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BACKGROUND PAPER

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Abstract

Growth in the horticulture sector, after taking off in the mid-1990s, has encouraged growth in horticultural trade, per capita availability and share in farming systems. Developing countries, especially China, have benefited from the horticulture sector expansion. The Horticultural Revolution (HR) benefited the poor by generating employment and income opportunities, improving resource use efficiency, encouraging commercialization in agriculture, and enhancing the availability of health-promoting micronutrients. This study describes the differential scenarios that instigated the HR of the 1990s and the Green Revolution (GR) of the 1960s and 1970s. Learning from the lessons of the GR, this paper highlights the challenge of making the HR available to the poor and suggests policies that will provide support through research and public-private partnerships. It concludes that to expand and deepen the participation of the poor in HR, research should identify the niche horticulture markets, find appropriate technological solutions, innovate market arrangements to ensure input supplies and efficient output delivery systems, and link small farmers with the market.

Horticulture Revolution for the Poor: Nature, Challenges and Opportunities

Mubarik Ali

Introduction

Since the 1970s, global horticultural production has been consistently increasing at the highest rate of all crop groups. As it started from a low base, the expansion in horticultural production was not observed until the mid 1990s when its growth rate further increased and became a significant factor in farmers' incomes and consumers' plates. This Horticultural Revolution (HR) is partly driven by the Bennett's Law which states that with urbanization and increasing incomes, the share of food staples in total agricultural output will decrease along with a concomitant increase in non-staple foods, including fruit and vegetables (Timmer *et al*. 1983).[1] Improved infrastructure and institutional arrangements, such as a strong private sector, an expanding free trade regime with food quality and safety standard compliance (Jaffee 2003), a changing market structure (Reardon and Timmer 2005), demand for diversification of cereal-based cropping systems with horticulture crops (Ali 2003), and better education and training of farmers have improved the input supply and output delivery systems and have been the main driving forces behind the HR. Even in poor countries, the HR is transforming food supply systems while improving and diversifying diets.

The HR has been relatively unnoticed in relevant literature. It has been discussed mainly in the context of international trade for certain countries (Jaferee 2003 and Lenné et al. 2005 for Kenya), even though the trade implications of the revolution were relatively small. Some studies have discussed it in the context of individual countries (Ali and Hau 2001 for Bangladesh and Ali and Abdeullah 2002 for Indochina). But the broader global trends in horticultural production, trade, domestic availability, and the impacts of these trends on income, employment, health, nutrition, environment, as well as the opportunities and challenges for the poor have rarely been discussed together. The main objectives of this paper are to elaborate the discussion of the HR, compare it with the earlier Green Revolution (GR), and draw implications for the poor in the broader sense.

The following section discusses the trends in horticulture area, production, yield, trade, availability, and its share in cropping systems since 1970, observes the specific upward link since

[1] The Bennett's Law is based on relatively high expenditure elasticities for non-staple foods empirically proven to be true (Seale et al. 2003). In addition these elasticities are positively related with income and urbanization with

1995, and highlights the share of developing and developed countries in these trends. Section 3 compares the specific features of the HR with the GR of the 1960s and 1970s for cereals. Section 4 discusses the implications of the HR for the poor, and section 5 depicts the future challenges it has generated for the poor and the environment. The final section suggests policy measures for the greater involvement of the poor in this revolution and to mitigate its negative impact on the environment.

The Horticulture Revolution

Production

The horticulture sector (i.e., fruits and vegetables combined) has been the fastest growing food sector in the world. Its production has increased from 495 million tons in 1970 to 1,379 million tons in 2004. Although cereal, livestock, and fish production each increased by approximately100 percent during this period, the horticultural sector's production increased by 178 percent.

Among the horticultural sub-sectors, vegetable production increased at the fastest rate, especially during the later period, 1995-2004 (Figure 1). It has grown at an annual average rate of 3.6 percent for the last thirty-five years (1970-2004), from 255 million tons in 1970 to 876 million tons in 2004. Although the growth in the vegetable sector in developing countries was high, almost equal to the highest growing livestock sector in these countries, expansion in this sector was exceptionally high in China, especially during 1995-2004. Production growth in horticulture in developed countries was small during the overall period, and was even negative for fruits in the later period. This created a space for developing country production, especially in China. During 1970-2004, about 52 percent of the increase in global horticultural production came from China, 40 percent came from all other developing countries, and the remaining 8 percent came from developed countries, suggesting that the HR is benefiting developing countries more than developed, especially China.

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consumers' awareness about the role of micronutrients in health, and horticulture products as the efficient sources of these nutrients.

