synchronous and early maturity (60-75) days and *Mungbean yellow mosaic virus* (MYMV) resistance, allowing the crop to fit in rice-wheat systems of the Indo-Gangetic plains. Ongoing breeding priorities include bruchid and MYMV resistances, incorporation of high methionine trait into mungbean from black gram, and mungbean for sprouts. Vegetable soybean is traditionally popular in parts of East Asia and was selected by AVRDC because of its high protein content and usefulness as a green manure. Research objectives include incorporation of photoperiod insensitivity, basmati flavor, and super-nodulation.

Although AVRDC had an allium breeding program at HQ from 1992 there were a number of constraints that limited its success. The main breeding targets were the development of onions with a long shelf life under ambient storage and development of summer season cultivars through interspecific crosses and introgression of disease resistance and heat tolerance from *Allium fistulosum* into onion (*A. cepa*). However, although promising long shelf life lines were developed at HQ, seed production could not be scaled up because of the unfavorable climate for large-scale onion seed production in Taiwan. The *A. fistulosum* strategy failed to deliver onion lines that could produce large bulbs, set seed, and possessed disease resistance and summer stress tolerance. As a result of these difficulties, the onion breeding focus was relocated to Mali, a process completed in 2012, where onion is of regional importance, the climate is more suitable for seed production, and AVRDC has a full-time onion breeder. Now that the Regional research station for West and Central Africa has the infrastructure, equipment, and staff to breed onions, progress is being made in evaluating onion lines for yield, early maturity, bulb qualities, and shelf life, and also in selecting lines within local landraces.

Cucurbit breeding began in 2007. The initial crop focus was cucumber and pumpkin but shifted to bitter gourd and pumpkin. The program is based mainly at the East and Southeast Asia regional research station. Major breeding objectives include strong gynoecy, earliness, fungal disease resistance, fruit quality, high nutrient content, including compounds associated with anti-diabetic properties. Pumpkin objectives include multiple virus resistance, fruit quality, early maturity, and high carotene contents.

Okra breeding started in Niger in 2007, ceased temporarily in 2011, but has now resumed in Cameroon in 2014. Okra breeding will give priority to yield, resistance to *Okra yellow vein mosaic virus* and other diseases, and okra quality traits to meet the local food preference. AVRDC's interest in traditional vegetable research and breeding has increased significantly since the mid-2000's, especially after the GIZ- and BMGF-funded projects in Africa, and the COA-funded indigenous vegetable project in Taiwan. AVRDC breeding of traditional vegetables has been based on mass selection within landraces/accessions (no crossing) and farmer participatory selection. Good progress has been made with African nightshade, African eggplant, vegetable cowpea, amaranth, spider plant, Ethiopian kale, and others, resulting in the release and commercialization of several cultivars of different crops over the past five years. Malabar spinach has been targeted for research and improvement at HQ because the crop is nutritious and flood tolerant, and can be grown in flood-prone areas like Bangladesh during periods of vegetable scarcity.

Quality

AVRDC has a number of comparative advantages allowing it to carry out its breeding programs with a high degree of success. These include a world-class genebank containing abundant genetic diversity, encompassing the wild relatives of major crops, and underpinning the breeding programs. Very few competitors are working at a similar level with tropical vegetables to develop new inbred line cultivars for heat tolerance, multiple disease resistance, and improved nutritional characteristics. AVRDC has effectively mobilized multidisciplinary teams of researchers with expertise in plant pathology, entomology, crop production, nutrition, and molecular breeding supporting the front-line breeding effort. The success of the program has also depended to a great extent on AVRDC's global partnerships and networks involving collaborators in the public and private sector.

Overall comparison of AVRDC's breeding programs with those of commercial seed companies and national breeding organizations is difficult because of AVRDC's unique status and distinct objectives. The breeding programs have earned a solid track record of cultivar release. Pepper breeding is top class and probably as good as any in the world. The tomato breeding program is excellent with few competitors using wild relatives, and greater future use of MAS will maintain its position. Breeding programs with legumes, especially mungbean and vegetable soybean, are of high quality, and AVRDC has good location advantage and a strong germplasm base to make significant progress with bitter gourd and pumpkin. At present the large commercial breeders may be able to operate at a scale greater than that AVRDC can aspire to, including wider use of MAS, but the overall quality of breeding at AVRDC is equal to or better than most and there are few alternative suppliers in the same niche.

Future Opportunities

Looking to the future Theme Breeding has identified a number of challenges. Inevitably, over time, there will be shifts in the targets of the breeding programs as new issues arise or assume greater importance. Such issues include biotic and abiotic stresses due to climate change, urbanization bringing changes to market requirements, and greater consumer demand for safe, nutrient-rich, visually attractive, and diverse vegetables. No

doubt AVRDC can make progress in all of these areas and can respond to changes in demand for different crops.

There is, for example, a strong case for further breeding work with indigenous and traditional vegetables. Introducing indigenous vegetables into growing urban markets would enhance diet diversity for consumers while creating income opportunities for small famers. On the other hand, the breeding programs already face limited resources and deal with a half dozen main crops. AVRDC needs to be judicious in its choices about work on indigenous vegetables. Any changes in focus crops or target traits should not be made at the expense of continuity. Plant breeding is a long-term endeavor and any breeding program must be given enough time to complete development and seed production of finished lines and add them to the online seed catalogue for distribution.

Achieving critical mass to allow more advanced breeding in the regions remains a challenge. There is a need for more trained pathologists in the regions to give a critical mass to the teams there. The Theme would also benefit from a technology dissemination specialist in each region, able to coordinate multilocation testing of new lines. At the same time, it is important for breeders to focus on breeding for most of their time without being overly diverted to development project management, administration or extension. The regional programs would also benefit from greater capacity to produce large amounts of breeder seeds, working with seed companies to scale-up foundation seed production, and stimulation of farmer demand.

These challenges notwithstanding, **the Panel commends AVRDC's successful integration of new molecular methods with conventional breeding**. Molecular marker-assisted selection can increase options and improve efficiency. Inbred lines are likely to remain the main output of the breeding programs although some successful hybrids have also been released and have value. The Panel considers that Theme Breeding has articulated a well thought-out strategy for future work. Further advances can be made in breeding for abiotic stress, including raising the level of heat tolerance.

Markers will continue to facilitate stacking of multiple disease resistance genes in the same line, with tomato lines resistant to important virus, fungal and bacterial diseases a good prospect. Further effort in mapping resistance genes in mungbean and pepper, and developing marker systems for crops such as okra to allow mapping of disease resistance genes, can fairly rapidly lead to disease resistant lines. Routine marker-assisted selection for disease resistance can be expected for most AVRDC crops as is the case with tomato breeding now. Insect resistance breeding is ongoing for bruchid resistance in mungbean, whitefly resistance in tomato, and mites and aphid resistance in pepper. In the near future, new technologies will increase the possibilities for breeding for insect resistance. Markers and mapping will be particularly critical in the detection and introgression of favorable alleles from wild species.

AVRDC has designed or has access to protocols to quantify micronutrients, phytochemicals, antioxidants, and anti-nutritional factors as well as protocols for quality traits. Although the nutritional quality of vegetables depends heavily on environmental factors such as season, breeding of both main crops and traditional vegetables for enhanced nutrient and phytochemical content will be a high priority, especially with the greater focus on nutrition and health favored by the Panel. Similarly, improvement in postharvest and storage qualities are in prospect.

Changes proposed in monitoring, evaluation and impact assessment can help track the use of AVRDC germplasm and breeding lines, and obtain a clearer picture of downstream impact. Theme Breeding will need to redouble efforts to gain seed company compliance with recognition clause in the AVRDC MTA and Regional Directors can play a significant role in achieving this.

3.4 Production

Overview

This Theme has a clearly conceptualized theory of change that orients its work. The Theme's framework focuses on improving the productivity of small vegetable farmers but its work also has implications for human health (e.g. more affordable vegetables) and systems sustainability (e.g. reduced pesticide pollution). The Production Theme has three main outputs: knowledge, technology and dissemination of innovations.

The discovery of novel and strategic information about key constraints forms the basis for coming up with solutions. New vegetable technologies have to be integrated into and adapted to specific systems. The Theme distinguishes two broad classes of systems for which it works; more extensive systems, typically of farmers who are not specialist vegetable producers; and intensive systems of farmers who are typically running a commercial enterprise with high levels of inputs. Dissemination is critical to transform outputs of knowledge and technology into outcomes of improved farmer incomes, affordable vegetables for consumers, and healthier ecosystems.

Strategic research to generate knowledge about constraints is principally carried out by a headquarters-based team composed of five internationally recruited scientists, all plant protection specialists, who are supported by a cadre of nine research assistants and specialists. They have excellent access to research fields and greenhouses, as well as basic laboratory facilities. Although based at headquarters, they travel extensively and much of their research is conducted on a regional basis. Technology integration into systems and dissemination work is carried out mainly in the regions by regionally based scientists, eight of whom have a part-time association with the Theme, constituting about three full-time equivalents. They are supported by nine research assistants and specialists. Research on knowledge generation tends to be on components that may have a broad applicability across many production systems and even across regions, while systems integration occurs at a more local level.

Efforts to generate novel information for crop management has resulted in excellent research using up-to-date methods. Breeding programs cannot advance while resistant material risks failure in the absence of proper identification of diseases and pests and understanding their variability. For example, variation on virulence and phylotype of *Ralstonia solanacearum* has permitted the mapping of QTLs associated with stable and phylotype-specific resistance in tomato. Likewise, information on local variation of begomoviruses allows the selection of tomato lines carrying appropriate resistance genes for different locations.

Through natural evolution, perhaps accelerated by climate change and certainly supplemented by globalization that widely disseminates invasive pests and diseases, the

pests and diseases that a country has today will be different tomorrow. Research is required to keep abreast of these rapid changes. AVRDC is highly active in this area. A molecular diagnosis procedure using the FTA® card was established for rapid diagnosis of tomato foliar diseases. Whitefly populations attacking vegetables in India, Indonesia, Thailand and Vietnam have been characterized by their gene sequences. PCR assay has been used to understand variation in *R. solanacearum* attacking tomato and sweet pepper in Kenya, Taiwan and Vietnam. Genetic sequencing was used to assess the genetic diversity of begomoviruses infecting tomato, chili and/or mungbean in India, Thailand and Vietnam. Six distinct species of poleroviruses were detected infecting cucurbit crops in Mali, the Philippines, Thailand and Uzbekistan, including two novel species for which the names Pepo aphid-borne yellows virus (from Mali) and Luffa aphid-borne yellows virus (from Thailand) were proposed.

Clearly AVRDC has an unusual capacity to study widespread diseases and pests of vegetables in the tropics, to characterize their populations, and to monitor changes. This may be one of the strongest comparative advantages of AVRDC research.

While the case for a strong program of research on crop protection is clear and is being acted upon, AVRDC research on soils or plant nutrition receives considerably less attention. There does seem to be a strong logic for AVRDC's focus on pests and diseases. Many pests and diseases are regionally or even globally important. In contrast, soils issues are much more location-specific due to the great variability in soils and production systems. Moreover, vegetables often only occupy a modest share of the land under cultivation, making them less important in overall soils management compared to field crops.

On the other hand, the high demand for nutrients and moisture that vegetables have means that the introduction of vegetables into cropping systems fundamentally changes nutrient flows in the system. Since farmers often concentrate fertility and moisture on high value vegetable crops, vegetables may be a useful entry point for the study of soil improvement strategies, which in many cases should not be simply a question of adding chemical fertilizer. The role of mungbean as a soil-enhancing, nitrogen-fixing legume can also be relevant. Finally, with careful characterization of cropping systems, it may be possible to use case studies to generalize between similar systems.

Nevertheless, the more widespread nature of diseases and pests make them a more appropriate focus of action for an international center, while location specific soils research would seem to be more within the comparative advantage of national or even sub-national research. **The Panel commends AVRDC's priority on plant protection research and sees this work as a nearly unique role**. This does not rule out soils or plant nutrition research in particular cases where it is a major issue, but rather reflects agreement with the greater emphasis that AVRDC is placing on biotic constraints in its production research.

Future Directions

AVRDC Production Theme scientists are rightly aware that the future of vegetable production is towards increasing intensification. Sustainable intensification could be the key concept. This may be particularly important for existing extensive systems. Cultural

practices that allow intensification and yet retain system ecological balance and sustainability need to be identified and implemented.

The form that intensification takes is different in East Asia, where management and input use are already very high, compared to Africa, which is starting from a base of more extensive systems. While scattered pockets of small-scale, relatively extensive vegetable production may still persist for some years, even decades, the overall tendency is towards more intensive production systems. Consequently, AVRDC is right not to focus too much on perpetuating minimum input systems, but instead envisages a future of greater intensification. Opportunities for more intensive systems, for example, could include vegetables as an understory crop in tree systems, or peri-urban farming where intensive crop management and input use can be compensated by growing urban demand for vegetables.

The research challenge, even in relatively extensive vegetable systems in sub-Saharan Africa or the central tribal belt in India, is how to effectively promote systems intensification to increase productivity. In this process, AVRDC may be able to leverage the experience of farmers that have already undergone the transition to more intensive systems. The adjustments that farmers have made in countries like South Korea or Taiwan may provide clues for the development paths appropriate in those parts of Asia and Africa that are today less intensive. However, with its focus on small farmers in low-income countries, it is not appropriate for AVRDC to give priority to research on the highly intensive vegetable production systems that are diffusing from high-income to middle- income countries. The research and development priority for AVRDC should thus be neither on production systems that are in a low input equilibrium trap, nor on highly intensive systems that are practically industrialized; rather, priority should remain on small farmer systems in low-income countries that are in a process of transformation.

Production research may wish to link more closely to nutrition. Although farmers will of course always be concerned with incomes, analyzing production systems through the lens of “nutrient productivity” could be a useful approach, especially from a policy or advocacy perspective.

The scope of the challenge to improve vegetable production systems is immense in comparison to the resources that AVRDC can deploy. Even the doubling or tripling of AVRDC’s resources would not redress the imbalance between limited research resources and vast needs for vegetable improvement. Howsoever successful AVRDC may be in future resource mobilization, capacity is going to continue to be stretched compared to demand. Choices therefore remain inevitable. Above in this section the report discussed choices between plant protection and soils or agronomy research; elsewhere, the need for crop choices has been discussed (Section 2.3). Priorities also have to be considered among which crop systems AVRDC works on.

There is huge variation among vegetable production systems, depending on market preferences, resource endowments, climate and soils, and human and social capital. AVRDC cannot possibly deploy resources to deal with all this complexity through Africa and Asia and beyond. To some extent this reality is the basis for AVRDC’s heavy investment in research on information of broad applicability as an international public good or as a component to technology to be integrated into specific systems. But AVRDC

is right to engage with research on vegetable systems as well; research on knowledge generation alone risks becoming untethered to practical applicability.

As part of the priority planning exercise discussed above (Section 2.3), the Panel believes that the Production Theme should make explicit priorities among the production systems and constraints on which it will work. Such a prioritization exercise could start with an analysis of the potential impact on development outcomes of improving different production systems. This would be based on an analysis of production constraints and the importance of different systems to human nutrition, farmer income, or opportunities for women, etc. Alternatively, AVRDC might wish to consider its flagship technology components (e.g. grafting, biopesticides, varieties, etc.) and where they might most effectively be deployed. A qualitative analysis based on expert knowledge supported by secondary data rather than a formal modelling approach should be sufficient for this exercise.

Once AVRDC prioritizes research for different production systems, it would then enter into negotiation with national partners and donors to seek collaboration and funding. The reality is that unrestricted resources can never be remotely adequate to support systems research, but there are substantial resources available from development-oriented donors to support systems improvement work. By making a clear analysis of the priorities among systems, AVRDC will be in a better position to influence its national and donor partners about what systems to work on. This can never, though, be a unilateral AVRDC decision.

Accepting negotiation about priorities with donors and national partners is not becoming donor-driven; it is simply good partnership skills. A thorough prioritization among vegetable systems will not allow AVRDC to decide by itself where to work, but it will provide important elements for dialogue with partners and a roadmap for AVRDC about where to place the most effort in developing proposals for partnerships and mobilizing resources.

In the Production Theme's work on its third output, dissemination of technology, there is considerable recognition of the need for adaptive research and participatory evaluations. Participatory studies in Odisha, India, identified key constraints and opportunities for vegetable production. Adaptive research in Bali, Indonesia, showed how seedling management can increase chili production. These approaches need to be stressed even more.

Indeed, co-innovation with partners and beneficiaries may be a healthier guiding principle than dissemination, with its strong implications of distributing something ready-made, top down from a central source (Section 7.1). Community action plans and participatory action research could be key tools in this regard.

Sometimes there is tension between AVRDC's vocation for research and donor impatience to scale out technology from the shelf, but the case can be made that research findings can be gotten out more quickly by moving to participatory evaluations and adaptive field trials at an earlier stage in technology development. Testing innovations with farmers early in the prototype stage can enhance learning, speed technology development, and kick start diffusion. Moving from a "dissemination" approach to one of "co-innovation" with farmers melts the boundary between research and development,

thereby helping to ease the contradictions that are sometimes perceived between research and development.

3.5 Consumption: Nutrition and Health

Due to the critical links between vegetables, nutrition and health, historically AVRDC has probably been the international agriculture research center with the second-highest investment in nutrition research. Vegetables are important sources of micronutrients such as vitamins and minerals and are also high in dietary fiber. While increased consumption of vegetables can alleviate the nutritional deficits in the malnourished world, the developed world can also benefit from greater intake of vegetables to prevent non-infectious chronic diseases, which are the major causes of death.

Nutrition research makes essential contributions to AVRDC breeding programs: locating baseline of good or enhanced nutritional quality (tomato, pepper, mungbean, pumpkin, bitter gourd); identifying variability in nutritional quality; helping to understand its inheritance; developing molecular markers; and introducing genes for nutritional quality in suitable agronomic backgrounds.

Laboratory studies have also been an important dimension of AVRDC nutrition research. For example, 33 of the most popular vegetables in Taiwan have been evaluated for phytonutrients. Anti-inflammatory activity and cold/hot food nature of vegetables have been studied. A metabolomics approach to study phytochemicals in vegetables has also been developed in collaboration with Academic Sinica and the National Health Research Institute of Taiwan.

Recently, AVRDC nutrition research has expanded its work in community nutrition to take advantage of the potential of school and home garden programs. Community nutrition studies guide AVRDC in understanding food preferences, dietary patterns, food availability and nutrition gaps. This helps clarify which vegetables are appropriate for different target populations and can drive breeding priorities. Nutrition-sensitive, community-based agricultural interventions and strategies can enhance access to health-promoting diets.

AVRDC has undertaken a number of projects with important community nutritional components. The SRTT (Sir Ratan Tata Trust, India) project “Home gardens for diet diversification and better health” emphasized the integration of food preparation and nutrition concepts in home garden training. The home garden program demonstrated that continuous vegetable and nutritional supplies from a 6 x 6 m^2 garden provided nutritious food to fulfil 60-100% of daily dietary requirements for vitamins A and C for a 4-person household (2 adults, 1 adolescent and 1 child) in India. Other nutrition-oriented projects include “Improving incomes, nutrition, and health in Bangladesh through potato, sweet potato and vegetables” (USAID); “Improving vegetable production and consumption for sustainable rural livelihoods in Jharkhand and Punjab, India” (Sir Ratan Tata Trust, India); and “Vegetables Go to School: Improving Nutrition through Agricultural Diversification” (Swiss Agency for Development and Cooperation).

AVRDC approaches nutrition from an agricultural perspective, but recognizes the importance of links between nutrition and health. Working with Giessen University in a BMZ-funded project, a food-based approach has been used to assess whether

consumption of bitter gourd can help manage type II diabetes. The effectiveness of bitter gourd treatment was confirmed in a human study with 65 and 62 pre-diabetics in India and Tanzania, respectively. Research in India revealed that consumption of bitter gourd (2.5 g dry powder/day) led to a significant ($P < 0.01$) reduction in body weight, body mass index, waist circumference, fasting blood glucose level and glycosylated hemoglobin (HbA1C) level. This project also developed new protocols for studies of bitter gourd phytochemicals and efficacy using cell and animal models, and it also worked with a certified food factory to generate bitter gourd processing techniques to mask the bitter taste of bitter gourd for use in "blinded" human trials in India and Tanzania. Among several publications, this research yielded five SCI journal papers.

In the future, laboratory-based food and nutrition research will remain an essential part of AVRDC nutrition research. These studies are crucial for assessing food composition and nutritional and functional values of food, especially indigenous and/or locally important but underutilized or under-researched vegetables. Nutritional values will continue to be taken into account in varietal development. Breeding for improved nutritional quality should be explored/expanded when 1) sufficient genetic variation exists, 2) effort to breed such varieties is worthwhile, justifiable, and cost-effective, and 3) improved varieties could contribute significantly towards better nutrition and incomes. In addition, basic biochemical research could help better understand the health-promoting compounds in vegetables, which would support improved breeding, postharvest handling, processing, marketing, and promotion of increased vegetable production and consumption.

Nutrient-rich vegetables cannot contribute to improved human health unless they are produced and consumed. Through the research work of community nutrition in field data collection, food behaviors and nutritional requirements can be understood. With community nutrition education and promotion, the gap in the value chain between agriculture and public health nutrition can be filled. Community nutrition thus plays a significant role in dissemination of AVRDC's R&D results and in achieving the outcomes of AVRDC in improving the health of low-income people.

Recent worldwide interests in the health-promoting properties of plant materials, especially vegetables, offer another opportunity for AVRDC to attract donors from developing or developed world to conduct research on the health benefits of the phytochemicals in vegetables, especially indigenous and traditional vegetables. Strong partnerships with health sciences are essential because AVRDC is not a health research institute. Understanding and monitoring health impacts of vegetable consumption and the effects of health enhancing phytochemicals are beyond AVRDC's scope. Consequently, new partnerships are required, both in target and high-income countries. Resources in the health field dwarf those available for agricultural research. AVRDC can play a niche role by bringing an agricultural dimension to research efforts typically led by health science partners. AVRDC has to have in-house nutrition research strength to engage in these partnerships. Moreover, nutrition is so central to AVRDC's mission and research that this area cannot simply be outsourced to partners.

As recommended above (Section 3.1), to achieve these vital objectives, nutrition should be treated as one of AVRDC's main research themes. Demerging nutrition research from Theme Consumption could signal the priority AVRDC gives to this research while

providing a more coherent organizational platform to support expanded nutrition research.

3.6 Consumption: Market Chains and Postharvest Management

Overview

In line with the EPMR Panel's recommendation to emphasize nutrition research as a separate theme (Sections 3.1 and 3.5), the remaining principle elements from the former consumption theme naturally form a related theme of marketing and postharvest management. Postharvest work aims to improve the physical handling of vegetable crops after harvest, with a principal focus on reducing postharvest losses. Marketing research examines the value chain from the farm to the consumer, aiming to understand how small farmers and other disadvantaged groups like women farmers or traders can better participate in the value chain and claim a greater share of the value that is created. Market and consumer demand studies can improve understanding of the psychological and socio-cultural constructs of low (or increased) vegetable consumption, serving as a crucial input to Breeding and Production Theme-related technology development.

Postharvest research and development initiatives were revived in 2012 with two major projects, after having lapsed since 2010. Several adaptive research studies on simple postharvest handling techniques have been conducted in Africa and Asia. To facilitate dissemination of improved postharvest practices, a Postharvest Training and Services Center (PTSC) was set up in Arusha, Tanzania. In other work on postharvest handling and research on evaporative coolers in Tanzania found that these practices extended shelf life of green leafy vegetables 25%. Similarly, new packing methods for tomatoes were shown to lower damage from 52% to 22%. Surveys for postharvest needs assessment were conducted in Tanzania, Ghana and Kenya. In addition, a seconded scientist joined the group at headquarters to strengthen postharvest lab-related research in early 2014.

Vegetable value chain studies in several countries such as Mozambique and Malawi, Bangladesh and Indonesia were conducted and published. Innovative approaches for linking to input and output markets through market information systems and entrepreneurship skills were tried in selected countries in Africa and the Pacific. For example, AVRDC researchers collaborated with the IT department to develop a more efficient and web-based user friendly seed supply and distribution system and produce marketing databases in Tanzania, and facilitated the development of a participatory market guaranteed system in Fiji Islands.

Overall, AVRDC work in this area has concentrated on adaptive research and development activities including training rather than strategic upstream research on food processing or food technology. AVRDC is working to facilitate a process of transformation in the vegetable sector, from subsistence home or community gardens on through successive stages of greater intensification of production and increasing commercialization.

In the first stage of the transformation vegetable production is promoted in home or community gardens to improve nutrition in an essentially subsistence setting. This work is carried out in collaboration with AVRDC community nutritionists who work to understand local attitudes and dietary practices to promote increased awareness of the

benefits of vegetable production. Scaling out of validated vegetable food-based intervention technologies, for example, home and school garden interventions with complementary seed kits, are priority activities in this stage.

In a second stage of transformation, farmers who have been principally staple grain producers diversify into vegetable production as a commercial enterprise in a mixed farming system. Making this transformation involves participation in new marketing systems and coming to grips with unfamiliar issues involved in the postharvest handling of a high value but highly perishable product. Most of AVRDC's work is concentrated on this group of farmers. The principles involved in these processes are well-known, so AVRDC's focus is on adapting known concepts to new situations rather than on strategic upstream research. In addition, the formation of farmers' associations and other platforms for collective market action and advocacy has to be a concern during this transformation.

A third transformation is beginning in middle-income countries with the rise of specialized vegetable producing agro-enterprises. Increasingly these farmers will become the main source of vegetables to a growing urban population, already the majority in Asia and soon to be so in Africa. Food safety, increased on-farm processing to add value, and new market structures all become important issues with this transformation. It is to be expected that in the future AVRDC will become more involved with these types of value chains as their importance increases in low-income countries.

Because most of AVRDC's work on postharvest and marketing is right on the cutting edge of rural transformation, development-oriented donors strongly support this work. Thus, AVRDC relies mainly on the mobilization of restricted projects to fund this work. As noted below in Section 6.5 on resource mobilization, this research theme is the least dependent on unrestricted resources. Although projects are an important funding source, reliance on such funding creates challenges for the research process. AVRDC needs to avoid the mere implementation of a disconnected set of development projects tailored to the regional priorities of particular donors.

AVRDC must consistently look for opportunities for cumulative cross learning among different restricted projects. Development-oriented donors may not always be inclined to support such research activities. There are two principal ways AVRDC can overcome this limitation. First, since donors usually have a strong interest in evaluation, research can often be designed around evaluation questions: Do community gardens increase vegetable consumption? What type of organizational approach best enables small farmers to enter vegetable markets? How are the benefits of improved postharvest handling distributed among participants in the marketing chain? A second approach to keeping a coherent research framework across a set of separate donor funded projects is the strategic use of unrestricted resources to ensure that some common lessons can be learned across projects.

Besides differences in the financing of this theme, it also differs from most other AVRDC themes in the nature of the partnerships in which it is involved. At the national level, universities or specialized institutes are typically more involved in postharvest and marketing issues than national agricultural research institutes, which are AVRDC's more usual partners. In addition, work in this area requires close partnerships with private sector traders and processors and with development agencies promoting rural change. It

is far more effective for AVRDC to work through development partnerships rather than to try to massively scale out to farmers on its own. Consequently, building partnerships and strengthening the capacity of partners is a key part of this theme's work. These partnerships are an integral part of resource mobilization approaches to development-oriented donors.

Future Prospects

The postharvest dimension of this theme is expected to continue to focus mostly on the adaptation of existing technology to new emerging vegetable value chains. However, as the vegetable sector progresses, new challenges and opportunities are likely to arise. For example, there could be unique opportunities for innovation in the postharvest handling of traditional indigenous vegetables. There could be future partnerships with retailers or food processors to develop new products based on traditional indigenous vegetables that could enhance their attractiveness in rapidly growing urban food markets.

Postharvest and market research, though, should not serve solely to enhance vegetable value chains, for example, by helping to improve the nutritional status of the urban poor or enable indigenous vegetables to compete in non-traditional markets. A focus of this theme also has to be keeping the small-scale producer as an active element in modernizing value chains, earning a proportionate share of the value. Research on smallholder market linkage opportunities and *value webs* can help to upgrade value chains to enhance smallholder incomes while ensuring consumers receive good value for money. Of potential importance in this regard could be policy-related studies, including integrated biophysical-economic policy modelling of the impact of vegetable value chains on smallholder welfare.

Consumer studies can identify options for bridging asymmetrical market information between producers on one hand and the dynamic preferences of consumers in terms of taste, texture, form, price, convenience, and quality and safety attributes, etc. Similarly, it would be useful to have evaluation studies on the effectiveness of social marketing technology dissemination approaches (e.g., mass community rallies, radio programming) on the nutritional outcomes of key interventions.

Low-cost technologies that reduce postharvest losses could be evaluated not just from an economic perspective, but also in terms of nutritional impact. Farm business and entrepreneurship skills and farm records training will be useful for enhancing integration of smallholders into global value chains. Earlier up the value chain, at the point of farm inputs, promoting farmer-led seed and seedling enterprise development, including grafted seedlings, could be a high return activity for AVRDC. Strengthening existing market information systems and building collaborative networks (e.g. with CABI) on information and communication technology to link smallholders to high value markets might also be worthwhile.

3.7 Disaster Management

AVRDC has an established history of disaster recovery work with communities after natural disasters and in post-conflict situations, for example in Fiji, Haiti, India, Indonesia and Mali. The work primarily involves the provision of seed kits of hardy, fast-growing and nutritious vegetable crops, accompanied by information and sometimes

training. Typically the distribution of seed kits is carried out by a third party. The work represents only a small part of AVRDC's activity and currently falls within the objectives of Theme Consumption alongside work on home gardens and community nutrition. It also draws from AVRDC expertise in selection and multiplication of environmentally adapted vegetable species and varieties.

Disaster management is increasingly seen an important subject in its own right with a range of disciplines working to avoid or minimize potential losses from disasters, provide rapid and appropriate assistance to disaster victims, and achieve rapid and sustainable recovery; all within the so-called disaster cycle of mitigation, preparedness, response and recovery. There has been limited research into the effectiveness of short- and long-term impacts of disaster interventions. While there is evidence of medium- to long-term benefits of disaster recovery interventions to post-disaster communities—including adoption of new crop diversity or production technologies—the approach also has pitfalls, with evidence in some areas of adverse effects on local crop diversity, vegetable supply chains, seed suppliers or the environment.

The specific linking of agriculture to disaster management is an area where few IARCs are active and could represent a niche area of research and development for AVRDC where it has a head start and comparative advantage. The area might also attract support from a different or wider donor base than other AVRDC focus areas, including both governments and humanitarian agencies.

The Panel does not wish to give a recommendation to management as to whether AVRDC should continue to work in this area, nor whether work, if continued, should remain at the present level or be developed more seriously. However, the Panel suggests that AVRDC commission a disaster management specialist to review the work of AVRDC, assessing its performance against best practice elsewhere and the potential for further involvement in research and development within the full disaster management cycle.

Suggestion No. 1: The Panel strongly suggests that AVRDC commission a review into its role in disaster management.

3.8 Research Quality

To fulfil its remit as an international research organization, AVRDC has to aim for excellence in all of its activities, but especially in research. A reputation for research quality is an extremely important way of demonstrating its excellence to potential donors, to reviewers of competitive grant applications, and to potential partners. Externally, donors and research funders need assurance that AVRDC has well-qualified staff with a proven track record of high quality research outputs, and the necessary facilities and resources to undertake research in relevant areas at the highest level. They also need assurance that institutions have management structures and procedures in place that enable research projects to progress satisfactorily to successful completion. This includes attention to issues such as ethical approval procedures and financial accountability, as well as monitoring and reporting arrangements. Internally, assessment of research quality is useful for management in considering value for money of individual research programs and deciding future allocation of resources, to ensure that research is carried out where

it can be properly supported, and that limited funds and other resources are distributed to best effect.

Research at AVRDC

As part of the 8th EPMR, the Panel considered the quality of research at AVRDC. For criteria of research quality, the Panel referred extensively to published work by UK REF2014 Research Excellence Framework (2011) and UK Research Information Network (2010). AVRDC operates over a wide range of research. The Panel recognizes that AVRDC conducts research across the spectrum of applied or adaptive at HQ and in the regions. Basic and strategic research has traditionally been conducted mainly at HQ, but this is less the case since much of the breeding work has been decentralized to the regions.

In research terms, AVRDC has a very wide remit, ranging from genetic improvement, research into improved methods of vegetable production and protection, the nutritional and health value of vegetables, and field evaluation of its outputs in projects around the world. Its research covers not only traditional agricultural sciences but also health and social sciences, economics and development. The Panel does not attach greater weight to any particular topic or level of research and considers that the whole range of research activities, from pure to applied, can be of importance in achieving the development objectives of the Center.

An essential part of AVRDC's primary mission is to conduct research that can produce technologies with development potential and to ensure the impact of these on increasing production and consumption of nutritious and health-promoting vegetables. For AVRDC to retain its relevance and comparative advantage it is essential for a significant part of its research to be of the highest quality, generating new knowledge that feeds into downstream applied research.

Assessing Research Quality

Increasingly, the concept of research quality is considered as being much wider than a narrow assessment of peer reviewed publications. The UK REF2014 for example, in forming its overall quality judgment of an institution, assessed three distinct elements: outputs, impact and environment. The quality of research outputs is assessed in terms of their 'originality, significance and rigor', with reference to international research quality standards. Impact is assessed by the 'reach and significance' of impacts that were underpinned by excellent research, including social and economic impacts beyond the research environment, in the case of AVRDC's development objectives. Finally, the research environment is also assessed in terms of its 'vitality and sustainability', including its contribution to the vitality and sustainability of the wider discipline or research base, resources, staff development, graduate student programs, etc.

As part of the 8th EPMR, the Panel visited the facilities of each of the research themes at HQ, research facilities at the Regional Offices in Eastern and Southern Africa, West and Central Africa, East and Southeast Asia, and South Asia. The Panel held meetings with research staff of each theme and regional office. The Panel also had the opportunity to view lists of publications online and in annual reports, to review selected publications in more detail, and to interview research collaborators and beneficiaries. This approach

enabled the Panel to form an overall expert view of research quality. The panel did not attempt to carry out a detailed bibliometric analysis of outputs but did consider the extent of peer review publications, journal impact factor and citation data when looking at published outputs. The Panel did not assess research quality of individual staff members, but only of Themes and groups in a broad way. Bibliometric data such as impact and citation indices have been criticized as inaccurate and inequitable measures of performance, sometimes having a negative impact by adversely influencing what is researched and constraining where and how it is published. However, many research funders and donors such as DFID do pay attention to bibliometric data and may require proof of a track record of publication in journals with a particular minimum impact factor, so it is impossible to avoid these issues entirely. The impact of AVRDC research is dealt with in the sections of this report devoted to the individual research themes and regions. Monitoring, evaluation and the measurement of impact, and suggestions for how to improve these are covered in Section 7.7. This section is primarily concerned with research quality as defined by research outputs and environment.

The assurance of research quality at the level of the individual researcher is a management function of the institution. Clearly it is essential that the Center recruit staff with excellent track records, and retain and promote staff who produce high-quality research and attract research funding. The Panel understands that at the individual researcher level, AVRDC assesses research performance against agreed objectives as part of the staff appraisal process. These include performance measures such as volume and quality of research outputs; knowledge transfer and exchange; professional contribution and measures of esteem; administrative duties and performance; and resource mobilization.

Research Quality

Overall, the Panel recognizes that most of the research is of high quality and relevance, with examples of excellence. The research carried out using molecular techniques is of high standing. The application of molecular techniques to map genes of interest and develop protocols such as genotyping by sequencing and marker-assisted selection will allow AVRDC plant breeders to improve efficiency and produce outputs that could not be accomplished through conventional breeding. This work provides the foundation for significant downstream gains through the breeding programs. It has enormous potential for high returns on investment in achieving AVRDC's goals. The Panel encourages AVRDC to further develop its work in this rapidly evolving area of molecular plant breeding, to widen its application within the current range of crops to which it is applied, and to widen its focus from heat tolerance and multiple disease resistance to include more work on traits related to nutrition and health.

AVRDC's research to improve production methods also has good examples of advanced research leading to significant innovation, including the development of integrated pest management technologies of major insect pests. Research into interspecific grafting has the potential to yield significant advances in developing soil-borne disease and abiotic stress tolerant rootstock/scion combinations. By exploiting AVRDC's germplasm collection fully, and linking the grafting work closely to the breeding program, AVRDC can make important advances in this area.

On the other hand, much of the effort directed towards improved vegetable production is downstream adaptive research on well-established technologies, trialing best-bet technologies or evaluating techniques developed elsewhere. These categories include the work in developing technologies to improve soil nutrient use efficiency, some of the IPM interventions, postharvest storage techniques using zero energy cooling chambers, and the application of biochar. While each of these areas is valuable in its own right, the Panel believes there is a higher priority need for a pipeline of novel production technologies, unique to the Center, coming through from the upstream research and feeding into adaptive research in the regions.

Recommendation No. 5: The Panel recommends that AVRDC ensure that its elite upstream research delivers significant innovations in vegetable production.

Funding Upstream Research

Funding upstream research is clearly a challenge for AVRDC. Restricted funding is increasingly focused on development projects with limited opportunity for even applied research. With many demands on core unrestricted funding AVRDC has limited opportunities to fund significant amounts of in-house research from its own funds. In this context, the Panel shares the enthusiasm for the Innovation Fund for which Management recently got Board approval. It promises to be a mechanism to support exciting new research initiatives on a time-bound basis. It offers the flexibility for AVRDC to seize the initiative to respond quickly to new scientific breakthroughs. It could be an important vehicle for enhancing science quality. Initially it was financed on a one-time basis from an excess accumulation of reserves. It would appear to merit inclusion in the budgeting process on a regular basis if at all possible.

Suggestion No. 2: The Panel strongly suggests that the Innovation Fund become a regular part of budgeting.