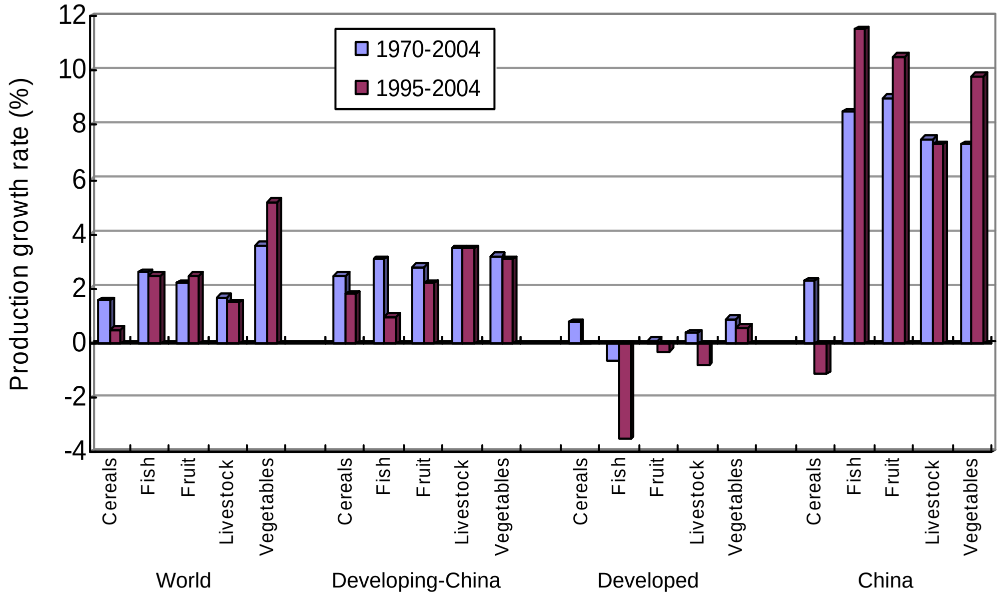

Figure 1. Growth in food production by food groups during 1970-2004 and 1995-2004

Due to the differential rate of increase in production, the shares of various regions in different foods have changed (Figure 2). In general, the production share in developed countries has decreased over the period 1970-2004. China's share of production in fruits, vegetables, fish, and livestock has increased dramatically. The shares of other developing countries in fruit and cereal production did no change significantly as a result of China's emergence as a major horticultural producer.

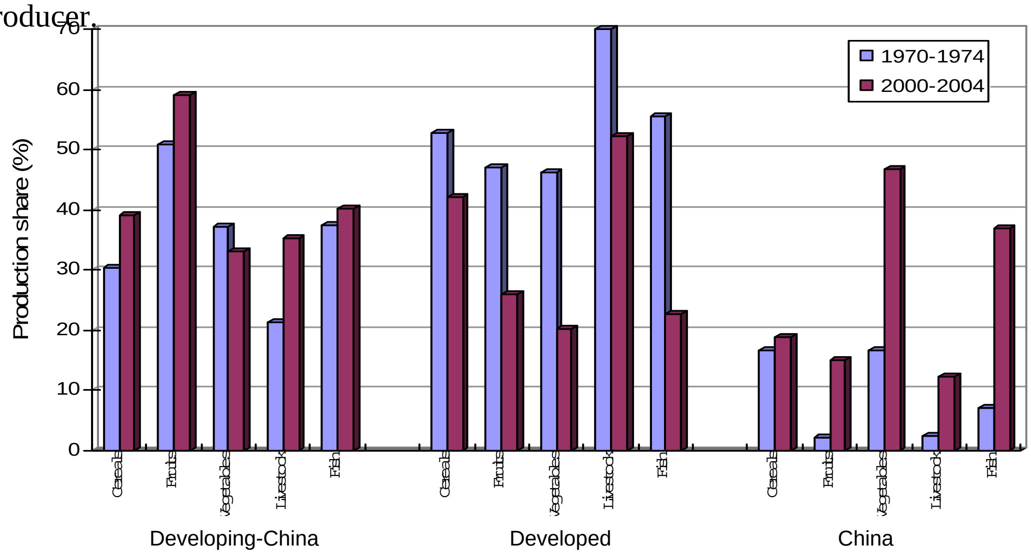

Figure 2. Regional share in food production by food groups during 1970-2004 and 1995-2004

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The production of almost all major vegetables expanded at a faster rate during 1995-2004 compared to growth in the overall period, 1970-2004. However, the major source of the expansion was from China. In the rest of the developing world during the period 1995-2004, only the growth rates in the production of eggplant and chili had significant upward drift from the trend in the overall period. The growth in the production of all major vegetables in the developed world over the entire period was small or negative (Table 1).

Table 1. Annual growth (%) in area, production, and yield in major vegetables during 1995-2004 and 1970-2004

Vegetable/region	Production		Area		Per ha yield	
	1970-2004	1995-2004	1970-2004	1995-2004	1970-2004	1995-2004
World						
Cabbages	2.2	4.4	2.4	5.8	-0.2	-1.4
Chili and Pimento	3.3	5.5	1.7	2.1	1.7	3.3
Cucumbers	4.1	7.8	2.7	6.5	1.3	1.3
Eggplants	4.8	9.0	3.1	6.7	1.7	2.2
Onions, Dry	3.6	5.1	2.5	4.3	1.1	0.7
Peas, Green	1.6	2.5	0.8	3	0.8	-0.5
Tomatoes	3.4	3.7	2.4	3.4	1.1	0.3
Developing country-China						
Cabbages	4.0	1.8	3.2	2.5	0.8	-0.7
Chili and Pimento	3.1	4.3	1.4	1.2	1.7	3
Cucumbers	4.3	3.4	3	2.3	1.4	1.2
Eggplants	4.7	7.0	2.4	4.4	2.4	2.6
Onions, Dry	3.9	3.8	2.5	3.1	1.3	0.7
Peas, Green	4.1	3.7	3.6	6.6	0.4	-2.9
Tomatoes	5.1	3.5	3.1	2.5	2	0.9
Developed countries						
Cabbages	-0.6	-0.8	-0.5	-1.1	-0.1	0.3
Chili and Pimento	1.1	0.4	0.4	-1	0.7	1.5
Cucumbers	0.9	2.5	-0.5	1.1	1.4	1.4
Eggplants	0.0	0.9	0	2.3	0	-1.4
Onions, Dry	2.1	1.8	1	1.3	1.1	0.4
Peas, Green	-0.9	-3.0	-2	-4.3	1.1	1.3
Tomatoes	1.3	0.2	0.1	-0.4	1.3	0.6
China						
Cabbages	6.1	11.9	6.2	14.6	-0.1	-2.7
Chili and Pimento	5.8	10.9	5.1	10.2	0.7	0.7
Cucumbers	6.4	12.0	4.9	10.7	1.5	1.3
Eggplants	6.0	11.8	4.5	9.8	1.5	2.1
Onions, Dry	5.5	11.6	5	11.2	0.5	0.5
Peas, Green	7.4	14.8	5.7	13.2	1.7	1.7
Tomatoes	6.1	12.0	5.8	11.9	0.4	0.1

Almost all major fruits, except grapes, had similar growth patterns during 1970-2004. During the later period, 1995-2004, the growth in the production of all major fruits, except oranges and apples, drifted upward from the long-term trend (Table 2). In China, however, the growth rate of orange production was negative in the later period, while in the developing world, the growth rate for the production of apples and oranges decreased significantly. Surprisingly, growth in mango production (a tropical fruit) in developed countries (mostly temperate) remained high in the later period while production in bananas and oranges increased. The production of apples and grapes in the developed world and apples in the developing world are being replaced by China. In contrast, orange production in the developing world, including in China, is being replaced by developed-country production, whereas production of mangoes and bananas is on the rise everywhere.

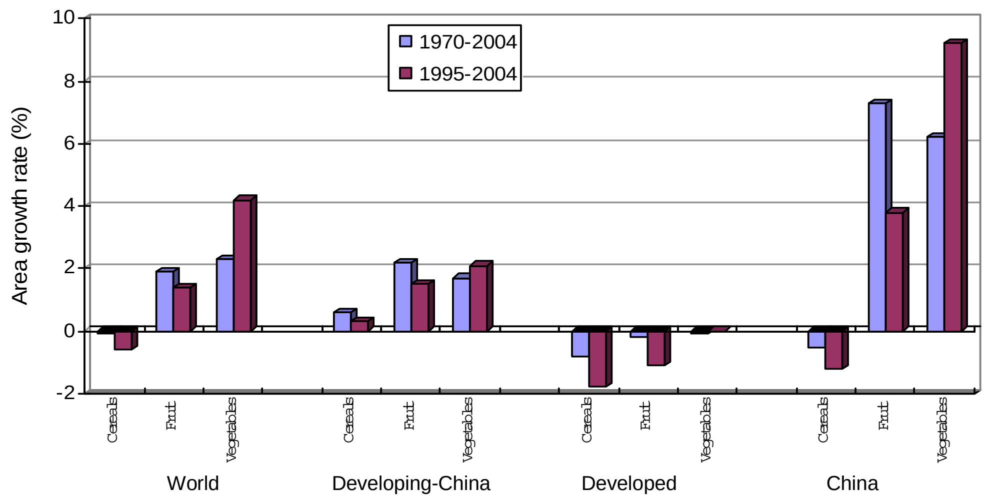
Table 2. Annual growth (%) in area, production, and yield in major fruits during 1995-2004 and 1970-2004

Vegetable/region	Production		Area		Per ha yield	
	1970-2004	1995-2004	1970-2004	1995-2004	1970-2004	1995-2004
World						
Apples	2.6	2.4	2.3	-1.6	0.3	4
Bananas	2.7	3.6	1.7	2.3	1.0	1.3
Grapes	0.1	0.7	-0.9	-0.6	1.0	1.3
Mangoes	2.5	3.5	3.2	5.1	-0.7	-1.6
Oranges	2.8	1.2	2.7	0.5	0.1	0.7
Developing country-China						
Apples	4.8	0.1	3.7	-0.4	1.1	0.5
Bananas	2.5	3.1	1.5	2.1	1	1
Grapes	1.2	2.0	-0.8	-0.1	1.9	2
Mangoes	2.1	2.5	2.8	4.4	-0.8	-1.9
Oranges	3.8	0.5	3.5	0.1	0.3	0.4
Developed country						
Apples	0.2	-1.6	-0.3	-2.9	0.4	1.4
Bananas	1.4	1.8	0.4	1.2	1	0.7
Grapes	-0.5	-0.7	-1.1	-1.3	0.6	0.6
Mangoes	7.4	8.0	6.5	4.3	0.8	3.8
Oranges	0.9	2.0	0.1	1.4	0.8	0.7
China						
Apples	10.2	10.8	6.9	-2.3	3.3	13.2
Bananas	9.8	11.3	9.2	6.8	0.6	4.4
Grapes	12.9	13.5	9.8	8.3	3.1	5.2
Mangoes	9.8	13.5	7.8	13.2	2.1	0.3
Oranges	9.7	-1.6	8.2	-2.4	1.5	0.8

Area

Globally, horticulture crops and trees occupied about 104.6 million ha in 2004, up from 73.9 million ha in 1990. The share of vegetable area was 51 percent in 2004, up from 44 percent in 1990. The long-term growth in the area under horticulture during the period 1970-2004 was at 1.9 percent for fruits and 2.3 percent per annum for vegetables while it remained stagnant for cereals for the overall period and became negative during 1995-2004 (Figure 3). During the later period, worldwide the growth in area under vegetables increased to over 4 percent and for fruits it decreased to 1.7 percent. The growth in area under vegetables increased in developing countries, but more dramatically in China, while the area under fruits decreased in developing countries, including in China. The negative trend for cereals and fruits in developed countries further deepened in the later period.

Figure 3. Growth in area under major food groups during 1970-2004 and 1995-2004



The long-term trends in area under all major vegetables were positive throughout the study period in the range of 1-3 percent, with the growth rates in the later period ranging from 2-7 percent. This was mainly due to the significant increase in the growth rate of area under all major vegetables in China. In other developing countries, only area under green peas and eggplant increased at a significantly higher rate during 1995-2005 compared to the long-term trend in the overall period. In developed countries, cucumber, eggplant, and dry onion had growth in area ranging from 1-2 percent during the later period, while the long-term growth in almost all vegetables was either negative or insignificant (Table 1).