Research Environment

Because its research is impact-oriented, deeply innovative cutting-edge research work may not be the highest priority for AVRDC, while acknowledging the need for evidence of research excellence discussed above. Where AVRDC staff have successfully published in high ranking scientific journals, most such publications are the results of teamwork with academic scientists. This is very positive. Therefore, to increase research of high scientific standard, the panel recommends that AVRDC should encourage greater collaboration with outstanding universities and research institutes. Inviting scholars to spend sabbatical leave at AVRDC, encouraging AVRDC scientists to be adjunct professor of universities, and co-advising graduate students are all ways to enhance research quality at AVRDC.

Suggestion No. 3: The Panel strongly suggests that AVRDC further strengthens its collaboration with academia and research institutes to improve research quality.

The Center's HQ in Taiwan, where most of its elite experimental work is conducted, currently has excellent research fields, glasshouses and laboratories necessary for its research programs. The Panel considers it essential that the Center has an ongoing program of adequate capital investment to ensure that state-of-the-art facilities are

available to support cutting-edge research. This includes a commitment to resourcing the molecular research facilities that are vital to the excellent molecular plant breeding approach and to the valuable diagnosis and characterization of major insect pests, and viral, bacterial and fungal pathogens. Investment may also be needed to upgrade the facilities to allow more cutting-edge research in the areas of nutrition and health, and in vegetable production. The Panel appreciates that it may be cost effective to outsource some laboratory analyses where a cost-benefit analysis indicates that this is preferable to establishing in-house capability.

Recommendation No. 6: The Panel recommends that AVRDC make adequate investment to maintain state-of-the-art laboratory facilities.

Maintaining Research Quality

The Board of Directors takes its responsibility to oversee the AVRDC research program seriously. Regular scientific presentations are made to the Program Committee of the Board, and several Board members have strong scientific backgrounds. Although Board members do have some interaction with scientists and visit some research locations, time does not permit Board members to become intimately familiar with AVRDC research. Though part of individual staff appraisal and targets, assessing and benchmarking research quality does not seem to have been a priority for the Center and could be improved and expanded. The Center does list its publications in the annual report and distinguishes those published in impact factor journals.

Although the Panel recognizes that much of the science at AVRDC is of high quality, it believes that regular intensive reviews by distinguished outside scientists would serve many valuable functions. It would offer AVRDC scientists the opportunity to interact with leading scientists in their field about the latest directions in research; it would be an important support to the Program Committee of the Board in the exercise of its oversight responsibility, especially taking into account that the Board will not always have scientific expertise in all AVRDC research areas; and it would provide to external stakeholders credible technical appraisals of AVRDC research quality from reputable scientists.

The precise functioning of external scientific reviews would have to be determined by the Board based on a proposal from Management. In general terms, though, in consultation with Management and scientists, the external reviewers should be appointed by and report to the Program Committee of the Board, which would also approve the terms of reference for the review. The size of the panels could be limited to two or three and their work could be done in two weeks, including time for desk work.

Recommendation No. 7: The Panel recommends that external in depth scientific reviews of AVRDC research programs be regularly commissioned.

UK REF2014 Research Excellence Framework. 2011. Assessment framework and guidance on submissions. Available from: http://AVRDC.ref.ac.uk/media/ref/content/pub/assessmentframeworkandguidanceonsubmissions/GOS%20including%20addendum.pdf

UK Research Information Network 2010. Quality assurance and assessment of scholarly research. A guide for researchers, academic administrators and librarians. Available from: AVRDC.rin.ac.uk/quality-assurance

4. REGIONAL PROGRAMS

4.1 East and Southeast Asia

AVRDC's first regional office was established in East and Southeast Asia in 1992. It grew out of an earlier bilateral effort, the Thailand Outreach Program, which dated back to 1982. A 25-year Memorandum of Agreement (MOA) was signed in 1992 between AVRDC and Kasetsart University (KU) which was designated the official collaborator and host agency by the Royal Thai Government. The AVRDC administrative office is located at the Bangkhen campus of KU in Bangkok while field sites, laboratory, training facilities and cucurbit breeding are located at the Kamphaeng Saen campus of KU in Nakhon Pathom Province. KU established the Tropical Vegetable Research Center adjacent to the AVRDC's Research and Training Station in the spirit of the MOA signed in 1992 to serve as the Thai counterpart for the regional center.

This regional office supports work in 16 countries including 10 ASEAN countries. Currently, seven AVRDC staff (2 IRS, 5 NRS) are located at the Administrative Office in Bangkhen and sixteen (1 IRS, 15 NRS) are based at the Regional Research and Training Station at Kamphaeng Saen. Increases in local wages is making it more difficult for AVRDC to recruit suitable staff at what has heretofore been considered affordable costs.

The region has 10 donor-funded projects at the moment. Six of these are regionally led, and four are led from headquarters. Misunderstandings between the regional office and HQ have sometimes been counterproductive with unfortunate effects on relations with partners and donors. With new personnel in place and implementing the EPMR recommendations on management (Section 6.2), such incidents can hopefully be avoided in the future.

The International Vegetable Training Course (IVTC), now in its 33rd year, is a highly regarded and prominent activity that serves training needs not just for this region, but also for other regions and AVRDC HQ. In the last five years, 202 participants have been trained. The course is co-organized by regional staff, KU, Mahidol University, and the Department of Agriculture. The annual training course consists of units on vegetable production, postharvest technologies, farmer education, human health and nutrition, and vegetable economics as well as cross-cutting issues like gender and climate change.

The major achievements of this region in the last few years include (1) establishment of a vegetable R&D network, (2) creation of the global cucurbit breeding program in Thailand, where disease-tolerant lines have been bred and tested in Cambodia, Lao PDR, Philippines, Tanzania and Vietnam, and commercialized by Thai based seed companies, (3) identification of bitter gourd lines tolerant to powdery mildew and pumpkin lines with desirable fruit shape and size, and (4) revitalizing and strengthening of the International Vegetable Training Course, with high enrollment numbers and international recognition for this KU-certified course.

The level of collaboration between AVRDC and KU has varied over time but has been strong recently. Before the AVRDC/KU MOA expires in 2017, the future relationship needs to be consolidated to ensure continued regional operations from a Bangkok base. This depends on commitment to co-development of tangible outputs such as scientific

publications and high visibility research products, outcomes and impacts. While the IVTC is an excellent platform for exchange of technologies, there needs to be more focus on development of demand-driven and utilized technologies specifically for the region through research projects.

New research projects will need to be developed with donors in Bangkok and the region. Regional strategy has to cultivate two broad types of partnership. First, more development-oriented projects can be formulated to attract international funding for work in the low-income countries in the region with relatively weak research capacity (e.g. Cambodia, Laos, Myanmar, etc.). Second, in more prosperous countries with better developed vegetable sectors and greater national capacity (e.g. Thailand, Malaysia, etc.) AVRDC needs to work with partners to design joint projects that are largely nationally funded (Section 5.3).

Both types of project are needed to strengthen vegetable research and development and to overcome the lack of a critical mass of AVRDC scientists in the region. Heavy reliance on support mediated from HQ has been vital to sustain work in the region, but to attract new partners and donors, the regional office has to gain increased visibility and credibility.

For middle- to high-income countries, nutrition and food safety is key and could become a major area of future work. Research is needed to ensure that only appropriate pesticides are used (type, timing and dose, and to include biological alternatives) that are effective against the causal agent of disease (through appropriate diagnostics), that clean water is used during production, and that perishable products are free from human disease (due to improved sanitation).

For low-income countries, support on establishment of sustainable cultivation is required. Future focus could be on improved nutrition through vegetables through breeding, postharvest management, and community nutrition work. For all countries, more resilient systems are needed. This requires more attention to natural resource management and agronomy, mixed cultivation systems, and market linkages. All of the aforementioned activities have to be open to collaboration with the CGIAR, NGOs, landscape and forestry partners if the AVRDC regional office is to be successful.

There are good opportunities for the future development of regional research in East and Southeast Asia. With the significant economic progress in the past three decades in this region, demand for safe, nutritious and culturally appropriate vegetables is increasing. Vegetable production systems must be modernized and become more environment-friendly and climate-smart. AVRDC can take advantage of the extensive network of alumni from AVRDC's Training Courses and look for donors internationally or within the region (such as the Asia and Pacific Seed Association) and thus contribute to the heath of people in this region.

The People's Republic of China (PRC), the world's largest producer of vegetables, is naturally an important player in the region. The PRC was initially somewhat isolated from the international agricultural research system (i.e. the CGIAR). Nonetheless, the PRC has achieved a major transformation in agriculture, largely through its own efforts and with little direct international assistance. The PRC has had some exchanges of technology and received some training from the international system, and this has

included AVRDC. Scientists from AVRDC have visited the PRC; nurseries have been sent; and Chinese scientists have received AVRDC training.

AVRDC has for some time sought to strengthen these ties, but the PRC response has varied with shifts in broader geopolitical concerns with which AVRDC, as a non-political independent entity, has no involvement. AVRDC is always open to greater interactions with the PRC, recognizing that as the world's second largest economy, the PRC has abundant resources for agricultural research and is not a significant recipient of international development assistance. Important opportunities for technical cooperation remain to be realized.

Some AVRDC partners have expressed the sense that the PRC on occasion may have exerted its influence to discourage international agencies and even individual countries from collaboration with AVRDC. While this is disappointing and inconvenient, AVRDC operations have for the most part continued un-impeded. Regardless of geopolitical factors, AVRDC will continue to explore possibilities for technical exchange and a true partnership with Chinese research institutes.

4.2 Eastern and Southern Africa

AVRDC has established a solid foundation for promoting vegetable production and consumption in Eastern and Southern Africa. The resources that the Center has assembled support a varied research program that is yielding results.

It has developed field, laboratory, training and office facilities at its regional station in Arusha, Tanzania. The Center has assembled a critical mass of eight international scientists with support staff covering a wide range of disciplines: genetic resources conservation, breeding, socioeconomics, and postharvest management. From the regional office, numerous activities in several other countries in Eastern and Southern Africa are being supported. Important partnerships have been established with private sector seed companies, national and international research organizations, community-based organizations, non-governmental organizations, and governments. Significant donor support has been attracted. For example, USAID supports traditional vegetable production for nutrition and market development; FAO has funded the distribution of disaster relief seed kits; GIZ supports research on disease and pest management; and Taiwan has provided funds for the development of infrastructure at the regional research station.

The deployment of these human and financial resources has led to a diverse research and development effort. A significant collection of vegetable genetic resources is conserved at the regional office. There is an active selection and breeding program working on the improvement of indigenous African vegetables (e.g. African eggplant) while tomato, pepper and mungbean lines have been introduced from other locations. Postharvest loses in the region have been assessed, and techniques for improved handling have been tested. The regional office is also known for training large numbers of people in Arusha, Tanzania or in-country.

This research is producing significant results. Tomato varieties developed by the Center have been distributed through the regional office and released by the Tanzanian national program. They are now the dominant varieties in Tanzania and private seed companies

are disseminating these varieties to other countries in the region. Young farmers have been trained to tap into new market channels to make traditional vegetables available in fast growing urban markets. Genetic resources are being conserved and made available to regional researchers.

AVRDC is thus bringing a number of strengths to the development of the vegetable sector in eastern and southern Africa: a multi-disciplinary team; good infrastructure; strong partnerships with the public sector, private firms and donors; the capacity to work across the entire vegetable value chain from genetic resources to postharvest management; and an unusual ability to work both in research and development.

The time is ripe for vigorous initiatives to promote the vegetable sector in the region. Per capita vegetable consumption is low, but with urbanization and recent improved economic performance, the demand for vegetables is growing fast. The private sector is making important new investments in the vegetable seed business, and food processing is beginning to take off. Specialization in vegetable production is advancing and larger national markets are appearing as transportation infrastructure has improved. Opportunities are plentiful to continue to scale out to other countries in the region. New partnerships are being built. There is a strong demand for training in vegetable production and research. There is recognition of emerging new problems like adaptation to climate change.

These strengths and opportunities notwithstanding, serious challenges remain. The regional team has many strengths, but lacks some expertise, for example, plant protection and nutrition. National agriculture research and extension systems in the region are generally very poorly funded and consequently have severely constrained operational capacity. Awareness of AVRDC remains limited in the region, despite over 20 years of presence. This lack of public awareness may impede both partnership and resource mobilization efforts. Pressure to achieve short-term progress in development outcomes and impact dilutes the attention that the Center's scientists are able to dedicate to research. Likewise, the team is hard-pressed to undertake the volume of proposal development and project reporting inherent in the high dependence on project funding that they face.

Looking forward, the regional team needs to undertake a number of tasks to deal with these challenges. Continued focus on traditional vegetables puts AVRDC in a unique position. Nonetheless, there is great diversity in vegetable species and production systems in the region. Priorities need to be clarified. New opportunities may emerge; for instance, relatively little has been done on mungbean in the past, but this crop could generate not only good local demand but also important export opportunities to South Asia. More attention could be placed on vegetable legumes.

Work on community nutrition should be strengthened, to identify how best vegetables can contribute to overcoming nutritional deficiencies; how to enhance public knowledge of vegetable consumption to improve health; and how vegetables can best be prepared in an attractive and appealing manner. The Center needs to work with partners in nutrition and health, but these are such critical factors that it cannot simply outsource all this work to partners; rather, the Center needs some capacity to at least work with partners on nutrition and health-related issues.

The Center should continue with a strong systems approach. This means first, proceeding on an understanding that vegetables are one component in complex farm systems involving staple crops and livestock. In addition, a systems approach has to span the entire vegetable chain, from breeding to postharvest handling and food consumption practices. Obstacles to an increased role for vegetables can occur at any point along the value chain: a new insect pest or plant disease; excessive losses in postharvest handling; or poor acceptance by consumers of an unfamiliar product.

Although AVRDC needs to retain the capacity for action at any stage in the vegetable value chain, it may not be possible to have the full range of expertise required within the region. Clearly that is the case for breeding: tomato breeding is based at headquarters; mungbean breeding in South Asia, etc. (Section 3.3). What is true for breeding is likely true for other disciplines, for example, pathology, entomology, molecular genetics, etc. While AVRDC needs to have a broad multi-disciplinary team in Eastern and Southern Africa, this team cannot work in independent isolation, but must work as part of an integrated global team, and this has implications for Center management (Section 6.2).

4.3 South Asia

Overview

South Asia has over one-fifth of the world's population and more malnourished people than sub-Saharan Africa. The Central India tribal belt is the largest concentration of poverty in all of Asia. Rates of child stunting are commonly around 50% and rates of anemia in women are often up to 70%. Per capita vegetable consumption across the region is below recommended levels.

AVRDC has been disseminating germplasm and training regional scientists since the 1970s. By the 1990s, AVRDC had joint projects and a regional network involving India, the world's second largest vegetable producer, as well as Bangladesh, Nepal and Pakistan. In 2006 AVRDC established a regional center in Hyderabad, India, graciously hosted by ICRISAT. Since then, AVRDC work in the region has expanded rapidly. AVRDC's global legume breeding, emphasizing mungbean, was moved to India in 2010 and a number of projects have been initiated in South Asia.

In addition to long-time scientific collaboration with the Indian Council for Agricultural Research, principally in germplasm improvement, since 2007 AVRDC has been working on production systems in the more technologically advanced Punjab, as well as in Jharkhand in the Central India tribal belt, where subsistence farmers are trying to make the transition to commercial vegetable growing as well as increase home gardening to meet nutritional needs. By 2014, AVRDC's work had expanded to seven projects across India supported by international and national donors to develop begomovirus-resistant tomatoes, chili and mungbean, home gardens, and improved bitter gourd varieties to address type-2 diabetes. AVRDC currently has 18 staff working in India.

In Bangladesh AVRDC has 13 staff working on projects to promote improved vegetable varieties and production practices as well as on the reduction of postharvest loses. In Pakistan AVRDC has 10 staff working on protected cultivation, mungbean improvement, and value chains in its single largest project worldwide. Nepal and Bhutan are also participating actively in AVRDC various projects, notably school gardens.

AVRDC's biggest research effort in the region is in mungbean breeding. This program has clear breeding objectives for rapid maturity to fit into rice- and wheat-based cropping systems; large commercially acceptable seeds; and yield. Recent work is focusing on improving bruchid resistance (a major pest of stored seed) and increasing the methionine content of seed. Improving mungbean tolerance to heat and salinity stress is expected to expand. This well-organized program has access to good field and greenhouse facilities at ICRISAT; testing sites throughout the region with national partners; and the support of AVRDC headquarters in the development of molecular markers and nutritional analysis.

Over a 20-year period AVRDC has led a consortium of 27 Asian national partners to breed fast-maturing, disease-resistant mungbean varieties that revolutionized the industry and increased Asian production by 35%. Maturing in less than 65 days, the improved varieties created a new niche for the crop in irrigated wheat/rice rotations, reducing fertilizer requirements by a quarter, improving cereal yields, and improving farmer incomes by up to $250/ha. By 2005 the improved varieties were grown on more than 1.5 million ha worldwide, and accounted for over 70% of the crop across the Indo-Gangetic plain from Pakistan to India and Bangladesh.

AVRDC tomato varieties have been taken up by local seed companies, which have co-invested in this work. Both for tomatoes and peppers, South Asian seed companies could become more involved with AVRDC in varietal development. Home gardens are another major area of effort that has revealed strong preferences, particularly in disadvantaged communities, for traditional vegetable species, which have been little researched but could have future potential. There are widespread reports of significant postharvest loses and AVRDC is seeking hard data to assess the importance of the phenomenon and how it might be addressed.

South Asia is the world's largest producer of eggplant, and during the monsoon season it is one of the few affordable vegetables for the poor. Eggplant fruit and shoot borer is the crop's worst major pest, and farmers regularly spray up to 140 times a season to control it, with considerable impacts on their health and the safety of the crop consumed. Between 2000 and 2006 AVRDC introduced a simple IPM package in India, Bangladesh and Sri Lanka involving pheromones and removing damaged shoots. It reduced pesticide use by 70% and growing costs by over 30%, increasing returns for winter crops by 60% and almost six-fold for summer crops. Nine companies got involved in manufacturing the pheromones, which reduced the price by 90%. Hundreds of thousands of farmers and consumers benefited across the three countries involved.

Future Prospects

AVRDC is undersized in comparison to the scale of the challenges and opportunities in vegetable improvement in South Asia. Any expansion depends principally on securing project funding in the region, and there has been strong recent growth, with restricted funding having doubled since 2012. With project funding, strategy becomes a question of assembling a coherent portfolio of projects that would be worthwhile to implement, rather than a resource allocation decision of unrestricted funds. AVRDC has been successful in keeping a strong research component in many South Asian projects.

Different partners and donors in the region are driven by different objectives. Some donors have a strict poverty agenda to focus on the poorest most disadvantaged farmers, while other partners see economic growth as the key to ultimately alleviating poverty. AVRDC needs to be able to address both agendas. Likewise, national research institutes value the opportunity to work with AVRDC on advanced research topics (e.g. late blight, begomoviruses, Cercospora, gene silencing, interspecific breeding, underexploited leafy vegetables and minor Solanaceae, protected cultivation), while local development NGOs appreciate not only AVRDC's technical expertise, but also AVRDC's collegial style, approachability and spirit of inquiry, which are seen as more helpful than the more traditional public sector approach of research delivering knowledge to extension in a linear, top-down relationship. AVRDC needs to continue to build partnerships with both types of organization, playing different roles with different partners.

AVRDC has many outstanding staff in the region, both international and national. Turnover could become a problem as the regional job market is far more fluid than it used to be, while the stability of international as well as national staff is also subject to fluctuations in donor support.