The long-term growth in area under individual fruits was positive for all fruits except grapes, which had negative trends in all developing and developed countries except China (Table 2). During the later period, growth in apples also became negative in all regions. For banana and mangoes, growth rates in area improved during the later period, which was supported by the higher growth in area for the two fruits in developing countries and for mangoes in China. Surprisingly, the growth in orange area decreased during the later period in all developing countries including China (where growth even became negative), while in developed countries it increased to about 1.5 percent.

Yield

A substantial gain in the per ha yield of vegetables was achieved during 1970-2004, improving from 11 tons/ha during 1970-74 to 16 tons/ha during 2000-2004. However, the gains in fruit yields were relatively smaller over this period. The increase in vegetable and fruit yields spread across all regions; however, each region's growth and level of yields varied (Figure 4). For instance, China's average per ha yield of vegetables has already reached the developed country level of 20 tons, while in other developing countries it is about 60 percent lower. On the other hand, the average yield of fruits in developing countries is higher than in China and almost par with the fruit yields in developed countries. For example, orange yields in China are significantly lower than orange yields obtained in other developing countries. Some of these differences are due to the different fruit composition of each region.

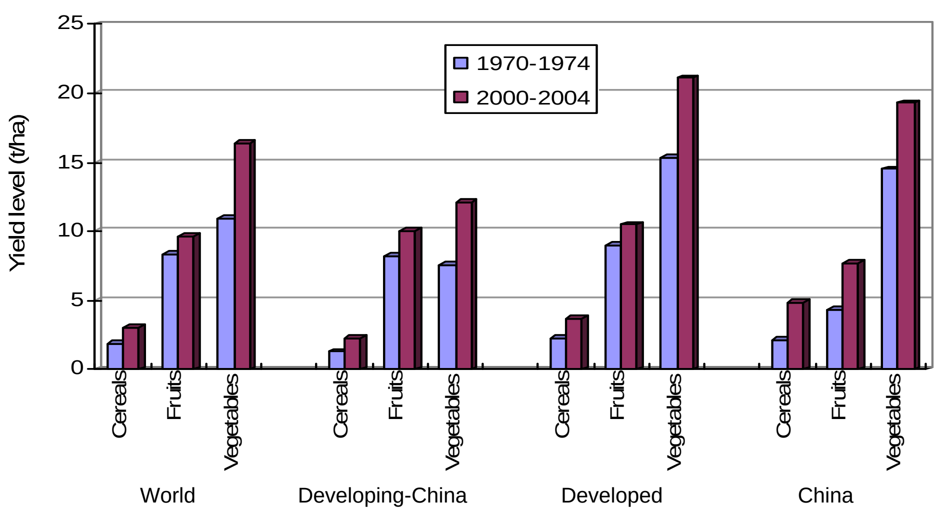


Figure 4. Average per ha yield of major food groups during 1970-1974 and 2000-2004

The long-term growth in per ha yield of cereals was much higher than in fruits and veg … e 1960s and 70s which focused mainly on cereals (Figure 5). However, growth in the productivity of fruits picked up during the later period of 1995-2004, and became equal to the productivity growth in cereals. The growth in the later period, however, was mainly concentrated in China, while in developing countries yield growth in fruits and vegetables remained lower than cereals, even in the later period. This suggests continued policy bias for cereals in designing agriculture research and development strategies in these countries. Surprisingly, in developed countries the growth in cereal yield was also higher than the growth in fruit and vegetable yields.

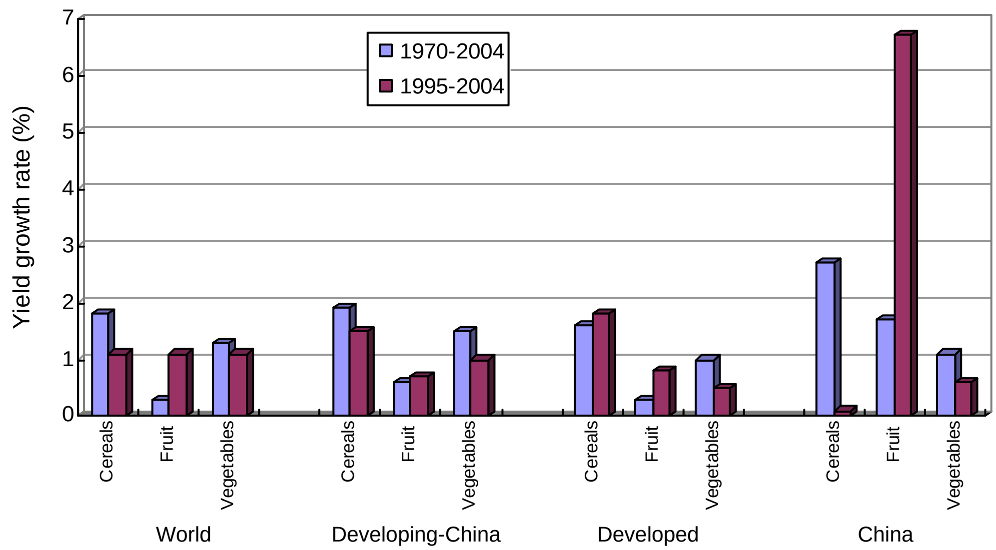


Figure 5. Growth rates in the yield of major food groups during 1970-1974 and 2000-2004

The contribution of yield improvement in the production increase was relatively small compared to the contribution of expansion in area in both fruits and vegetables. The fruit yield contributed 16 percent in the overall production in the period 1970-2003, while the remaining 84 percent came from area, although the area contribution decreased to 55 percent in the later period 1995-2003. The increase in vegetable yield contributed 36 percent to the overall increase in production during the period 1970-2003, which decreased to only 21 percent during the later period. The high contribution of area to the production increase was opposite to the GR in cereals, where its contribution was negative both in the overall as well as in the later period.

The long-term growth in per ha yields was positive in all major individual vegetables, except cabbages. The growth was highest in chili (includes pimento) and eggplant, interestingly because the highest growth of these crops was in developing countries. The growth rates of chili and eggplant yields improved during the later period in all regions except in developed countries, while yield growth rates remained stagnant for cucumbers, decreased for onions and tomatoes, and decreased dramatically for green peas in developing countries (Table 1).

The growth rates for yields of all major fruits were small, except for apples during the later period, which mainly came from China. The growth in the yields of bananas and grapes also occurred in China during the later period (Table 2).

Role in the Farming System

The share of fruit and vegetable area in the global farming system has increased from 3 percent and 2 percent respectively during 1970-74 to 4 percent each in the period 2000-2004, with startling differences across regions. In developing countries, the share of vegetable area in the farming system remained stagnant over the period while fruit area only increased from 3 percent to 4 percent. In China, the share of fruit area increased from 1 percent to 6 percent and vegetable area from 2 percent to 12 percent in the corresponding period. In developed countries the share of fruit and vegetable area remained almost stagnant at a low level. However, in the East Asian countries of Taiwan, Japan, and Korea, the share of individual fruits and vegetables in total area under all crops ranged from 15-25 percent. The difference in the share of fruit and vegetable area across regions indicates the potential for horticultural expansion in developing countries if appropriate policy environments are provided.

More impressive achievement was made through the increase in the value of fruit and vegetable products. The value of vegetables is estimated to have increased from US$8.1 billion in 1991 to US$10.8 billion in 2000.[2] The value of vegetables was 32 percent of the value of cereals in 2000, up from 24 percent in 1991. In Korea, Taiwan and Japan, however, the value of vegetables are now equal or even higher than the value of cereal crops.

[2] The increase in vegetable values would have been much higher if the economic crisis would not have led to melt down of regional currencies.

Trade

The trade in horticultural products (import and export) has increased from 74 million tons in 1970, worth US$14.3 billion, to 285 million tons, worth more than US$210 billion. The growth rate in horticultural trade quantity and value stood at 3.9 percent and 8.0 percent per annum, respectively. The higher increase in value than in quantity of horticultural trade implies a significant upward trend in prices due to improvements in the quality of these products. The share of fruit and vegetable export in the total value of agricultural export has increased from 10 percent in 1980 to 14 percent in 2003 and is expected to continue to rise. In contrast, the share of traditional agricultural commodities (coffee, tobacco, textile fibers, sugar, tea, cocoa, and cereal preparation) has declined from 40 percent to 24 percent in the corresponding periods.

In 2004, developed and developing countries exported a similar quantity of horticultural products, while their share of imports was 75 percent and 25 percent, respectively. Developed countries' share in total exports has declined from 51 percent in 1970 to 47 percent in 2004, and in imports from 86 percent in 1970 to 75 percent in 2004. While China has picked up almost all the declining share of developed countries, the developing countries were able to maintain their share in the import and export value of horticultural products.

Developing countries, especially China, have become net exporters of horticultural products due to the rapid increase in exports and relatively lower growth in imports of fruits and vegetables. Meanwhile, developed countries have incurred a large and growing horticultural trade deficit, which is now larger than the trade deficit for all food products taken together. This indicates the growing demand in developed countries for horticultural products and the growing opportunities for exporters in developing countries. Certain regions, such as Latin America and the Caribbean, Southeast Asia and China, have relatively large trade surpluses in horticultural trade, while in Sub-Saharan Africa and South Asia the surplus is relatively small but growing. The factors behind these trends are increasing awareness among developed country consumers about the role of fresh food in health, the opening up of markets, regional trade agreements such as the North American Free Trade Agreement (NAFTA), preferred trade status in EU countries under the Lomé Convention, and direct contact between developing country supermarkets and producers in developing countries.

Expanding trade opportunities in horticultural products from developing countries have positive implications for poverty. First, employment is generated on the export farms, small or large. Often landless women fill these jobs who have few other income-earning opportunities

(McCulloch and Ota 2002). The processes involved in the production of horticultural goods for export, such as chopping, washing, labeling and bar-coding, are all labor-intensive and generate many new jobs, again mostly filled by women (Dolan *et al*. 1999). In addition, increased foreign exchange earnings enhance the ability of developing countries to import technologies and materials for their industries thus generating the multiplier employment impact.

Per Capita Availability

When horticultural production was the fastest growing sector, its availability from domestic sources was also high (Figure 6).[3] Among horticultural commodities, average annual per capita availability of vegetables increased at a faster rate, from 61 kg in 1970-74 to 111 kg in 1999-2003, than fruit commodities that increased from 44 kg to 66 kg in the same period. The growth in the availability of fish and its products followed the trend of horticultural commodities and increased from 12 kg to 16 kg during the corresponding period. Cereal availability increased at the lowest rate from 143 kg to 153kg, while livestock product availability increased from 107 kg to 126 kg in the study period.