AVRDC can make further contributions to South Asia through new tomato, chili and mungbean varieties as well as through improved IPM practices. There are a large number of donor agencies seeking to have an impact in the region and strong science capacity in some national programs. There is an opportunity to consolidate home garden work, to strengthen our connections to the seed industry and to expand the work to include the development of indigenous vegetables, improved postharvest management, and protected cultivation.

4.4 West and Central Africa

West and Central Africa with a population of about 300 million people relies heavily on the complex mixed farming systems of smallholder farmers for food security. The region experiences severe climatic challenges and frequent crop failures. In the past decade there has been an increase in the cultivation of horticultural crops, in particular vegetables, mainly grown and traded by women. Growth in this sector has considerable potential to increase income for women and enhance household food and nutrition security. However, production and consumption of vegetables in the region remains far below ideal levels. Key issues that need to be addressed to improve vegetable production and consumption in the region include very high losses during production due to limited inputs and irrigation, poor cultivation techniques, insufficient pest and disease resistance, inadequate pest control practices, high postharvest losses due to poor storage and transport, and inadequate adaptation and dissemination of research-based technologies and knowledge.

AVRDC's Regional Office for West and Central Africa (WCA) is relatively new, existing in its current form only since January 2014, although AVRDC work in the region has been ongoing since 2003. AVRDC commenced operation in the region in 2003 with staff posted first in Côte d'Ivoire and subsequently in Mali under the umbrella of the Africa Rice Center. When Africa Rice relocated to Benin in 2004, AVRDC remained in Mali to form the sub-regional office for West and Central Africa, under the Regional Center for Africa in Tanzania, and was hosted by the International Crops Research

Institute for the Semi-Arid Tropics (ICRISAT). It also posted a vegetable breeder under a joint arrangement with ICRISAT in Niger in 2007.

AVRDC set up a liaison office for Central Africa in Cameroon in 2007, hosted first by the World Agroforestry Center (ICRAF) and then with the International Institute of Tropical Agriculture (IITA). A host country agreement was signed with the Government of Mali in January 2009 and the Government of Cameroon in August 2009. The sub-regional office became AVRDC's Regional Office for West and Central Africa (WCA) from 1 January 2014 and is no longer under the administration of the Regional Office for Eastern and Southern Africa. There has since been a determined effort to build a critical mass of staff at the regional level, including experienced professionals in plant breeding, cropping systems agronomy, food science and nutrition, socioeconomics, and project management. WCA has also established okra breeding capacity in Cameroon.

WCA works across AVRDC's four research themes. It focuses its breeding and selection work on three globally important crops; tomato, pepper, onion, and five regionally important traditional African crops: okra, eggplant, amaranth, jute mallow and roselle, and may possibly also work on nightshade. It has the global remit for onion breeding. Research and development in vegetable production is often carried out in an agricultural systems context that involves much wider crops diversity and vegetable/non-vegetable rotations.

WCA has received funding from an impressively wide range of donors including ACIAR, the World Bank-coordinated Multi Donor Trust Fund, CORAF, the Volkswagen Foundation, USAID and BMZ/GIZ. WCA has become a leading partner for vegetable research and development in the region as indicated by its involvement in the CGIAR Humidtropics Research Program and the USAID Africa RISING program.

Among recent achievements of WCA has been the development of the best practice hubs (BPH) model and its testing in southern Mali to achieve greater connection between research and practice. Varieties, technologies and educational interventions are tested at the hubs. The BPH model was visited in Mali by an EPMR Panel member. The technologies tested are now ready for large-scale deployment in southern Mali and elsewhere. Around 50 locally adapted improved vegetable varieties have been tested in the hubs, many receiving grower acceptance. Approximately 300 vegetable growers have been direct beneficiaries of the interventions at the hub sites, and about 200 of them have adopted the technologies. Recent breeding successes also include the release of 23 varieties in Mali in 2011 and 25 varieties submitted for release in Cameroon. WCA's collaboration with ICRISAT in Niger developed and promoted a model for combining water harvesting techniques, land reclamation and suitable varieties, known as the African Market Garden initiative. In March 2010, CGIAR presented AVRDC and ICRISAT with the 2009 CGIAR Science Award for Outstanding Partnership for this effort.

WCA faces many of the challenges experienced by AVRDC as a whole and identified throughout this report. WCA is heavily committed to projects at the development end of the research-to-development continuum. It has a particular need to avoid undertaking work that could be done by national extension systems or NGOs, especially where this occupies the time of its research staff. WCA's impact is almost certainly being

underestimated. The recent arrival at WCA of a new staff member for Monitoring and Evaluation should help this.

For the future, WCA must continue to be the organization of choice of donors and collaborators for vegetable projects in the region. This requires advocacy and networking, and local WCA management has this well in hand. The decentralization of roles and responsibilities from AVRDC HQ to the Regional Directors, as recommended in Section 2.3 of this report, will undoubtedly enhance the overall performance of WCA. WCA needs to increase collaboration with their CGIAR neighbors ICRISAT and ICRAF, and with the Malian NARES partner, IER. More access to biotechnology laboratories would be beneficial, probably via links with universities or other CGIAR stations. WCA needs to anticipate how vegetable production technologies, consumption patterns and markets in the region might change in the medium- to long-term and plan accordingly.

Target advances for 2015 are the demonstration of protocols for efficient seed production and drying to seed entrepreneurs and establishment of low cost storage facilities at vegetable technology immersion clusters and BPHs. WCA will likely continue its focus on downstream dissemination and adaptation of tested technologies, with the prospect of increasing its downstream research effort and engaging in more upstream work in breeding and production. Achieving this will require sound scientific evaluation of the technologies and dissemination process, issues equally relevant for the AVRDC's work in Eastern and Southern Africa and elsewhere.

4.5 Oceania

Oceania is a region covering the island nations spread over the vast tropics of the Pacific Ocean, with a total population of around 10 million. Countries in the region are among the lowest ranking in 2013 of Gross Domestic Product per capita in the world according to World Bank. Nearly 90% of Oceania's population is rural. Vegetable production can not only contribute to food and nutrition security, but can also improve the family income of smallholders in Oceania.

AVRDC started its work in the region from the Solomon Islands in 2006. Currently, there are two project offices, one in Honiara, Solomon Islands (set up in 2009) and the other in Sigatoka, Fiji (set up in 2012). The total staff is only three: one IRS and two NRS. The Australian Centre for International Agricultural Research (ACIAR) and Ministry of Foreign Affairs of Republic of China (MOFA) are the major donors to AVRDC in this region. The ACIAR projects are for smallholder gardens in Solomon Islands, high-value crop production (led by the University of Queensland), linking farmers to markets in Fiji and Solomon Islands (led by the University of the Sunshine Coast), and traditional vegetable production (led by Charles Darwin University). MOFA has provided funds to strengthen vegetable networking in the region, such as holding a workshop on vegetable production, and collaborating with Taiwan Technical Missions.

Although the region is short of staff, with the full support from the Production Theme of HQ there have been some major achievements, including (1) improving livelihood of smallholders through vegetable production, (2) establishing partnerships with international organizations, local ministries, NGOs, and farmer communities, (3) the first release of AVRDC tomato lines ('Rose's choice') by the Solomon Islands Ministry of Agriculture and Livestock in February 2014, (4) the expected release of AVRDC chili

pepper and sweet pepper lines in 2015, and (5) attracting a one-year service contract with WorldFish to guide communities in Malaita Hub on sustainable crop production.

Oceania is a region often overlooked by international donors. FAO has sent out a warning signal to donor communities on the state of food insecurity in Oceania. AVRDC has made impressive advances in this region in helping smallholders in vegetable production. The future contribution of AVRDC in Oceania is highly dependent on the legal status of AVRDC, diversifying donor support, and technical support from HQ. One possible future direction is to merge this region into the existing East and Southeast Asia office following the practice of other international organizations such as FAO and GIZ, in order to have more effective communication with donor communities.

4.6 Central Asia and the Caucasus

AVRDC has had a presence in Central Asia and the Caucasus since 2005. Its regional base is in Tashkent, Uzbekistan and covers Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, and Turkmenistan. AVRDC is physically located within the CGIAR Program Facilitation Unit and works within the CGIAR Collaborative Research Program for Sustainable Agricultural Development in Central Asia and the Caucasus. A significant amount of AVRDC's work in the region contributes to the Central Asia and the Caucasus Regional Network for Vegetable Systems Research and Development (CACVEG).

The countries vary in their economic status, with Azerbaijan, Kazakhstan, and Turkmenistan considered by the World Bank to be upper-middle income countries; Armenia, Georgia, Kyrgyzstan, and Uzbekistan lower-middle income; and Tajikistan a low-income country. An important constraint to the development of the vegetable sector in most of the former Soviet Union countries has been a lack of improved germplasm. The region has a challenging climate for agriculture and the cotton- and winter wheat-based cropping system has decreased soil fertility in many areas. There is a need for drought-, heat-, and salt-tolerant lines of vegetable crops, for crop diversification, and for improved varieties with commercial traits such as early maturity, resistance to diseases, and high yield.

The most important AVRDC activity is the collaboration with partner institutes to conduct regional vegetable varietal trials in all eight countries. Crops evaluated include tomato, pepper, eggplant, cucumber, vegetable soybean, mungbean, yard-long bean, cabbage pea, snap bean, squash, lettuce, basil, celery, and marrow. As a result, a number of new varieties have been released and included in State Registers and many others are currently under state variety evaluation. A significant proportion of new vegetable varieties released in the region during 2007-2013 originated directly from AVRDC genebank accessions. AVRDC has also successfully transferred tomato grafting technology in some countries to address the problem of soil-borne diseases. Work has also been carried out to increase the level of vegetable consumption through distribution of vegetable seed kits to home and school gardens, and the promotion of nutritious vegetable varieties and recipes in school and community garden programs and at farmer field days.

The AVRDC office for Central Asia and the Caucasus has a very small staff led by a Regional Coordinator supported by visits to the region by senior management and subject

specialists and normally one visit per year to HQ by the Regional Coordinator. Despite the small scale of AVRDC's operation, it appears to be highly effective, achieving impact and offering excellent value for money. The success is due to a large extent on the strong collaboration developed through national coordinators of the CACVEG R&D Network in each country, and through other public and private sector partners including seed companies and universities.

A major constraint to further development of AVRDC's work in the region is a lack of funding. It appears very difficult to mobilize financial support from within the region, although good networks and support in-kind in some of the countries goes some way to compensate for this. External donor interest is also variable, and there is little commitment from the three Caucasus countries in particular. Any substantial increase in AVRDC activity in the region would require more staff and would continue to rely heavily on collaboration with local partners. The Regional Coordinator already has a very heavy workload, including much hands-on delivery of training farmers and contributing to displays. In the short to medium term, critical mass is unlikely to be achieved in the Central Asia and the Caucasus office to increase its level of activity to that of the larger Regional Programs. The Panel has suggested elsewhere in this report that management explore whether there are any advantages in running this regional office as a sub-network from the South Asia Region.

5. PARTNERSHIPS

5.1 Global Partnerships

AVRDC has actively promoted institutional innovation in international agricultural research, having been one of the catalysts for the founding of the Global Horticultural Initiative (GHI) as well as the Association of International Research and Development Centers for Agriculture (AIRCA). AVRDC remains a committed participant in both these global partnerships.

GHI was founded in 2006 under the auspices of AVRDC, the Centre de cooperation internationale en recherche agronomique pour le développement (CIRAD) and the International Society for Horticulture Science (ISHS). It is an inter-institutional consortium that advocates for horticultural research, encourages networking among horticultural scientists, and strengthens horticultural research capacity in low-income countries. It serves as a forum to bring together major players in international horticultural research including, among others, the USAID Horticultural Innovation Lab, FAO, and GFAR (Global Forum on Agricultural Research). The Director General of AVRDC is the Chair of the Board of GHI and AVRDC formerly hosted the GHI secretariat at its regional center in Arusha, Tanzania. Taiwan has been a generous donor to GHI. **The Panel commends AVRDC, in particular the Director General, for compelling and tireless advocacy for the vegetable agenda.**

AIRCA is an alliance established in 2012 that brings together nine established international research centers. Together, it members have a combined turnover in excess of US$ 200 million/year and operate in over 60 countries comprising more than 70% of the world's population. The focus of the alliance is on food security, smallholder agriculture, and climate-smart landscapes. AIRCA sponsors communities of practice to share expertise on topics such as monitoring and evaluation, carbon footprinting, gender, human resources, and communications. It also is intended to serve as a platform for joint project development and is pursuing funding for collective initiatives in East Africa and Central America. The Director General of AVRDC is the Chair of AIRCA.

AVRDC has extensive collaboration with some partners in AIRCA. For example, AVRDC has especially collegial and effective partnerships with *icipe*, the African Insect Science Center based in Nairobi. For example, AVRDC and *icipe* work together validating technologies for integrated pest management strategies for spider mite; improving management of the pod borer (*Maruca vitrata*) on vegetable legumes in Southeast Asia and sub-Saharan Africa; implementing integrated thrips and tospovirus management strategies in smallholder vegetable cropping systems of eastern Africa; and using pheromones to reduce losses from insect pests and plant diseases on vegetable legumes and leafy brassicas in Southeast Asia. *icipe* is in a rapid growth phase and its strength in insects is complemented by AVRDC strengths in breeding and plant diseases. The future of AVRDC/*icipe* collaboration should be bright.

Though not a member of the CGIAR, AVRDC has an extensive web of relations with CGIAR centers. Most senior managers at AVRDC have previously worked in the CGIAR. AVRDC is an active participant in the Humidtropics Program, led by IITA. This is an especially effective CG partnership for AVRDC and should be nurtured with real attention. Likewise, ICRISAT hosts AVRDC regional research in Mali and India, and

IITA hosts AVRDC in Cameroon, while AVRDC hosts IITA in Arusha. There have been joint projects and there should be further such opportunities in the future. Complementarity between ICRAF's work on tree fruits and AVRDC vegetable research would appear to be the basis of a promising relationship, and this has been under exploration for some time. AVRDC was originally founded as a complement to IRRI rice research, and the first DG of AVRDC was also the founding DG of IRRI. Nevertheless, collaboration between IRRI and AVRDC is relatively modest today.

Given the nutritional importance of vegetables, articulation with the CGIAR Agricultural for Nutrition Program would seem like an obvious match. Limited small-scale collaboration is underway. Bioversity International is making a major expansion in nutrition, a topic on which AVRDC has historically been stronger. Greater collaboration is being actively explored by management of both institutes. The CGIAR Climate Change Program is one with which AVRDC has not been closely associated, but there are topics of common interest that could be worthwhile to explore. Crops for the Future has a common interest with AVRDC is promoting greater exploitation of a wider range of vegetable crops.

While there are real opportunities for collaboration with the CGIAR, AVRDC has to have a realistic approach. The CGIAR institutes are unlikely to feel themselves in a position to share their declining unrestricted resources with third parties. Rather, collaboration will more typically center around the formulation of joint proposals to raise restricted resources. It is well-known that relations among some CG centers have on occasion been tense as they compete for resources among themselves, and such a tendency could impede partnerships with AVRDC that would otherwise appear to be of common interest. Like in all partnership relations, building up long-term trust is crucial as is the clear definition of roles, responsibilities and resources.

5.2 Host Country

Taiwan's support of AVRDC both as host country and as main donor has been wholehearted and absolutely vital. AVRDC has valuable connections with Taiwan in finance, governance, research partnerships and headquarters operations. AVRDC enjoys strong political support at the ministerial level and this has been translated into generous financial support. Naturally, Taiwan is well-represented on the AVRDC Board with three Board members, among whom is the current Chairman of the Board. It is essential to the success of AVRDC as an international organization that Taiwan continue its practice of fully respecting the governance and management independence of the Center. **The Panel commends AVRDC for its outstanding partnership with its host country.**

Since the establishment of AVRDC in the early 1970s, vegetable production in Taiwan has transformed into a technically advanced, high value, internationally competitive sector. AVRDC has contributed to this transformation through the development of many varieties that have been released in Taiwan. While AVRDC can continue to develop improved germplasm of relevance to Taiwan, production systems in Taiwan have intensified to a degree far beyond most systems for which AVRDC works in Africa and South and Southeast Asia, so it is difficult for AVRDC to contribute as much in the way of crop management research in Taiwan. Nevertheless, AVRDC is engaged in some work on automated greenhouse systems with Taiwan research partners.

Just as the vegetable sector in Taiwan has transformed, so also has its agricultural research system. TARI, the Taiwan Agricultural Research Institute, founded in 1895, has a budget and scientific staff greater than that of AVRDC. At the same time, academic research in Taiwan universities is strong, and many of the best AVRDC publications have been co-authored with Taiwanese academics. Mutual expectations between AVRDC and Taiwan need to recognize and take advantage of these new realities. Taiwanese experience in the transformation of its vegetable sector and its strong research capacity could have much to offer to developing countries through AVRDC. As discussed more generally below (Section 5.3), AVRDC should develop new research partnerships with advancing countries like Taiwan that leverage their research capacity to tackle problems of common interest.

AVRDC should not be seen so much as a supplier of advanced vegetable technology to Taiwan as it should rather strive to be a research partner with Taiwanese institutions, linking national research to a broader international context. Senior Taiwanese officials have strong expectations about AVRDC's role in in-service training for young Taiwanese scientists, including in the regions; hosting high-level scientific meetings involving Taiwanese scientists; and serving as a bridge to a wider array of research partnerships. AVRDC is already making steps along these lines, but a greater level of such activities is clearly a high priority for near-term action to cultivate this important partnership. Enhanced communication to ensure awareness of AVRDC activities in this regard is also critical.

To express appreciation and to help insure continuation of its generous support, communication with various audiences in Taiwan is essential. AVRDC has made significant efforts to communicate with different audiences through a variety of channels in Taiwan, largely through the office of the DDG - A&S, but also with the support of the Communications and Information group. These include contacts with local media, open house field days, publications and many other activities. Nonetheless, with the emergence of new media in an urbanized society that has little contact with agriculture, and with a growing spirit of democratization in Taiwan, AVRDC should open additional channels of communication.

Recommendation No. 8: The Panel recommends that further efforts be made to promote public awareness in Taiwan.

AVRDC staff are best equipped to design and implement a strategy to improve public awareness. Nonetheless, the Panel would suggest consideration the establishment of a general information Chinese language website. This website's coverage does not have to be as broad or deep as AVRDC's English web site aimed at a more varied set of international audiences. In particular, AVRDC needs to emphasize to urban audiences, now the majority in Taiwan, the contributions to global welfare that they are making through support for AVRDC's global agenda. Links with Taiwanese development agencies, including NGOs, could be strengthened.

5.3 Members and Other Middle-Income Countries

AVRDC has lost some of its relevance to some of its member countries. Since its inception, AVRDC has counted on the engagement of its member countries. Currently AVRDC has two types of member countries: original Asian country members

(Philippines, South Korea, Taiwan, and Thailand); and high- income donor countries (Germany, Japan and the United States). Among the donor countries, the USA and Germany are active participants who provide substantial financial support, while Japan's contribution to AVRDC is minimal, less, for example, than the Philippines or Thailand. Japan seems to have scaled down its commitment to international agriculture research in general, but it is nevertheless disappointing that AVRDC has not been able to retain closer ties with Japan, one of its founding member countries.

The original Asian members were, by and large, the initial intended beneficiaries of AVRDC work. Over time, though, AVRDC has broadened its scope to work for the needs of low-income countries in Africa and South Asia. At the same time, its original member countries have achieved notable economic growth and significant transformation in their vegetable sectors while building up their research capacity. They are no longer low-income countries with weak agricultural research capacity. Although in recent years AVRDC has rightly emphasized partnerships with low-income countries in Africa and South Asia where poverty and malnutrition are most widespread and international donor funding is more forthcoming, AVRDC should not neglect the different set of opportunities presented by partnerships with its original Asian member states, now middle-income or even high-income countries.

Recommendation No.9: The Panel recommends that AVRDC pay greater attention to partnership opportunities with middle-income countries, especially among its members.

Research capacity in South Africa, India, South Korea, Taiwan and other former developing countries may be as good as or better than AVRDC in some areas. A renewed effort at scientific engagement with such countries could lead to useful joint research for the AVRDC agenda, sometimes tapping in-kind resources and sometimes evolving to direct financial investment.

Middle-income countries, both AVRDC members and others, also have valuable experience to share with low-income countries. They have already made the transition to intensive, commercially integrated vegetable systems from extensive systems with poor market links where vegetables are a sideline to staple crops. Middle-income countries are facing problems today that will soon become problems in low-income countries, for example, new pest and disease pressures or excessive pesticide use. Likewise, technologies that are beginning to spread in middle-income countries will soon come within the reach of low-income countries, for example, protected cultivation or grafting.

Moreover, national research systems in middle-income countries are often strong and have ample access to national funding. New partnership arrangements with middle-income countries can contribute to overcoming serious malnutrition and environmental problems while leveraging the experience, scientific capacity and financial resources of middle-income countries to address issues that low-income countries face today and will face in the near future. This entails new partnership relations of co-generation of innovations distinct from traditional modes receiving unrestricted funding or being essentially the sole or lead supplier on donor-funded contracts.

It is perfectly understandable that AVRDC management has devoted considerable energy to traditional development donors, and to maximizing direct income, but more attention

to these partnerships could help position AVRDC for the longer-term future. This is not a call to reduce AVRDC efforts to address the problems of low-income countries, but rather it points to mobilizing a new set of allies who can contribute to this effort while keeping AVRDC current with the vegetable system changes that today's extensive systems will be facing in the coming decades. Prospects for these new partnerships include both member states of AVRDC—Philippines, South Korea, Taiwan and Thailand—as well as other middle-income countries like India, Malaysia, and South Africa.

5.4 Development Partnerships

AVRDC is the only international agricultural research center explicitly incorporating both research and development activities into each of its themes and regions. To satisfy this broad remit, it is essential for the Center to organize participatory field evaluation of its improved vegetable varieties, lines, and technology, as well as technology dissemination, capacity building, and training. These development activities are necessary to attain impacts on human welfare from AVRDC's state-of-the-art research in breeding, nutrition and plant protection. To reach larger numbers of poor farmers and consumers than would be possible alone, AVRDC forms partnerships with a range of types of institutions and currently the Center collaborates with more than 170 partners across the globe.

Among the partners who contribute to AVRDC's development activities are agriculture ministries and national agricultural research and extension systems (NARES) in many countries. Civil society organizations (CSOs) and nongovernmental organizations (NGOs) are also frequent partners with valuable local knowledge and connections. In the case of AVRDC's improved vegetable varieties, the private sector, especially small seed companies, play a development partnership role in helping to rapidly spread beneficial research outcomes to farmers groups and individual farmers. Effective partnerships undoubtedly make more efficient use of the expertise and scarce resources available in countries where AVRDC is active. Moreover, partnerships in development with some donors may encourage their unrestricted contributions to AVRDC research.

AVRDC's development partnerships fulfil a number of roles. Partners provide the Center with regional information on vegetable production, including major pests and diseases and the preferences of local consumers and farmers, allowing AVRDC and its partners to develop more coherent strategies to meet their needs. Effective development partnerships have included NGOs such as the Child in Need Institute in India with whom AVRDC works with on both variety trials and home/kitchen gardens. Government backed development partners include, for example, the Assessment Institute for Agricultural Technology under the Indonesian Agency for Agricultural Research and Development with whom AVRDC has established 30 school gardens in Bali and five in East Java, also producing brief field guides on different production technologies for use in training of trainers courses and farmer field schools.

Partners are essential for disseminating new varieties and information on best practices for vegetable production and often conduct the Center's farmer training programs. Variety releases may be through public sector partners such as the recent release of a tomato variety by the Ethiopian Institute of Agricultural Research or the earlier successful release of the vegetable soybean variety 'Swarna Vasundhra' by the Indian

Council for Agricultural Research – Jharkhand. Commercialization through partnership with the private sector has also been vital, for example, to the outstanding success of the tomato breeding program in East Africa where, in 2013, the East African Seed Company produced and marketed about 9 tons of seeds each of tomato cultivars 'Tanya' and 'Tengeru 97', Alpha Seeds produced and marketed 3-4 tons of seeds of each cultivar, and Africasia produced and commercialized between 2.5 and 4.5 tons of each cultivar.

Partners also have an important role to play in strengthening AVRDC's monitoring and evaluation capacity, ensuring that the Center's outcomes and impact are properly focused and quantified. This includes the participation of development partners in monitoring the impact of vegetables on health—for example, the participation of the Kilimanjaro Christian Medical Centre (KCMC) in Tanzania in evaluating the anti-hyperglycemic effect of including bitter gourd in the diet.

A strong feature of AVRDC is its admirable capacity building work with its development partners and its ability to integrate capacity-building activities into joint research and development projects. There are numerous examples of good practice across the themes of AVRDC in strengthening the capacity of local partners and farmers to promote technology adoption through training of trainers, farmer field schools, field days and group discussions. In 2013, a total of 137 training courses were conducted through various activities in 14 countries. Many of the 3142 individuals trained were extension officers from NARES organizations or NGOs. In West Asia and the Caucasus, AVRDC is helping to improve the ability of partner staff members to communicate in English by sponsoring attendance at an English language course. Elsewhere AVRDC is aiding its development partners by translating training materials into Swahili, Bambara (local language in Mali), Assamese (local language in Assam, India) and Russian. AVRDC also provides a wide range of services for its development partnerships providing access to information via its website, farmers' guides, posters, technical pamphlets, video and training manuals, and provides a forum for exchange of experiences in a bulletin, Feedback from the Field.

One challenge faced by AVRDC is its need to maintain an appropriate balance between research and development activities at HQ and in the regions to ensure that institutional and individual staff levels and the essential research focus are not diluted by projects or components of projects that could equally well be delivered by national extension agencies or NGOs. It is likely ultimately to be counter-productive to employ staff with advanced plant breeding or agronomy research skills only for the majority of their time to be devoted to development project management. In the case of the onion breeder in West and Central Africa, it has been estimated that as much as 80% of job time was spent on non-breeding activities. Thus the balance between delivery of development outputs directly by AVRDC staff, jointly in partnership with other organizations, or through independent third parties, needs regular appraisal to ensure effective performance.

Recommendation No. 10: The Panel recommends that AVRDC ensure that its development work is maintained at a level and scale that does not detract from its essential research program.

The balance between research and development, at least as far as adaptive research is concerned, may be addressed by incorporating a research component into development projects. AVRDC should not renounce all effort to learn from its development experience

or to share this learning through publications, but it is appreciated that this may not appeal to some donors, and should not be done if the development objectives compromise the scientific rigor of experimental designs or vice versa. It is not clear whether AVRDC can aspire to state-of-the-art excellence in research on development or that such an aspiration should be part of its mandate.

5.5 Private Sector

Although AVRDC is a non-profit organization, it has a wide array of partnerships with private sector companies (See Appendix IV for a list of MOUs with private sector firms). Private sector partnerships are an important mechanism through which the outputs of AVRDC breeding work can reach a much larger number of farmers. AVRDC sends large numbers of both bred materials as well as genebank accessions to seed companies.

Since AVRDC sees the private sector as critical to getting seeds of new varieties to farmers, it generally distributes materials to private companies without charge. Nevertheless, this has not been simply a one-way relationship. The Asia and Pacific Seed Association contributed over US$ 1.1 million in unrestricted funds to AVRDC over the period 2006-2014. Recently AVRDC has signed an MOU with the African Seed Trade Association.

Many small- and medium-sized seed companies lack their own breeding programs, so materials from AVRDC are crucial to them. Often AVRDC lines are directly commercialized as varieties without further improvement, while in other cases they are used as parents. For example, AVRDC has supplied tomato and pepper (sweet and chili) lines to 34 private Indian seed companies over the last five years. AVRDC has provided 4,140 improved lines to Indian seed companies over the last 12 years.

While AVRDC is convinced that providing materials to private seed companies accelerates the dissemination to farmers of seeds of new vegetables varieties and information about them, an enhanced flow of feedback to AVRDC from private sector firms on varietal performance would not only make the breeding process more effective, but also reassure AVRDC donors that its products are indeed reaching intended beneficiaries. Many firms, however, tend to treat such information as trade secrets and have been reluctant to share information. AVRDC is now working to encourage seed companies to be more forthcoming with data as part of the relationship.

Besides distributing materials to seed companies, AVRDC also conducts joint research with private sector firms. For example, AVRDC is working with Takii & Co., Ltd. (Japan) to assess the effect of heat stress on tomatoes under field conditions. Lal Teer Seeds (Bangladesh) seconded one of their scientists to AVRDC to collaborate in developing markers for hybrid verification of 27 vegetable crops. This work produced a streamlined DNA extraction technology suitable for multiplex marker studies.

AVRDC collaboration with the private sector is not limited to seed companies. For example, AVRDC and *icipe* are now working together with the Real IPM Company in Kenya to develop a bio-insecticide to control the legume pod borer. AVRDC research on the management of the eggplant fruit and shoot borer has stimulated 10 companies in India to commercially produce pheromones. AVRDC has also worked with nurseries in Vietnam and Indonesia to commercialize the production of grafted tomato seedlings.

6. INSTITUTIONAL FRAMEWORK

6.1 Governance

Composition of the Board of Directors

AVRDC is a non-profit, independent, non-political institution devoted to agricultural research designed to strengthen vegetable productivity, to contribute to human economic well-being, and to improve nutrition through increased and diverse vegetable consumption. A Board of Directors governs AVRDC. The Board has ultimate authority and responsibility for policy making, oversight of finances and research, and appointment and oversight of the DG. The AVRDC Board is comprised of two types of Directors: member country appointed Directors and Board-elected Directors.

From the time when AVRDC was founded in the early 1970s as an Asian-oriented institute, several countries have remained active members to this day: Japan, Korea, Philippines, Taiwan, and Thailand. Each member country appoints a Director to the AVRDC Board and makes a financial contribution. These country representatives serve at the will of the member countries, which can remove them and appoint new representatives to serve on the Board at any time.

The Asian Development Bank and Vietnam were original members but are no longer active, and do not appoint Directors to the Board. Recently Germany has joined as a member and it names a Director to the Board. The United States continues as an important stakeholder and a major donor to AVRDC, but it does not exercise its right to appoint a Director to the Board. As a practical matter, though, at least one American citizen has always been one of the elected members.

Soon after its foundation, AVRDC expanded its Board beyond representation of member countries to include fixed-term Directors elected by the Board. These elected Directors provide stability to the Board by serving for a fixed term not subject to removal by an external national decision. They also enable the Board to exercise some judgment and control in assembling a varied and balanced composition of Board members with a broad set of expertise.

Currently the Board is composed of six country members; eight elected members; and one ex officio member, the Director General. Of the eight elected members, two are effectively named by the host country, Taiwan. Strong host country representation on the Board is the norm among international agricultural research centers.

Of the six elected members actually chosen by the Board, three are female; of the eight members actually named by member countries, one is female. Given the mixed composition of the Board between elected and country appointed representatives, AVRDC has made a reasonable effort to ensure gender diversity on its Board.

Half the Board members (7) are Asian, while the other half, plus the DG, are from the rest of the world: one is from Africa; one from Oceania; four, including the DG, from Europe; and two from the United States.

At the time of the most recent Board meeting, 12 of the Directors had agriculturally related backgrounds (e.g. agronomy, agricultural economics, breeding, food science, plant pathology, extension, agricultural communications, etc.). One Director had been elected for his finance background. Overall the Board of Directors brings an appropriate mix of relevant disciplinary backgrounds and essential skills to AVRDC deliberations.

Although there has been a move towards reducing Board size among some international agricultural research centers, that does not appear appropriate to AVRDC's situation. Member country representation is specified in the original statues of foundation, and their numbers cannot be reduced without agreement to amend these statues. While not all member countries may appear to be highly involved with AVRDC at the moment, all attend AVRDC meetings conscientiously and there is no indication that any would be willing to relinquish their seats nor would it seem sensible to seek resignations of membership. Instead, elsewhere it has been recommended that AVRDC should seek to upgrade rather than de-emphasize partnership with member countries (Section 5.3).

At the same time, because member country representatives serve at the will of their governments, their appointments can be changed at any time and the sum of individual decisions by member countries may not add up to a properly balanced Board. Thus, both to maintain some level of continuity as well as an appropriate composition of expertise, elected members are essential to the Board and their number cannot be reduced without jeopardizing continuity and balance.

Board Operations

The AVRDC Board carries out its business through an ordered set of committees. These include Nominations, Program, Audit, and the Executive Committee. As discussed below, the Nominations Committee has the responsibility to identify suitable new candidates for membership. The Program Committee is a committee consisting of the full Board. Its functions are discussed in detail in the following passage on programmatic oversight. Likewise, the Audit Committee functions are discussed below in the section on financial oversight. This section discusses the operating procedures of the full Board; the interactions among the Board Committees; and the functions of the Executive Committee of the Board.

The Executive Committee of the Board is composed of the three Chairs of the standing committees of the Board: the Board Chair, the Vice-Chair of the Board, and the Director General (ex officio). The Executive Committee meets twice a year: once during the full Board meeting (typically in the spring), and once on its own (typically in the fall). The Executive Committee is empowered to act on behalf of the full Board in-between Board meetings, and it regularly exercises this authority in an appropriate fashion. Sitting on its own in the fall, the agenda of the Executive Committee carries on with pending Board business, particularly with respect to programmatic review and fiscal planning (especially preliminary approval of the Center's budget prior to full Board approval at the Spring meeting).

The Board meets annually, often in AVRDC regional offices (e.g. Bangkok 2013, Arusha 2014, and Hyderabad planned for 2015). This has the advantage of enabling the Board members to familiarize themselves somewhat with the work that is being done in the regions while carrying its business forward. The agendas for the Board and its

committees are planned well in advance and relevant papers at an appropriate level of detail are distributed to the Board in a timely fashion at least a month ahead of meetings. Meetings adhere to the agenda and there is generally adequate time for discussion. Members participate actively in discussion, and while naturally some members speak out more than others, discussion is not overly dominated by a few and the overall atmosphere is encouraging for the participation of any member.

Where relevant, presentations are made by Management and staff to the Board and its Committees. Moreover, the Board offers appropriate scope to tap the perspective of Management and staff. However, it might be helpful for the Board agenda to specify the lengths of presentations to be made by staff. The Board Secretary takes minutes of all Board and Committee meetings and these are reviewed for approval before entering the official record.

At the time of the full Board meeting most agenda items are first dealt with in committee (i.e. Nominations, Program and Audit). The Chairs of the respective committees then report on committee deliberations to the Executive Committee, and finally the committee Chairs report again to the full Board. In the face of especially difficult or controversial items, there might be advantages to allowing the Executive Committee to discuss issues coming out of the other committees, and try to sort them out preparatory to the full Board meeting. However, when there is clarity and consensus around agenda items, this appears to be an overly repetitive process that might be streamlined.

The Board might wish to consider whether, at the time of the full Board meeting, the Executive Committee might convene before the other committees to review actions taken by Management on Executive Committee decisions made at the last Executive Committee meeting; to deal with any matters that cut across the responsibilities of the other committees; and to review the agenda of the other committees. In particular, the Executive Committee might review changes in the updated annual budget presented by Management from the initial version presented at the previous Executive Committee meeting. The other committees would then report directly to the full Board rather than first to the Executive Committee and then again to the Board unless there was a particular reason for Executive Committee review prior to taking a particular matter to the full Board.

Self-Governance of the Board

The Board takes a systematic approach to self-governance. With respect to elected members, it monitors and anticipates upcoming vacancies and plans succession explicitly in terms of appropriate profiles to be sought in new members. This assignment is carried out through a Nominations Committee tasked with this responsibility. Members of the nominations committee include the Board Chair and Vice Chair, giving the committee strategic strength and continuity. The Nominations Committee advises the full Board, which retains authority to elect members. The Nominations Committee also considers succession plans for membership and Chairs of the various Board Committees. Likewise, consideration of the reappointment of Board members to a second three-year term, the maximum permitted, is done with careful deliberation and frank discussion, guided by a systematic set of performance criteria.

Efforts are made to orient new Board members. A few Board members have attended CGIAR-organized Board member training events, but it is certainly not practical that all new members do this. Typically new Board members receive at least a general orientation to AVRDC upon their arrival, but a more comprehensive and systematic orientation would likely contribute to Board performance. One possibility for newly elected members is that they would be elected one year before formally joining the Board and in the intervening time they would attend a Board meeting as an observer. To some extent this is already being done, but this does not work for member country representatives since they become members immediately upon being named.

There are many possible approaches to orienting new board members, e.g. naming a specific mentor for each new member; interviews with other board members or staff prior to entering the board; receiving documentation describing the center and the operations of the board. Rather than have the EPMR Panel pre-empt this process with a recommendation, it might be better to assign to the Nominating Committee the responsibility to develop, with Management support as required, a more formal structured induction process for new members.

The Chairs of all the Board committees and the Board Chair are all active, informed and industrious. The Committee Chairs and the Vice-Chair are freely elected by the Board. By custom, the Chair of the Board is usually the country representative from Taiwan. Although this is not common practice among international agricultural research centers, many major international organizations have similar customs (e.g. World Bank, International Monetary Fund, Asian Development Bank). Taiwan consistently appoints senior figures with the skills and international perspective commensurate with the responsibilities of serving as the Chair. The Board Chair is an ex officio member of all Board committees. The Vice-Chair works closely and effectively with the Board Chair.

The Board conducts an annual self-appraisal based on a highly structured and comprehensive set of performance criteria. Time is allocated for serious reflection on the findings from the self-appraisal.

Programmatic Oversight

Oversight of the research and development efforts is a particularly important function in non-profit organizations where the objective function is not profit maximization, which can be monitored in a relatively straightforward quantitative manner. For non-profits performance is a matter of progress towards the overarching institutional objectives, which in the case of AVRDC includes research and development activities aimed at improving small-scale farmer incomes and/or human nutrition. While impact studies (Section 7.6) can generate valuable information in this regard, impacts generally occur after several years of first research and then an adoption process, which also often takes several years. In the meantime, the Board has to take responsibility for due diligence oversight of whether the Center is heading in the right direction and at a proper pace towards achieving these impacts.