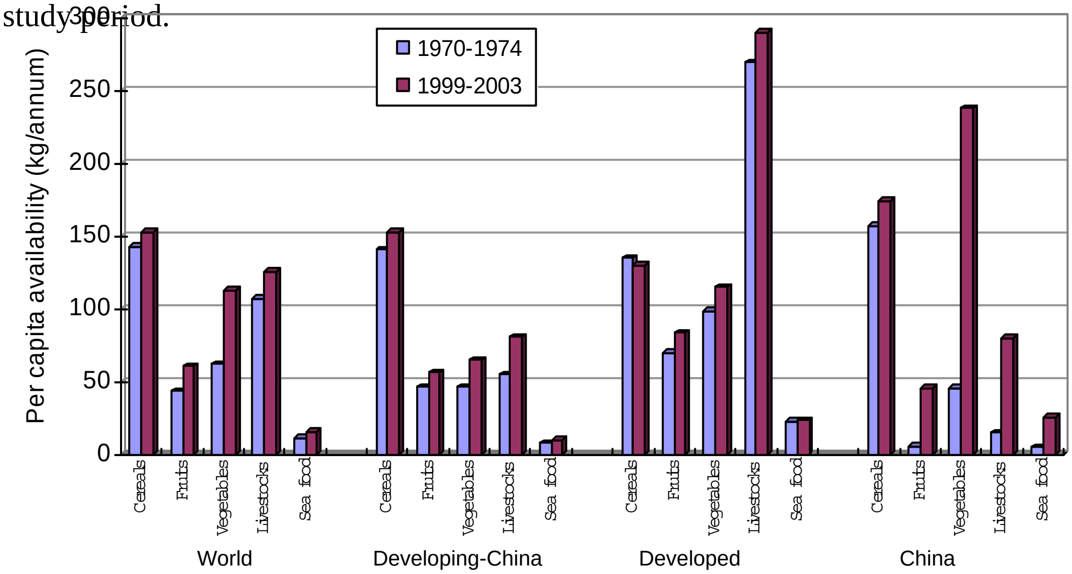


Figure 6. Per capita availability of different food groups during 1970-1974 and 1999-2003

Most of the increase in per capita availability of horticultural commodities was in China, where the vegetable availability increased from just 46 kg in 1991 to 238 kg in 2003. Similarly, the

[3]Per capita availability from domestic sources may deviate from consumption because of trade flow. However, the impact of trade on consumption is relatively small a its share in consumption rarely exceed 5%.

availability of fruits in China increased from 6 kg to 46 kg for the same period. However, developing countries also benefited from the horticulture boom. For instance, during 1991-2003 the availability of vegetables in these countries increased from 45 kg to 63 kg, and of fruits from 47 kg to 57 kg. Although the horticultural boom increased the availability in developed countries as well, the increase was relatively small because of the high level of consumption before the boom.

Impacts of the Horticultural Revolution

As noted earlier, the horticultural revolution is pro-poor. It not only benefited developing countries, but also poor people within these countries. In this section, we look at farm-level evidence on the impact of the HR in terms of generating employment, enhancing resource productivity, commercializing agriculture, and improving diet and health.

Creation of Employment

The expansion of horticultural production has generated additional employment opportunities in rural areas where labor is abundant, which is critical for achieving widespread and equitable growth. Horticultural production offers opportunities for poverty alleviation because it is usually more labor-intensive than the production of staple crops. On average, horticultural production requires 2.5 times as much labor as cereal production (Table 3). Our estimate suggests that, on average, one ha of vegetables provides about 1.5 full-year jobs just on the farm, which is about one additional year-round job if one ha of cereal is converted to vegetables. Currently, vegetables are grown on about 53 million ha in the world which employs around 80 million people. If this area been allocated to rice instead, 53 million less people would be employed. A similar number of people are estimated to be engaged in the off-farm jobs of transporting, processing, wholesaling, and retailing of vegetables.

The labor requirements for individual vegetable production may be even higher. For example, snow pea and French bean production in Kenya requires 600 and 500 labor days per ha, respectively (Dolan and Humphrey 2002). In Mexico, 20 percent of agricultural labor is employed in horticulture even though only 6.7 percent of arable land is under fruit and vegetable production (Barron and Rello 2000).

Table 3. Average number of labor days per ha for production of cereals and vegetables in Asia

Country	Cereals	Vegetables

Bangladesh	133	338
Cambodia	81	437
India	80	124
Lao PDR	100	223
Philippines	93	185
Vietnam (northern)	216	468
Vietnam (southern)	111	297
Average	116	297

Sources: India: Joshi, *et al*. (2003); Philippines: Francisco and Ali (2006); Lao PDR, Cambodia, Vietnam (northern) and Bangladesh: Ali and Abedullah (2002); Vietnam (southern): Ali (2002).

Often, additional labor requirements are met through hired labor, providing greater income opportunities for poor landless laborers (Ali and Abedullah 2002; McCulloch and Ota 2002; Weinberger and Genova 2005). Moreover, vegetables employ more women, compared to rice (Braun et al. 1989; Ali and Abedullah 2002).

Improved Resource Productivity

As cultivation moves from cereals to vegetables, resource use-efficiency improves. The return on land, labor, water and financial resources (benefit-cost ratio) are higher on vegetable compared to cereal farms (Table 4). Higher resource-use efficiency in vegetable cultivation reflects the higher managerial capacity of vegetable farmers as they make appropriate decisions in a timely manner.

Table 4. Resource use efficiency in vegetables versus rice cultivation

Crop	South Vietnam	Laos	Cambodia	Bangladesh
	Land (US$/ha)			
Vegetables	1151	696	452	553
Cereals	120	80	48	30
	Labor (US$/labor day)			
Vegetables	7.7	5.9	3.8	4.4
Cereals	4.1	1.6	2.0	1.4
	Water (% return on irrigation cost)			
Vegetables	21	11	8	65
Cereals	15	42	21	40
	Benefit-cost ratio on cash inputs (%)			
Vegetables	106	170	96	81
Cereals	43	54	53	13

Source: Ali and Abedullah (2002).

Once they learn the importance of timely decisions, they apply it to the whole farm. That is why the technical efficiency of vegetable farmers in rice production is about 20 percent higher than in rice production alone after controlling for farm size, education, and other factors (Ali and Abedullah 2002).