During the period covered by this EPMR, the Board reformed the membership of the Program Committee, expanding it to a committee of the whole Board. This makes sense because the research and development program is so important that all Board members should be involved, and also because the regional and disciplinary span of the program

is so broad that it is difficult for a single Board member or even a small group to have the relevant range of expertise. This practice is not unique to AVRDC but is followed in some other international agricultural research centers.

A full day is typically dedicated to Program Committee activities at the time of the Board meeting. This includes field and laboratory visits as well as presentations from AVRDC scientists and partners. In addition, the Executive Committee meeting is usually timed to coincide with the AVRDC annual planning meeting. This offers the Chair of the Program Committee and other Executive Committee members the opportunity to attend the planning meeting to become more familiar with research progress and plans. In addition, the Board receives an Annual Report and a Medium Term Plan, which lay out respectively progress achieved in the previous year and performance targets for the current year.

As discussed elsewhere (Section 3.8) the Panel recommends that external in-depth scientific reviews of AVRDC research programs be commissioned regularly.

This would be an important support to the Program Committee of the Board in the exercise of its oversight responsibility, especially taking into account the relatively limited amount of time available to Board members to undertake the function. The Program Committee could play a role in scheduling the sequence of Center-commissioned external reviews. It is proposed that the topics, terms of references, and reviewers of these Center-commissioned external reviews be decided by the Program Committee, based on Management proposals. The Program Committee would also receive the reports and use them as the foundation for further discussions relevant to the effectiveness of programmatic activity.

Financial Oversight

The Audit Committee carries a major part of the responsibility for financial oversight. It receives regular written and verbal reports from the Finance Director. Moreover, the Audit Committee selects the external auditing firm and receives its report. The Audit Committee receives reports from the internal auditor, but as discussed elsewhere (Section 6.4) organizationally the Internal Auditor reports to the Director General and in some cases the findings of the Internal Auditor have been presented to the Board of Directors by another member of Management rather than the internal auditor. To effectively support the Board of Directors in its governance responsibility, the independence and direct access to the Board by the Office of Internal Audit should be assured. **The Panel recommends that the Internal Auditor report directly to the Board of Directors.**

The Board might want to consider whether the Audit Committee might give increased attention to medium term financial planning, especially for the investment of unrestricted resources. Currently the Board seems to have thorough procedures to monitor the current financial state of AVRDC in terms, for example, of the balance between revenues and expenditures.

Recently the Board has proactively sought and begun to receive greater information from Management on the assignment of resources to the different thematic research areas and regions. Management must retain its authority to make operational budgetary decisions, but it does need to be able to inform the Board about how these decisions correspond to

any Board-determined policies on broad patterns of investment decisions. While in fact the Themes are not budgeting units in the sense that Theme Leaders do not have responsibility for the management of theme budgets beyond a few thousand dollars to convene meetings, nonetheless it is of strategic interest to the Board to consider with Management how resources are being allocated between themes and among regions. The Board is encouraged to continue to work with Management on a financial information system that better enables the Board to understand and review how resources are being strategically allocated among alternative research areas, thereby facilitating informed discussion and decision making about programmatic direction and performance.

Similarly, the Board might wish to take a more strategic view of resource mobilization. Just like expenditures, the Board receives properly audited accounts on annual income. However, the Board does not appear to engage in systematic, forward-looking financial planning. For example, while there is a general sense that the Board expects some income growth, there is neither a plan nor performance targets about how much growth can be expected or where, regionally or thematically. Of course it is impossible to know with any certainty what specific donor funding decisions will be in two or three years any more than a commercial firm knows three years in advance the sales of different product lines. Still, as part of planning for infrastructure needs and human resources, as well as to set performance targets for Management, expected or indicative fund raising targets by region and theme could be useful.

Board-Management Relations

Board-Management relations are cordial, healthy and constructive. Communication appears good. The Board interacts intensively with the DG, the DDG-R and the DDG-A&S and also has ready access to the entire institutional management group, including the Directors of Finance and Human Resources, and the Regional Directors. As appropriate, the DG calls upon any of them for relevant presentations to the Board. All attend the meetings of the Program Committee and the full Board, and as requested contribute to the discussion. There is no evidence of friction between Management and the Board about their respective roles.

The Board conducts annual performance reviews of the DG, which are thorough and not perfunctory. During the conduct of this EPMR, the Board took the positive step of beginning to request an annual work plan from the Director General. This provides an opportunity for a Board-Management discussion about key strategic directions upon which the DG is placing priority and it also establishes a clear basis against which to subsequently appraise the performance of the DG.

During the Board and committee meetings occasional suggestions for action or requests for information are made without constituting formal Board decisions. Sometimes these suggestions are intended to be no more than comments for Management to think about as it may see fit, but in other cases they may reflect, if not a specific decision or mandate of the Board, a reasonable or even valuable request to look at something and report back to the Board. The Board and Management might want to consider whether in the preparation of the minutes, such comments might be considered for inclusion in a list of items for follow-up and reporting back at the next meeting. For example, rather than leaving in the air an expression of interest by a Board member in knowing the allocation of unrestricted resources to locally recruited staff in the regions, in the preparation of the

minutes Board and Management might wish to decide whether this merits inclusion in a list of items to be followed, or whether it is merely a remark to be recorded in the minutes.

The Board and Management both aim for a constructive relationship, to which differences of perspective and constructive exchange of views naturally contribute. The Board recognizes and affirms that Management is responsible for ongoing operations and for the implementation of Board-determined strategies and policies. Management gives full-time professional attention to issues that the Board deals with largely during a one-week annual meeting and a similar time for the Executive Committee meeting. Nonetheless, even in the current situation where Senior Management is performing well and rightly enjoys the confidence of the Board, the Board shares heavy responsibility with Senior Management. When Board decisions or policy papers, for example on gender or monitoring and evaluation, are not well-received by key stakeholders, it is essential that this knowledge be shared between Management and the Board. In such situations the Board must provide guidance and exercise acute oversight of Management's remedial actions until it is clear that the matter has been satisfactorily resolved.

Board-Stakeholder Relations

Board members can make extremely useful contributions in relations with key stakeholders. The efforts of the Board Chair in Taiwan are exemplary in this regard. Both the Board and Management express support in principle of leveraging the contacts of Board members for the Center in partnerships and fundraising. Board members are properly conscious not to undertake unilateral initiatives on their own account without prior discussion and agreement with Management and Board leadership. For example, the possibility of Board members catalyzing interactions among European donors was proposed in a Board meeting. While there is an agreement in principle that Board members are willing to act on behalf of the Center, and agreement in principle that this can be useful, it is less clear in practice on a case-by-case basis how Board members can be best be mobilized to support stakeholder relations.

6.2 Management and Organization

AVRDC is a well-managed institution with a healthy culture. Scientists work smoothly together across themes and regions without rigid organizational boundaries impeding the formation of ad hoc working groups. Staff are generally competent, highly motivated and committed to AVRDC's mission. Reporting and control processes for finances, human resources, proposal development, and donor reporting, are systematic and adhered to. Administrative procedures are strong. Senior Management resolves appropriate issues decisively and advocates strongly for AVRDC's mission in international forums.

Roles among senior managers at headquarters (DG, DDG-R, DDG-A&S, Finances and Human Resources) are clear. There are good working relations among the members of this group. The Institutional Management Committee (IMC), under the chairmanship of the DG, properly brings these headquarters-based managers together with the four Regional Directors. However, while this form is appropriate, the IMC only meets briefly twice a year, so its agenda deals more with a checklist of administrative items rather than as functioning leadership body considering significant issues in a strategic and decisive fashion.

Although the roles of Regional Directors are in principal clear, in fact many research, partnership and project matters that occur in the regions are handled directly by headquarters without necessarily involving the Regional Directors. To some extent this occurs when projects are cross-region in nature or project proposals have been originally developed by headquarters scientists. Nevertheless, it does seem inconsistent with the responsibilities of Regional Directors that significant activities can occur in their regions without their input. As discussed below, a more active Institutional Management Committee could serve as a forum for communication to more clearly sort out such situations.

Theme Leaders are the next level of management at AVRDC. In contrast to Regional Directors who are recruited internationally on a competitive basis, Theme Leaders are appointed by the DDG-R with the approval of the DG. Theme Leaders have little financial or line authority and serve more as chairpersons of scientific competency groups than as leaders of research programs vested with authority. Individually all the current Theme Leaders are competent, hard-working, and respected by Theme scientists, so they are in fact influential and effective despite modest formal authority.

Theme Leaders together with the Regional Directors form the Institutional Research and Development Committee (IRDC), under the Chairmanship of the Deputy Director General - Research. Like the IMC, the IRDC meets at most twice a year for a couple of hours with an agenda that has significant administrative content rather than one focusing on strategic research decisions. Of course administrative matters need to be taken care of, but opportunities to deal with research issues would benefit from more attention. There is some useful discussion of important research issues, but it appears that these meetings are not structured to be an effective forum for decision making. For example, important items may be brought up, but there does not seem to be a systematic process of preparing papers in advance to bring matters to a decision, nor did it seem that there was an expectation that matters would be brought to decision.

Scientists all have a home in one theme, but most have responsibilities in three themes. This no doubt contributes to the flexibility with which healthy cross-theme collaboration occurs. In a sense, AVRDC almost acts as a single vegetable research program under the leadership of the DDG-R. This does not constitute an unmanageable task given that larger international agricultural research centers function with programs (e.g. maize at CIMMYT) that are of similar size to AVRDC.

However, AVRDC is becoming more complex and more geographically distributed, involving more partners, donors and contracts in more varied activities. This makes adjustments in roles and responsibilities essential. Culture and practices that have been successful in a smaller organization working mostly in a single location cannot be simply extended across a larger, more complex organization.

Furthermore, Senior Management has to take on new challenges: leading the engagement with the nutrition and health sector, nurturing scientific capacity in a technologically dynamic vegetable sector, engaging more with new partners in middle-income countries, and operating in an ever more complex environment of international agricultural research.

Greater challenges of coordination and opportunities for synergies are arising: between headquarters and the regions, among the themes, between regions and themes, among

the regions, and also among staff working at different locations in different disciplines within a region. Greater attention has to be given to teamwork, communication, delegation, and coaching throughout the organization, especially to integrate a steady flow of newly hired staff if AVRDC continues to grow as this report recommends. Senior Management is aware of these considerations, and has already begun addressing the challenge of enhancing teamwork.

Recommendation No. 11: The Panel recommends that Management lead through greater emphasis on teamwork, communication, delegation, and coaching.

Teamwork requires particular skill sets and management needs to provide leadership, mentoring, and guidance to foster the policies, procedures and culture that promote teamwork. Enhanced communication is critical. The Institutional Management Committee and the Institutional Research and Development Committee currently meet only twice a year for a couple of hours. These committees should have regular, monthly virtual meetings, with adequate time for substantive deliberation covering an agenda of important issues rather than housekeeping matters.

Senior Management will be increasingly able to focus its attention on high value, forward-looking strategic opportunities by delegating greater responsibility on more routine tasks. For example, responsibility for technical reports to donors and responsibility for personnel performance appraisals could be fully delegated to Regional Directors with the respective support of the Grants and Partnership Office and Human Resources. Publication review could be fully delegated to Theme Leaders. Once overall strategic approval for proposal development is granted by Senior Management, perhaps through the IMG or IRC, oversight and approval of most proposal writing, not including budgeting, can be delegated to Regional Directors and Theme Leaders.

Management retains a heavier oversight responsibility, exercised through advising and mentoring as well as enforcing accountability where performance is unsatisfactory. Regional Directors and Theme Leaders will need to follow the example set by Senior Management in fostering teamwork in the interdisciplinary teams operating in multiple locations that they lead.

6.3 Finances

Despite a sometimes turbulent operating environment, AVRDC has succeeded in managing its finances with prudence and is in a sound financial state.

Income

Over the period of this review, there have been fluctuations in total income, but no consistent growth. In 2008, total income was US$ 15.6 million. It rose to US$ 18.7 million in 2009 and then fell to a low of US$ 13.2 million in 2012. In the most recent complete year, 2013, total income was US$ 17.6 million.
The main driver in changes in income was variation in restricted project income. Restricted project income peaked at US$ 11.6 million in 2009. With the unanticipated phasing out of a large contract with the Bill and Melinda Gates Foundation, restricted income plunged to US$ 7.1 million in 2010 and continued to fall until 2012 when it bottomed out at US$ 4.3 million.

In response to this serious deterioration in income, Management and scientists, with the support of an effective Grants and Partnerships Office (Section 7.2), redoubled their efforts to generate successful project proposals. This effort has paid off. In 2013 restricted income rose for the first time since 2009, reaching US$ 8.3 million; 2014 and 2015 are expected to be roughly in the same range.

Over the 2008-2013 period Taiwan has been the largest investor in AVRDC in terms of restricted resources, excluding the Gates Foundation, which no longer has any projects with AVRDC, though it was a leading funder until 2010. Germany has been a consistent investor over the entire period and overall the second largest contributor of restricted resources. However, since 2012 USAID has been making the largest annual restricted investments in AVRDC. Australia has been a steady funder of restricted projects, with a recent trend towards increasing investments.

In contrast, unrestricted donations have been far more stable, and remarkably have even grown somewhat, from US$ 7.1 million in 2009 to US$ 9.3 million in 2013. Taiwan has been by far the most important unrestricted donor, with contributions comprising nearly two-thirds of total unrestricted donations since 2008. In 2013 Taiwan made an unrestricted donation of US$ 5.2 million, 56% of total unrestricted funds. Other major unrestricted donors in 2013 include the UK at US$ 2.5 million and the USA at US$ 1.0 million. Both the UK and USA have increased their unrestricted contributions by about US$ 1.0 million since 2008. Germany has recently become a growing donor while member countries South Korea and Thailand all make steady if modest contributions.

The funding base for AVRDC appears reasonably stable, but it is narrow, being heavily dependent on Taiwan and a few other funding sources. Diversification of funding sources is a high priority, and prospects for increased restricted project income appear particularly promising in Africa and South Asia. Prospective resource mobilization strategies are discussed in Section 6.5.

Expenditures

Despite substantial variations in income, AVRDC has succeeded in managing expenditures such that expenses have been less than revenue every year since 2009. Personnel is the single largest item of expenditure, accounting for 57% of expenses.

Among themes, in 2013 Consumption constituted 30% of total expenses. Consumption theme research is financed principally by restricted funds, which account for 85% of theme expenditures. The Production theme was the second largest, forming 22% of total expenses, and it too is funded mainly out of restricted funding, which comprise 59% of production expenditures. Breeding accounted for 16% of expenditures and was 46% funded by restricted contracts. Germplasm was the smallest research theme at 8% of expenditure, and only 23% of these resources came from restricted sources. Expenditures unallocated to themes were 24% of total expenses but were only 19% funded by restricted resources. Overall, restricted expenditures were concentrated further down the value chain, in production, postharvest handling and marketing, and nutrition.

The largest unrestricted expenditures in 2013 was US$ 3.0 million unallocated to research (e.g. governance, central services, and administration). Production and Breeding

both spent US$ 1.4 million in unrestricted funds in 2013, while the corresponding figure for Germplasm was US$ 1.0 million and for Consumption US$ 0.7 million. If AVRDC could grow restricted income and hence increase overhead recovery, it would be attractive to redeploy unrestricted resources to research from non-research support functions.

Among regions (budget 2014), Africa accounts for US$ 4.0 million in expenditures, US$ 2.3 million in Eastern and Southern Africa, and US$ 1.7 million in West and Central Africa. Since 2011 expenditures on restricted projects in Africa have nearly doubled, from US$ 1.5 million to US$ 2.9 million, while unrestricted investment has likewise risen, from US$ 0.5 million in 2011 to a planned US$ 1.1 million in 2014. Growth in South Asia has been even stronger, increasing from US$ 0.7 million in 2011 to a current level of US$ 1.9 million. Essentially all this increased expenditure comes from restricted projects that account for 80% of current expenses in South Asia.

In contrast, growth in expenditures in Southeast Asia has been erratic—from US$ 2.7 million in 2008, it fell to a low of US$ 0.4 million in 2011, and has subsequently recovered slightly to US$ 0.6 million. Expenditures in Oceania are modest, less than US$ 0.4 million in 2014, over 80% of which is from restricted projects. The smallest regional expenditure is in Central Asia, at around US$ 0.1 million, or about 0.5% of total expenses, all of it from unrestricted resources.

Net Financial Outcomes

AVRDC has managed to achieve operating surpluses in every year since 2009. Initially these surpluses were small, in the US$ 0.1-0.4 million range, but since 2012 surpluses have exceeded US$ 1.0 million annually. Consequently, by the end of 2013 AVRDC had liquidity to support 187 days of operation compared to a target of 120 days, and reserves sufficient for 131 days of operation compared to a target of 90 days. Although the future is not without risk, AVRDC's financial position is quite sound, exceeding commonly accepted indicators of financial health. In this context the Management and Board have recently moved to increase expenditures out of the capital and innovation funds. **The Panel commends AVRDC's prudent financial management in a turbulent funding environment**.

Financial Systems and Management

During the period of this review, AVRDC installed a project-based enterprise resource management software system, Maconomy. Among its functions is a complete financial management system, including general ledger, financial budgeting, accounts receivable, accounts payable, fixed assets, etc. Maconomy has routines to authorize and track expenditures as well as supporting some human resource functions. While not without built-in rigidities characteristic of any software system, overall acceptance of Maconomy by AVRDC users appears reasonably good, and it is used for financial management of projects and monitoring accounts.

Maconomy is accessible to project managers both in headquarters and the regional offices. It is a key tool to move responsibility and authority to researchers managing projects, especially in the regional offices. Besides a central finance team of eight professionals in headquarters, there is a finance officer, with varying levels of experience

and expertise, in each of the four regional offices: Arusha, Bamako, Bangkok, and Hyderabad. Working relations between the headquarters finance team and regional finance officers appear good.

AVRDC has an annual external audit by a recognized large international accounting firm. It has worked with the current external auditor since 2010 and the AVRDC Board has recently directed Management to seek bids for a new auditor. No major issues have been raised in any of the external audit reports during the period under review.

AVRDC has been persistent in the implementation of full cost recovery for project activities. While this has represented a change that has not been welcome by some project managers accustomed to the previous system that entailed extensive central subsidies to projects, this Board-endorsed policy has been vigorously implemented by Management. Partly as a result of the consistent application of full cost recovery, AVRDC has managed to reduce its overhead rate in recent years, from 23.2% in 2010, 21.3% in 2011, to 20.9% in 2012, to 18.5% in 2013.

Research managers, according to a survey, see the financial function as one of the most important services to research and one that is performing well. There are, though, challenges for the future. Institutional memory is held to a significant degree tacitly by key employees, and it would be desirable to have greater documentation about how the accounting system works. Continued growth in restricted funding, a key performance objective for AVRDC, would at some point require more finance staff. Likewise, greater activities in currently minor regions (e.g. Oceania, Central Asia), would require adjustments in the financial system.

The financial planning systems on a year-to-year basis appear systematic and thorough. There is though, less attention devoted to longer range financial planning. This is not mainly the responsibility of financial professionals alone, but rather is a matter that should engage the Board and the entire management team. Just as the Medium Term Plan should lay out challenging and aspirational research objectives over a multi-year period (Section 2.3), so also should AVRDC consider the formulation of a medium term plan for finances. This should include indicative fundraising targets by regions and themes over a multi-year period. These targets become performance objectives for the responsible Regional Directors and Theme Leaders, while also providing a basis for planning growth in infrastructure and human resources. Like any enterprise, future revenue streams cannot be predicted with precision some years into the future. However, without setting for itself realistic but challenging financial objectives, AVRDC risks remaining in a zero-growth stasis, which will ultimately threaten institutional sustainability.