Commercialization of Agriculture

Horticultural production requires more purchased inputs, such as fertilizers, pesticides, and irrigation water, which also obligate more liquidity in hand (Table 5). This ultimately translates into higher demand for agricultural business activities, i.e., more loans are required to finance vegetable production, and more fertilizer and pesticide providers are needed. Moreover, horticultural production instigates activities like sorting, grading, and packaging in rural areas, which are mostly done by landless labor, particularly by women.

In developing countries, most horticultural commodities are commercially produced for the market (except from home-garden), which creates substantial demand for marketing activities. Since horticultural products have a shorter shelf life compared to cereal crops, sophisticated marketing infrastructure, such as better roads, storage facilities, etc. are essential. Once such infrastructure is established, the efficiency of the whole marketing system is improved.

Table 5. Labor and non-labor input use and cash cost in vegetables and cereals

Crop/Input	South Vietnam	Laos	Cambodia	Bangladesh
		Fertilizer (kg/ha)		
Vegetables	534	91	148	276
Cereals	197	75	46	113
		Manure (t/ha)		
Vegetables	7.6	1.3	1.7	5.0
Cereals	1.8	0.3	0.3	1.4
		Pesticide (No. of spray)		
Vegetables	7.9	1.5	6.2	6.5
Cereals	4.1	0.1	0.6	1.3
		Irrigation (No.)		
Vegetables	31	21	50	3.3
Cereals	7	1	4	2.0
		Cash cost (US$/ha)		
Vegetables	625	134	388	428
Cereals	249	65	77	143

Source: Ali and Abedullah (2002).

Commercial production creates a higher multiplier effect for a given increase in horticultural production, compared to the same increase in cereals. Through a hypothetical example,[4] the same amount of initial increase in income for both sectors was shown to create a multiplier effect of 3 in vegetables and less than 2 in cereals. This is because horticultural production requires more inputs and sells more outputs to other sectors thereby generating higher incomes for other sectors.

Enhanced Micronutrient Availability and Improved Health

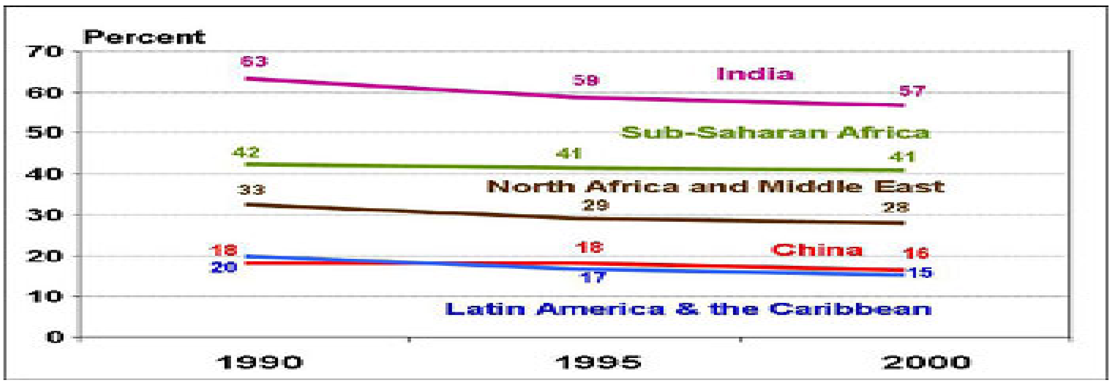
The extent of micronutrient deficiency in developing countries is quite high. Globally, about 3.5 billion people are affected by iron deficiency and anemia in the developing world, and 250 million children are victim to Vitamin A deficiency (UNACC/SCN/IFPRI 2000), causing an estimated 250-500 thousand Vitamin A deficient children to become blind every year (WHO, 2002). These deficiencies are causing billions of dollars in losses in terms of forgone human productivity ().

A growing body of literature is emerging on the effective role of horticulture in eradicating micronutrient deficiency. For example, vegetables are shown to be the most efficient sources of micronutrients in terms of dollar cost per unit of micronutrients (Ali and Tsou 1997). The presence of home gardens in Bangladesh has increased vegetable consumption, leading to increased availability of Vitamin A and reduced chances of night blindness in children (Cohen et al. 1985; HKI/AVRDC n.d.; Yusuf and Islam 1994; Greiner and Mitra 1995; Talukder et al., 2000). A significant positive link between levels of serum Vitamin A, or retinal, and the frequency of consumption of dark green leafy vegetables was found among adolescent (9-12 years old) girls in Bangladesh (Ahmad et al., 1997), and preschool children in northern Ghana (Takyi 1999). Among Vietnamese communes where home gardens were introduced, children experienced a significant reduction in diarrhea, respiratory infections and stunted growth (English and Badcock 1998). In Thailand, supplementing children’s diets with vegetables was found helpful in achieving adequate levels of Vitamin A (Charoenkiatkul et al. 1985), while increased consumption of vegetables and fruits has significantly reduced the risk of Vitamin A deficiency, including Xerophthalmia in Sudan (Nestel et al. 1993; Fawzi et al. 1993). Fruits and vegetables are rich in antioxidant compounds which reduce the risk of chronic disease by protecting against free-radical mediated damage (Southon 2000). The interplay of antioxidants found in fruits and vegetables and different micronutrients have important health impacts, explaining, for instance, the higher birth weight of

[4] This example assumes 90% of the vegetable and 30% of the cereal output sold in market. Similarly, 40% of the inputs in vegetables compared to 50% in cereals are assumed to be have been purchased.

children in India whose mothers consumed green leafy vegetables and fruits during pregnancy (Rao et al. 2001). Many studies have quantified a negative relationship between different types of cancer and vegetable consumption in relatively affluent societies (Bueno-de-Mesquita et al. 1991; Hirayama 1995; Jedrychowski et al. 1992; Yu et al. 1995).