6.4 Internal Auditor

Since 2010 the office of Internal Audit has reviewed a wide range of important functions, including the operations of regional offices in Bangkok and Arusha; headquarters operations of human resources, information technology, and inventory management; as well as undertaking special assignments such as participating in the renovation of the genebank after the 2010 fire and providing background material for the re-negotiation of the MOU with Thailand. Its findings have led to serious actions having been taken by Management, for example, in the case of management of toxic chemicals. The Board of

Directors receives information on the findings of the Internal Auditor. However, organizationally the Internal Auditor reports to the Director General and in some cases the findings of the Internal Auditor have been presented to the Board of Directors by another member of the Management.

To effectively support the Board of Directors in its governance responsibility, the independence and direct access to the Board by the Office of Internal Audit should be assured. **Recommendation No. 12: The Panel recommends that the Internal Auditor report directly to the Board of Directors.** The Board of Directors should approve the annual work plan of the Internal Auditor. This work plan should be designed to cover all major functions systematically and cyclically, as well as respond to any particular requests that the Board may have, in consultation with Management. The Internal Auditor should personally present findings to the Board, virtually if need be.

6.5 Resource Mobilization

With the resources it has now AVRDC cannot, even in alliance with its current partners, fully implement its strategy. Moreover, without increased funding, the fixed costs of maintaining its administrative and research infrastructure will become an ever-heavier burden. To be viable and effective, AVRDC needs to grow. To gradually double in size is a realistic objective.

Recommendation No. 13: The Panel recommends that AVRDC expand and diversify its donor base while exercising caution not to be diverted from its strategy.

Although AVRDC continues to enjoy exceptionally generous support from Taiwan, it is not reasonable to expect major additional support from Taiwan alone. AVRDC must diversify its donor base both to grow funding and to avoid being driven by a single donor. Although some donors are more oriented to technology dissemination and others more to cutting-edge research, AVRDC needs to calibrate a balance that reflects its own strategic priorities.

In addition to widening and deepening its support from traditional government funding sources, AVRDC should explore new opportunities with foundations, philanthropy, the private sector, middle-income countries, and nutrition and health agencies. Searching for new funding has to be a priority for AVRDC regional staff as much as for headquarters.

Success in obtaining financial support depends to a significant degree on building its reputation and its relations both with funding agencies and partners. AVRDC has often raised resources that it shared with partners. It needs to be equally open to seeking out partners that themselves have access to funding sources. In such relationships, AVRDC will naturally play a different role from the traditional one of leadership. This can have numerous advantages in terms of reduced administrative burdens and greater agility in avoiding the appearance of geopolitical entanglements. Although AVRDC has to generate sufficient resources to maintain its own financial viability, funding that partners bring to finance their own work can represent effective resources for implementing AVRDC's strategy and could be explicitly noted as such.

The role of commissioned projects will continue to be greater than that of competitive grants. Likewise, restricted funding will be more important in growth than unrestricted

funding. Consequently implementing strategy is more a question of assembling a portfolio of projects, consistent with AVRDC strategy, that would be worthwhile to implement if funding could be obtained, rather than a resource allocation decision of unrestricted funds. Strategic leadership depends more on developing relations that will induce funding agencies to invest in AVRDC priority projects, than it does on careful assignment of unrestricted resources, important though that may be. However, when donors' requests deviate from the long-term goals of the Center, the projects should not be conducted so that the Center's mission and goals will not be donor-driven.

Among its research areas, AVRDC may very well face its best fundraising opportunities in improving human nutrition and health. Small enterprise development in vegetable value chains and benefiting women through vegetables are also very appealing topics to funding agencies. To be successful in mobilizing resources in these areas, though, AVRDC needs to move beyond rhetoric to establish a real track record and expertise. Improving home and community gardens could be another very promising field for fundraising if AVRDC were to elevate its game above distribution of seed kits (Section 3.7). Raising the incomes of small farmers by linking them to markets provides solid opportunities and has been the mainstay of AVRDC resource mobilization. Climate change is of great interest to the international community, and it is a phenomenon that will certainly affect vegetable production. Organic farming offers uncertain prospects for fundraising, while indigenous and underutilized vegetables could be of interest to some donors.

Success in fundraising depends critically on partnership skills. Partners are needed not only to complement AVRDC capabilities, but also because partners often have their own access to donors. Resource mobilization with partners can only succeed in win-win situations, when AVRDC and its partners both have complementary capacities as well as a mutual willingness to share resources equitably.

7. SUPPORT FUNCTIONS

7.1 Global Technology Dissemination

AVRDC rightly places great emphasis on the conversion of its research outputs into outcomes that are used to produce positive impacts on human welfare. This is the focus of a significant share of work in the regions, supported by headquarters-based Global Technology Dissemination (GTD). Technology dissemination is undertaken by AVRDC as the main objective of specific restricted or unrestricted projects, as a component towards the end of projects, via training and capacity building at HQ and in the regions, and as a function of HQ to disseminate and promote technologies through a range of media outlets. GTD works across all four of AVRDC's research and development themes and is directly involved in projects in Asia, Africa and the Pacific. The group is currently staffed by a Technology Dissemination Specialist, two Associate Specialists, a Training Coordinator, a Principal Research Assistant, a Research Assistant, and six other staff.

GTD currently conducts a wide range of activities. It supports projects such as Vegetables Go to School; CGIAR Research Program on Integrated Systems for the Humidtropics; the ASEAN-AVRDC Regional Network on Vegetable Research and Development (AARNET); and the Network for Knowledge Transfer on Sustainable Agricultural Technologies and Improved Market Linkages in South and Southeast Asia (SATNET). The group administers and delivers a program for international trainees coming for capacity building activities at HQ across a range of disciplines. It also conducts capacity building activities in several of the regions, recently including training in integrated crop management across eight countries; healthy seedling preparation for off-season tomato farmers in Bangladesh; and grafting for staff members based in the Pacific and Africa. The group publishes Feedback from the Field, a quarterly bulletin communicating technology applications, via the website, email and Facebook. The group manages AVRDC's mature technologies database and training documents for use by AVRDC staff and to facilitate response to information requests worldwide. Collaborating with other groups in AVRDC, GTD develops and disseminates videos, training manuals and extension publications.

The group manages a fertigation research project, initiated in 2013, comparing two computerized fertigation systems for efficacy and cost effectiveness in glasshouse vegetable production. The group also coordinates AVRDC's disaster recovery program, which principally involves the distribution of seed of hardy, fast-growing and nutritious vegetable crops to disaster survivors. Core funding is provided for the demonstration garden and some travel; most other funding is from projects, while publications come from other budgets such as Communications. As a practical matter not all activities of GTD can be neatly placed in ordered boxes, and there has to be some flexibility to support institutionally necessary tasks, but the overall effect is to deprive GTD of strategic coherence that cannot be aiding the fulfilment of its core functions.

Naturally there is a great deal of variation among dissemination activities among the regions according to local circumstances. Some technology dissemination activity is best served from HQ, such as global information dissemination, HQ-based training, development of best practices in technical dissemination and the training and transfer of this, with expert advice and support to the regions.

GTD correctly aims to promote AVRDC-wide sharing of experiences rather than to impose a uniform orthodoxy. However, GTD does not deliver or have oversight of all the Center's dissemination activities. Some regions, such as South Asia, have staff specifically for technology dissemination, and West and Central Africa runs projects that have a strong technology dissemination focus, such as the USAID-funded best practices hub model to test technologies linked to vegetable technology immersion clusters to disseminate the technologies.

Within the variety of approaches being used in AVRDC development and dissemination, user evaluations and participatory methods are not uncommon. Nevertheless, across the range of its activities and in its communications, the tenor of AVRDC is one of a traditional, even outdated, model of technology development followed by transfer. AVRDC staff are not unaware of less linear, more interactive approaches to innovation, but these more modern methods seem not to permeate thinking, action, or communication. AVRDC scientists are urged to collectively reflect on their methods to see if they might replace the dissemination model with an innovations approach both in their activities and as a framework for their thinking and communication. GTD is coordinating a Google group of 35 AVRDC scientists worldwide who work on technology dissemination and capacity building, to provide a more unified and coherent effort to create outcomes and impacts.

Management might consider whether a tighter organizational connection could be drawn between GTD and the regional programs as well as across regions. While a great deal of development work is tightly bound to specific project funding, more cross learning could enhance institutional learning and even constitute a research opportunity. It must be said that the regional programs, where most innovation or dissemination occurs, do not find GTD in its current role either relevant or effective.

Suggestion No. 4: The Panel strongly suggests that strategy, relationship with the regions, and portfolio of responsibilities of Global Technology Dissemination be reassessed.

7.2 Grants and Partnership Development

The Grants and Partnerships Development (G&PD) function, with oversight from the DDG-R, is concerned with restricted fund projects, both commissioned and open call grants, but not unrestricted core funding. G&PD undertakes both pre- and post-award activities, contributing to resource mobilization and, to a lesser extent, project administration. However, G&PD does not have a role in directly developing relationships with donors and potential partners and collaborators, this being the remit of senior management and researchers.

G&PD has a staff of two administering the funding cycle. Pre-award activities include information gathering to alert staff to funding opportunities by monitoring donor trends and websites, and subscribing to on-line funding databases. There is an important role for G&PD in assessing the eligibility of AVRDC and partners, donor priorities and requirements, application guidelines, cost bases, etc. for specific funding opportunities. Once a funding source of interest has been identified, G&PD coordinates the application process including liaising with the proposal team leader, obtaining DDG-R approval to proceed, quality review and editing of proposals, liaising with finance, biometrics and

HR as required, and, after final DDG-R approval, submitting the proposal and following up as necessary with the donor.

The Panel understands that, in the future, G&PD will be less involved post-award in quality review of project reports but will continue to monitor adherence to deadlines to submit reports to donors. G&PD also interacts with donors concerning changes to partners, workplan or budget, no-cost extensions and close-out procedures. Complicated multipartner and multinational research projects require attention to run smoothly and G&PD clearly contributes to problem solving when issues arise. Databases of concept notes, proposals, contracts and agreements are maintained on Maconomy, which also alerts staff to key deadlines in the project cycle. All project-related agreements that the Center signs with donors and partners pass through G&PD, which supports negotiations and prepares, reviews and edits many agreements.

The process for resource mobilization and project administration laid down in 2010 look robust and logical, although the Panel suggests elsewhere in this report that some approval of project technical reports by the DDG-R could be devolved to theme leaders and Regional Directors. Overall, with the input of G&PD, AVRDC has a good track record of choosing winnable funding opportunities, a selective process that is important with the limited staff time and expertise available for proposal writing. As a result, the success rate is very good. In 2013, for example, AVRDC scientists worked on 57 proposals, of which 19 were dropped before submission. Of the remaining 48, 32 had been funded (67%) at the time of the EPMR visit. The Panel understands that a similar or higher success rate for 2014 will be achieved.

To effectively to screen and evaluate funding opportunities, it is important for G&PD to remain abreast of the work of AVRDC and to have a clear understanding of priorities of the Center, the strategy of the research themes, and the relationship between these and donor trends and requirements. This is achieved by personal contact and by participation in global theme and planning meetings. The Panel found almost universal agreement among Center service users that the role of G&PD was very important and that its performance was very good to excellent.

7.3 Biometrics

The 7th EPMR report recommended that AVRDC should employ a short-term consultant to advise on the setting up of a Biostatistics Unit serving the needs of scientists in headquarters as well as in regional offices. The unit was duly set up and is staffed by a biometrician with 75% time allocation to this role. Biometrics provides help and support across the themes and regions in the design of experiments, the processing of data, and other statistical issues. AVRDC has a mandatory biometrics review process for proposals to optimize experimental design, data collection and storage, as well as to guarantee the validity of statistical methodologies. The involvement of a biometrics professional from the planning stage onwards no doubt contributes significantly to the quality of the eventual research outputs.

Similarly, there is a mandatory review of all technical reports and scientific manuscripts submitted for publications in peer reviewed journals with follow-up advice in responding to reviewers' comments and revising manuscripts for resubmission. The biometrician also contributes to capacity building through training courses at HQ and occasionally in

the regions aimed at improving the statistical skills and understanding of scientists from AVRDC and some partners.

The biometrician also maintains an AVRDC-wide database of variety and crop releases. Information for this database is entered by the breeders at HQ and the in the regions and includes location, date and place released, local name, and characterization data such as yield, disease resistance, and days to maturity. The biometrician responds to requests for information from this database. On occasion, the biometrician also contributes quantitative input to desk-based studies such as the 2013 analysis of agricultural and meteorological data to highlight the effects of climate change on smallholder vegetable production.

In some biological and agricultural institutions, biometrics, focusing on the application of statistics, has been merged with bioinformatics, which is the application of information technology to the field of molecular biology. At AVRDC, these two areas remain separate with the Biotechnology group of Theme Germplasm working with IT to develop the area of bioinformatics. With the small biometrics function at AVRDC and the expertise required to develop bioinformatics, the separation seems a sensible approach. SAS is the main statistical software used in Biometrics. Biometrics has a small budget for the purchase of books and software as required, and resources appear adequate for the service required. Although there is only one professional biometrician at AVRDC, isolation is avoided by regular external contact through an informal network of former CGIAR colleagues. Staff development and professional updating is largely self-directed. Constraints to the work of the unit include the occasional need to work to tight deadlines and the uneven spread of work through the year. Further statistical training for the AVRDC research staff could lead to a modest reduction of workload in Biometrics by increasing staff competence and understanding in advance of statistical review. Within the constraints, the unit appears to provide a fast and efficient service and is appreciated by the Center's research staff.

7.4 Communications and Information

The aim of the Communications and Information group is to position AVRDC as the international expert on vegetable research for development. AVRDC needs to strengthen its image as a forward-looking, cohesive sector leader, or risk losing ground to larger agricultural research institutions that are adding vegetables to their portfolios to take advantage of growing donor interest in traditional indigenous crops and the links between agriculture and nutrition.

Communications targets a range of internal and external audiences, serving as a contact with media. The group produces print documents including a monthly newsletter, *Fresh*, as well as the major annual corporate documents (the *Medium Term Plan, Annual Report,* etc.); and maintains a variety of online presences including, among others, an intranet, Facebook communities in English and Chinese, Twitter, and a website. Since the launch of the new website in 2012, traffic has quadrupled.

Communications also provides editorial services and is responsible for the AVRDC library. A survey of AVRDC research managers finds that Communications is seen as among the most important and most effectively performing service functions at AVRDC.

The effectiveness of communications could be enhanced by greater clarity about institutional self-identity. The World Vegetable Center was selected in 2008 as the title under which the center would more accurately portray itself compared to the Asian Vegetable Research and Development Center, AVRDC. In practice, all communications, written or verbal, give precedence to the misleading legacy name and "World Vegetable Center" is never used in internal conversation and is displayed less prominently than AVRDC in written documents. Although the name AVRDC no doubt resonates with long-time partners, it is time past to complete the re-branding effort begun years ago by referring to the center as the World Vegetable Center always and everywhere. Design of a new logo, which appears timely, could help stimulate the implementation of this transition.

Likewise, redesign of the *Annual Report* and the *Medium Term Plan* around the key development objectives towards which AVRDC orients itself (Section 2.2), would make these crucial corporate documents more relevant to stakeholder concerns.

The media landscape is evolving rapidly. Tools and methods such as printed crop production brochures that were effective 10 years ago may be less so today when many small farmers in East Africa and India have cheap cell phone access. Social and interactive media are gaining prominence and reach, and AVRDC has to be forward-looking in this arena. The Head of Communications should be tasked and empowered by Management to embark on an intensified effort to work with staff members inclined to utilize new media either through a peer-to-peer network or a formal committee on new media.

7.5 Human Resources

Measured by the competence, motivation and commitment of staff, the human resource function at AVRDC has had outstanding success. There are a total of 381 staff members at AVRDC. Among them, 44 are Internationally Recruited Staff (IRS) while Nationally Recruited Staff (NRS) comprised nearly 90% of the total staff. The contribution of national staff is of prime importance to the success of AVRDC. **The Panel commends the performance of nationally recruited staff, both scientific and administrative, both in the regions and headquarters.** Their names do not appear on all publications, but their efforts are critical to all that AVRDC achieves.

AVRDC Management, in particular the Office of Human Resources (HR), is acutely aware of the importance of a healthy working atmosphere and positive staff morale both for institutional effectiveness and for the human welfare of AVRDC employees. The Panel found generally high morale and motivation among most national and internationally recruited staff. The HR leadership rightly sees its responsibilities to organizational performance as going beyond routine administrative functions. A survey of AVRDC research managers finds that Human Resources is seen as a relatively important service function with reasonably good performance.

AVRDC has prepared a *Regulation Manual for Nationally Recruited Staff* at headquarters and regional offices. Although the regulations are mostly in accordance with local customs and host country regulations, the annual leave of 30 days regardless of the length of service is considered quite unusual by some in Taiwan. The NRS at the HQ recognize the mission and goal of AVRDC and enjoy the working environment, but

they also have doubts in their mind concerning non-transparency in consultancies, promotion, and salary raises.

As a non-profit organization, AVRDC rightly does not want pecuniary incentives to be the sole or even principle motivation for staff, though of course compensation is a relatively more important factor for employees in categories of lower compensation. AVRDC has the responsibility that its employees should enjoy an adequate standard of living comparable to professional peers, and HR benchmarks with comparator organizations. Neither for IRS or NRS does AVRDC aim to pay above comparators. Unfortunately, salary increases and promotions have been particularly depressed since 2009 for HQ NRS in the difficult financial adjustment brought about by the early termination of the Bill & Melinda Gates Foundation project. It would appear timely to consider ensuring that comparability with comparator organizations has not fallen.

With the continuing globalization of AVRDC, theme leaders and IRS at HQ need to travel to different regions and support regional work. As a consequence, the responsibilities of some NRS at HQ have become heavier. While this might suggest that the number of NRS at HQ should increase to cope with the extra workload, especially in research, the number of NRS actually decreased from 220 in 2009 to 185 in 2014, mostly in the number of research scientists. Part of this may be associated with the decentralization of some research activities, as retiring NRS at HQ are not always replaced. Nevertheless, if ever-increasing workloads were to continue, eventually there is a risk that the research quality at headquarters will deteriorate.

The Panel detected some concerns among nationally recruited staff based at headquarters. NRS at HQ are also concerned about their fringe benefits such as annual health check-up, overtime pay, and annual salary raise according to performance. Such issues did not arise in Panel interviews with NRS in other locations, though in some locations (e.g. Hyderabad) conditions are set not by AVRDC but by host the host organization.

The perceptions of NRS staff at HQ contrast with those of Management on several issues. Policies that are perfectly clear to one group were not perceived with equal clarity by the other. Communication may be more difficult at headquarters than the regions due to the larger number of staff, which makes face-to-face communication more difficult than in the regions, and to greater language barriers. At the same time, the growing culture of democratic expectations is especially intense in Taiwan.

Maintaining an attractive working environment is more important for AVRDC than many other organizations, and effective communication with NRS has to be part of this. While there is a formal NRS staff committee in the West and Central Africa Center, such a body does not exist at headquarters. It is hoped that an internal communication channel can be formed for the NRS to better understand policy decisions and to have the opportunity to communicate with Management.

Suggestion No. 5: The Panel strongly suggests that an elected national staff committee be formed at headquarters to periodically meet with the top Management in order to widen communication channels.

Matters of interest vary between HQ and among the various regions so an integrated Center-wide NRS representative committee is not called for and is likely to be ineffective.

For example, many policies affecting NRS in India are set by ICRISAT as the host institution rather than by AVRDC. As noted above, face-to-face communication is more feasible with the smaller number of staff in the regions. In contrast to discussions at HQ, Panel interviews with NRS in the regions did not uncover any indications of a pressing need for more formal structures to replace existing face-to-face interaction. The Panel does not discount the potential utility of forming representative committees of staff in the regions, but there is less apparent need for that at the moment. Thus the Panel sees no need to delay the implementation of this suggestion at HQ. Subsequent assessment of the need for more formal communication channels can be undertaken across all AVRDC locations, but the panel suspects that many of these locations have such a small number of employees, or already existing structures, that representation by committee would be impractical or unnecessary.

An elected committee of national staff at headquarters could therefore open a useful additional communication channel. Periodic meetings between staff representatives and Management would give Management an additional opportunity to clarify policies and clear up misunderstandings as well as an opportunity to become more aware of staff concerns. Management and staff are best positioned to work out the process and composition of this proposed new communication channel.

7.6 Monitoring and Evaluation

Overview

AVRDC has recently taken significant steps to seriously strengthen its capacity to assess the impacts of its research. Although AVRDC has traditionally focused on technology development and dissemination while tending to rely on anecdotal evidence about the outcomes of its work, stakeholder interest in monitoring and evaluation has contributed to influencing AVRDC to elevate its efforts to assess the impacts of its work.

In little more than a year AVRDC has more than doubled the number of scientists conducting research on impact. Newly recruited economists are posted in Cameroon, Tanzania and Thailand, bringing the number of specialists working in the area to five—about 10% of total internationally recruited staff. Institutional profile has been given to this work by forming a Monitoring and Evaluation team to which one of the five scientists working in this area has been assigned.

More importantly, both the quality and the quantity of evaluation research have increased impressively. Studies using randomized control designs have been initiated: one is a four-country study evaluating the effects of school gardens on nutritional awareness and dietary behavior; another is a five-country study of the effects of seed kit distribution on malnutrition.

Other methodologically robust studies include a study of off-season tomato production in Bangladesh that used propensity score matching to find that farmers increased their income about 40%. Double difference approaches are being used to measure the effects of training women in home gardening in Bangladesh, and also to evaluate the training of young farmers in four countries in Eastern and Southern Africa.

A major effort has also been launched to evaluate the use and adoption of improved vegetable varieties that have been distributed in many countries over the last 40 years. Ongoing studies in East Africa and South Asia aim to quantify how many of the commercially available pepper, tomato, and African eggplant varieties in 15 countries contain AVRDC parental materials.

Particular attention is being paid to gender-related impacts. In a study in Bangladesh using a mix of quantitative and qualitative methods, it was found that home gardens succeeded by not contesting the household power of men, but nonetheless increased female empowerment and participation in decision making.

Future Prospects

This is an important research area that is being strengthened and shows evidence of impressive progress. The challenge for AVRDC now is how to consolidate and leverage those gains.

This may be the big research opportunity for impact assessment in development projects. Development-oriented donors who are otherwise reluctant to fund research can be engaged in questions like whether home gardens diversify diets, what determines sustainability of home gardens, do home gardens empower women? A major research agenda could be funded out of monitoring and evaluation studies in development projects.

There is an opportunity to use impact assessment studies in an immensely forward-looking way. When, for example, evidence is found of how a vegetable project can link women better to markets, it opens huge opportunities for scaling out for impact while providing an attractant to donors to invest. It is wrong, therefore, to think of impact assessment as an activity designed principally to convince donors of the effectiveness of past AVRDC activities. Rather it is important that impact assessment studies become integrated into a continuous learning cycle of innovation, dissemination, and evaluation.

However, in this process the impact assessment scientists must continue to avoid becoming cheerleaders for technology transfer. They have to retain a professional neutrality both for the sake of the credibility of their research and also because their most important function is not public relations, but institutional learning about how and when outcomes and impacts are achieved. Disappointments can be more instructive and valuable than success stories.

Recommendation No. 14: The Panel recommends that continued emphasis be given to impact assessment so that it becomes integrated into a continuous learning cycle of innovation, dissemination, and evaluation.

To promote institutional learning, the main purpose of assessing impact, a variety of research methods should be used. In some cases the most rigorous approaches are called for, but often quicker, less elaborate methods may suffice to deliver information of sufficient reliability for institutional decision making. Although much of impact assessment research may seem to focus on what has happened, its greatest value lies in being forward looking about what AVRDC should do in the future. Joint studies conducted with universities and other international research centers should be encouraged to help keep AVRDC scientists abreast of the latest methodological

developments in the field, even when such methods should be used selectively within a portfolio of different learning approaches.

Scientists currently working on impact assessment are tackling similar research problems with similar methods, but are housed in different themes or units. While it is a management decision of how best to deploy these scientists, some attention definitely has to be paid to ensuring that these scientists work together as a competency group, sharing methods and experiences.

7.7 Administration and Services

The administration of AVRDC is very efficient and well managed. Standard operating procedures are established for:

(1) Assets Management: Property Management and Physical Inventory in the Residential Area
(2) Purchase/Travel/Shipping: Self-sustaining funds and self-insurance scheme for staff vehicles at HQ, management for vehicles assigned to IRS, request for using car pool, Official Travel, Purchasing Procedures, and Shipping
(3) Building construction and maintenance: Construction Site Regulations and Construction Inspection
(4) Other Procedures: Measures for managing temporary laborers at HQ, Control of Toxic Chemicals at AVRDC HQ, and Mailbox System

The campus of AVRDC at HQ is self-sufficient; all vehicles, machines, equipment, housing and dormitories are self-maintained. The genebank, which is the most important property of AVRDC, has been renovated and elevated in 2009 to avoid possible damage caused by flooding.

The cafeteria and dormitories at HQ were criticized by some staff members for being too costly and the dormitories for NRS are not well maintained, reportedly due to the Center's full cost recovery policy. Since many other similar local employers subsidize the cost of meals and living expenses, some staff report a sense of incomparable treatment. Re-examination of this policy to seek alternative ways of recouping these costs rather than charging employees could have a beneficial effect.

Full cost recovery is also applied to the research units. The research units need to pay for the costs of electricity, instrument repair, and the rent of experimental farms even after deduction of the 20% overhead from the research budget. Full cost recovery is important for controlling the financial condition of the institute. But the degree of implementation of this policy needs to be discussed to avoid hindering the incentives for researchers to seek outside funding and to have a healthy and happy working spirit at AVRDC.

7.8 Biosafety and Ethics

AVRDC has a clear code of ethics and a commitment to abide by international norms and protocols, and the rules of its partners and countries of operation. The Institutional Biosafety and Ethics Committee (IBEC), chaired by the DDG-R, has a mandate to ensure that AVRDC's activities follow all necessary protocols and procedures to minimize risk

to AVRDC. IBEC has an effective approval process and provides a robust scrutiny of projects submitted for approval. However, IBEC considers only genetically modified organisms and animal and human trials—research topics that would be considered at the high end of ethical risk by most institution research ethics committees (IRECs).

Increasingly, many universities and national and international research centres have recognized the need for a more formal consideration of research projects across a wider range of ethical risk categories, including some research that AVRDC has hitherto simply assumed to adhere to its broad ethical guidelines. More formal procedures not only ensure compliance with the code of ethics, but also have the benefit of providing documentary evidence that ethical implications of research have been properly considered, providing useful support if the research is later questioned or runs into difficulty.

In practice, projects are usually divided into two or three categories by the research proposer using a checklist. Projects deemed to have no ethical risk can be self-certified and filed. Typically, an IREC carries out a light-touch evaluation of low-risk projects; for example projects collecting information on or from humans, tracking the location or repeated observation of people, providing payments to a local community, or involving some risk to researchers. However, higher ethical sensitivity would apply, for example, to research that involves children, patients or other vulnerable groups; experimental as opposed to observational human research; deceptive research; use of indigenous genetic resources, indigenous knowledge or intellectual property outside the research population; or modified organisms. Most IRECs accept the approval granted by a partner institution or host country in cases where research is conducted off-site.

AVRDC has a Global Risk Management Committee for general risk analysis but risk associated with the distribution of biological material fits more comfortably with the IBEC. Distribution of plants and seeds is already largely covered by adherence to phytosanitary and biodiversity regulations and should have oversight from the IBEC. Distribution of seeds of exotic plants also carries a potential weed risk, especially if they are reported as invasive, and should be subject to approval by IBEC using widely available weed risk assessment protocols. In revising its biosafety and ethical policy, AVRDC should review the many examples of good practice adopted by other institutions.

Recommendation No. 15: The Panel recommends that AVRDC revise its policies and project approval process in the area of biosafety and research ethics.

APPENDIX 1: LIST OF ACRONYMS

AARNET	ASEAN – AVRDC Regional Network for Vegetable Research and Development
ACIAR	Australian Centre for International Agricultural Research
AIRCA	Association of International Research and Development Centers for Agriculture
APSA	Asia and Pacific Seed Association
ASEAN	Association of Southeast Asian Nations
AVGRIS	AVRDC Vegetable Genetic Resources Information System
AVRDC	Asian Vegetable Research and Development Center
BMGF	Bill & Melinda Gates Foundation
BMI	Body mass index
BMZ	Federal Ministry for Economic Cooperation and Development, Germany
BPH	Best Practice Hubs
Bt	*Bacillus thuringiensis*
CABI	formerly Commonwealth Agricultural Bureaux International
CACVEG	Central Asia and the Caucasus Regional Network for Vegetable Systems Research and Development
CGIAR	Consultative Group on International Agricultural Research
CIP	International Potato Center
CIRAD	Centre de cooperation internationale en recherche agronomique pour le développement
COA	Council of Agriculture, Taiwan
CORAF	West and Central African Council for Agricultural Development
CSO	Civil Society Organizations
CIMMYT	International Center for Maize and Wheat Improvement
DDG-A&S	Deputy Director General, Administration and Services, AVRDC
DDG-R	Deputy Director General, Research, AVRDC
DFID	Department for International Development, UK
DG	Director General, AVRDC
EPMR	External Program and Management Review
FAO	Food and Agriculture Organization

FTA®	Fast technology for analysis of nucleic acids
GENESYS	Global Portal for Information about Plant Genetic Resources for Food and Agriculture
GFAR	Global Forum for Agricultural Research
GHI	Global Horticultural Initiative
GIZ	German Federal Enterprise for International Cooperation
GM	Genetic Modification
G&PD	Grants & Partnership Development
GRSU	Genetic Resources and Seed Unit
GTD	Global Technology Dissemination
HACCP	Hazard analysis and critical control points
HQ	Headquarters
HR	Human Resources
IARC	International Agricultural Research Center
IBEC	Institutional Biosafety and Ethics Committee
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICRAF	World Agroforestry Centre
IER	Institute of Rural Economics, Mali
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
IPM	Integrated pest management
IREC	Institutional Research Ethics Committee
IRRI	International Rice Research Institute
ISHS	International Society for Horticultural Science
ISO	International Organization for Standardization
IT	Information technology
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
IVTC	International Vegetable Training Course
IRS	Internationally recruited staff
KU	Kasetsart University, Thailand
MAS	Marker assisted selection

MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
MTA	Material Transfer Agreement
MTP	Medium Term Plan
MYMV	*Mungbean yellow mosaic virus*
NARES	National agricultural research and extension system
NGO	Non-governmental Organization
NRS	Nationally Recruited Staff
PCR	Polymerase Chain Reaction
PRC	People's Republic of China
QTL	Quantitive Trait Loci
RDA	Rural Development Administration, Korea
R&D	Research and Development
RNAi	RNA interference
SAS	Statistical Analysis System
SATNET	Network for Knowledge Transfer on Sustainable Agricultural Technologies and Improved Market Linkages in South and Southeast Asia
SCI	Science Citation Index
SINGER	Systemwide Information Network for Genetic Resources
SMTA	Standard material transfer agreement
SGSV	Svalbard Global Seed Vault
SRTT	Sir Ratan Tata Trust, India
TARI	Taiwan Agricultural Research Institute
TYLCV	*Tomato yellow leaf curl virus*
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
WCA	West and Central Africa

APPENDIX II: PROCESS OF the 8th EPMR

The EPMR process initiated with the attendance of the Panel Chair to the 40th Anniversary celebration of AVRDC in October 2013 at AVRDC headquarters in Shanhua, Taiwan. At this time he met with Board Members, Management, and a wide range of senior scientists. With the full constitution of the EPMR Panel, the Panel Chair next attended the AVRDC Board meeting in April 2014 in Arusha, Tanzania. At this time the Panel Chair attended the meetings of the Board and all its committees. In addition, the Chair attended the AVRDC Institutional Management Committee and the Institutional Research and Development Committee. The Chair conducted individual interviews with all senior management including the regional directors, most Board members, and the Board Secretary as well as representatives of Taiwan who were present.

The Chair then spent several days meeting with AVRDC staff and partners in the Regional Office in Arusha. All senior scientists who were present were interviewed and a meeting was held with nationally recruited staff. Field visits included the Tanzanian national vegetable program; five private sector seed companies; local vegetable markets and a vegetable processor; and the Arusha research station and facilities.

Subsequently a survey was administered to all AVRDC Board members. Telephone interviews were conducted with over 20 AVRDC donors and international partners who had been identified by the Board and Management. AVRDC made available electronically to the entire Panel an extensive set of documents that the panel reviewed. The Panel held monthly telephone conferences from May 2014 onwards to coordinate their work.

Further field visits were held. In May 2014, Dr. Sun visited the Regional Office for East and Southeast Asia in Thailand. In June Dr. Harris visited the Regional Office for West and Central Africa in Mali. In September, Drs. Sun and Pachico visited the Regional Office for South Asia in Hyderabad, India for four days. Dr. Pachico went on for another week of field visits to New Delhi, Jharkhand, and Bangalore. In all these field visits Panel member interviewed both international and national scientists. The panel also visited field research facilities and met with partners and beneficiaries.

Finally in November the entire panel visited AVRDC headquarters in Shanhua, Taiwan. The Panel interviewed a wide range of international and national staff, both in research and non-research. Many were interviewed on multiple occasions. The entire panel attended the first part of the Center's Global Strategic Planning Meeting, and at least one panel member attended all the latter sessions. The Panel made numerous requests for specific information, which was invariably supplied. A survey on the performance of cross-center functions (e.g. finance, human resources, etc.) was administered to the members of the Institutional Research and Development Committee. The Panel attended the meeting of the Executive Committee of the Board. The preliminary recommendations of the Panel were presented to the Executive Committee. Finally, Drs. Sun and Pachico met with host country partners COA, MOFA, and TARI.

APPENDIX III: PROFILES OF EPMR PANEL MEMBERS

Douglas Pachico, the Panel Chair, is an economist with extensive management experience. He was graduated from Cornell University with a PhD in agricultural economics. His research interests include small-scale farmer production systems and impact assessment, and he is the author of more than 20 refereed publications. As a Manager, he was variously Deputy Director of Research at CIAT, Director of Strategic Planning, Director of Natural Resources Research, Head of Impact Assessment, and Leader of the Bean Program. He has been based in Colombia, Nepal, and Turkey, working both in research and extension. He has overseen projects throughout Latin America, East and Southern Africa, and Southeast Asia. Recently he has undertaken consultancies for CRS in Central America and Liberia, as well as for the CGIAR Standing Panel on Impact Assessment.

Lucy Sun Hwang is Distinguished Professor at the Graduate Institute of Food Science and Technology, National Taiwan University. She was graduated from Rutgers University with a PhD in Food Science. Having published 122 articles in refereed journals, her research interests have been varied but she has conducted extensive research on the chemistry of edible oils. She has been President of the Chinese Agricultural Chemical Society, President of the Chinese Institute of Food Science and Technology, and President of the Taiwan Association of Analytic Communities. She has been a Fellow of Academy, International Union of Food Science and Technology, and Fellow, Institute of Food Technologies, USA. She has received numerous awards for her teaching.

Phillip Harris is Emeritus Professor of Biological Agriculture and Horticulture, Centre for Agroecology, Water and Resilience, Coventry University, UK. He was graduated from the University of Glasgow with a PhD in Botany. His research interests have focused on tropical agricultural and food and environmental security. He has published more than 120 articles in refereed publications. He is Editor of the journal *Biological Agriculture and Horticulture*. He has been Head of International Development and Director, Centre for Agriculture and Food Security, Coventry University. He was Lecturer at the University of Sierra Leone for four years. His research and consultancies have involved, among others, Argentina, Bangladesh, Brazil, China, Cuba, Ghana, India, Jamaica, Jordan, Kenya, Libya, Nigeria Oman and South Africa.

APPENDIX IV: AGREEMENTS WITH THE PRIVATE SECTOR

Some Current Center Agreements

MOU with **Enza Zaden, The Netherlands**: For Enza Zaden to obtain seed samples of AVRDC's cucurbit germplasm and to assist AVRDC in the seed regeneration process.

Non-exclusive License Agreement for Commercialisation of AVRDC-Developed Soybean with **Syngenta Crop Protection AG, Switzerland**.

MOU with **Clover Seed Company Limited, Hong Kong**: For Clover Seed to assist AVRDC in the seed multiplication of a total of 20 accessions of vegetable soybean at its research farm in Guangdong and seed production fields in Jiuquian, Gansu, the People's Republic of China.

MOU with **Lal Teer Seed Limited, Bangladesh**: Collaboration with the USAID Bangladesh Project.

MOU with the **African Seed Trade Association (AFSTA), Kenya**: For general collaboration.

Collaboration Agreement with **Kagome Co., Ltd., Japan**: For collaboration on the development of tomato varieties with sustainable TYLCD resistance and for the exchange of the information about tolerant materials, linked markers, methods for screening and protocols for analysis.

Seed Multiplication and Transfer Agreement with **Rijk Zwaan Iberica SA, Spain**: To conduct seed multiplication process of 32 accessions of *Citrullus lanatus* (watermelon) and 68 *Cucurbita* PC accessions (pumpkin) received from AVRDC.

Agreement with **Lal Teer Seed Ltd., Bangladesh**: For a seconded scientist from Lal Teer to work at AVRDC on developing marker-assisted selection tools for Lal Teer's breeding program.

Collaboration Agreement with **Takii & Co., Ltd., Japan**: For AVRDC to perform two trials of heat stress tolerance of tomato (CLN1621L x CA4) under field conditions in Taiwan.

Research Collaboration Agreement with the **Asia and Pacific Seed Association (APSA), Thailand**: For the project entitled "Multi-location evaluation of tomato lines carry different combinations of Ty genes for resistance against begomovirus infection."

MOU with **Asian Food and Agriculture Cooperation Initiative, Korea**: For general collaboration.