The impact of the expansion of horticultural production went beyond the farm-level to reach the urban and landless rural poor. The reduction in the percentage of preschool children who are Vitamin A-deficient (Figure 7) can partly be related to the trends in the horticulture sector.



Source: Micronutrient Initiative and UNICEF 2005

Figure 7. Vitamin A deficiency in preschool children

Nature of the Horticultural Revolution

The horticultural boom is different than the Green Revolution of the 1960s and 1970s for cereals, and in fact is unique in its nature and history. Some of the differences are highlighted in the following sections.

Commodity Spectrum of HR

Unlike the GR which was restricted to rice, wheat, and in some regions corn, the HR is not confined to a particular commodity or even few commodities. The commodity is defined depending upon the niche for a region or a country. It can be chili in a certain region of China (Ali 2006), asparagus in the Kamphaengsaen district of Thailand (AVRDC 1998), citrus in the Central Punjab of Pakistan (Sharif and Ahmad 2005), indigenous vegetables, tomatoes, and avocadoes in Kenya (Muendo et al. 2004), grafted tomato in the peri-urban of Hanoi (Palada and Ali 2007), green house vegetable cultivation in China (Liu *et al*. 2004), etc. So the HR exploited the potential niche for a crop grown in its most favorable ecoregion, rather than pushing a particular crop irrespective of its suitability in the ecoregion. In the GR, cereals were sometimes pushed in unfavorable ecoregions through government incentives or beyond the level an ecoregion can optimally take, like rice in the Gangetic region with the consequence of environmental and resource degradation of the ecosystem. On the other hand, the appropriate selection of horticulture crop or technology by farmers themselves in an ecoregion favorable for it helps to improve the resource use efficiency, enhance resource sustainability, and promote crop diversity and specialization.

Technology Spectrum of GR and HR

The GR was based on improved cereal varieties that were more responsive to fertilizer and water. Later pest-resistant varieties were also emphasized (Evenson and Gollin 2003). Public policy support, like the provision of improved variety seed, fertilizer, irrigation water, and sometimes pesticide and guaranteed minimum support price, played a key role in the initial dissemination of GR varieties and technologies.

The technology spectrum of the HR, on the other hand, is much wider than that of the GR, and the choice of appropriate technology is made by farmers themselves, rather than through policy support. No doubt it is based on the improved crop varieties and chemicals for productivity enhancement, but its technological spectrum also includes improved crop protection through the use of plastics, advanced irrigation methods like drip, improved fertilizer management like placement technologies, scientific methods of raising seedlings, improved land preparation like raised bed and furrows, integrated pest management approaches, mulching, and staking are just a few examples. Moreover, unlike in cereals, the main emphasis is not just increased yields; improvement in quality to meet the consumers' preferences in color, shape, and size, tolerance to environmental stresses to provide off-season supply and reduce heavy metal residue and nutrient enhancements are equally important goals of varietal improvement programs from the onset.

In cereals, technologies are adopted in a sequential manner based on their economic benefit (Byerlee and Polanco 1986), while in horticulture, advanced technologies such as fertilizer, pesticides, mulching, and staking are applied in an integrated manner. For instance, higher application of fertilizer and pesticides and raised-bed cultivation were adopted simultaneously to hybrids chili varieties in Asia (Ali 2006). Similarly, vegetable protection by plastic cover necessitates the use of raise-beds, higher chemical usage, and sometimes drip irrigation. One reason for the integrated technology adoption in horticulture is that the benefits are assured by the private sector who promote these technologies as a set. Secondly, the component technology becomes economically viable only if it is adopted in an integrated fashion, much like how hybrid varieties become uneconomical at low levels of fertilizer application. Thirdly, horticulture farmers are more educated and thus trained in adopting complicated technologies than cereal farmers.

Fast and Widely Spread

At the peak of the GR during 1965-75, global cereal production increased at an annual rate of 2.5 percent, while during 1995-2003, global horticultural production increased at an annual rate of 4.2 percent. Even in the developing countries of Asia and Latin America, the growth in the horticulture sector during the period 1995-2003, was comparable with the early GR period of 1965-75.

Unlike the GR which was initially concentrated in certain countries of Asia and Latin America, the horticulture boom spread almost everywhere in Asia, Latin America, and Africa (Table 6). Certain central Asian countries experienced setbacks in vegetable production during the early 1990s due to economic restructuring, but have been recovering since the late 1990s (Ali *et al*. 2002). In Africa, where the GR did not touch, the growth in horticultural production was impressive at 2.9 percent during 1995-2004, although wide country-level variation was observed in the growth. Certain African countries, like South Africa, Kenya, and Tanzania, experienced high growth in fruit and vegetable production, while in others political disturbances inhibited the HR. Poorer countries in Asia like Bangladesh, Nepal, and Cambodia also experienced high growth in vegetables (Ali and Hau 2001 for Bangladesh; Thapa and Paudyal for Nepal; and Abedullah et al. 2002 for Cambodia).

Table 6. Growth in area, production, and yield of horticulture produce during 1970-2004 and 1995-2004

Region	Area		Production		Yield	
	1970-2004	1995-2004	1970-2004	1995-2004	1970-2004	1995-2004
China	6.60	7.22	6.60	9.93	0.94	2.71
Africa	1.87	1.76	1.87	2.90	0.58	1.14
Developed Countries	-0.20	-0.73	-0.20	0.20	0.70	0.93
East & South East Asia	1.86	2.20	1.86	2.26	1.21	0.06
Latin America and Caribbean	2.39	0.97	2.39	2.38	0.50	1.41
South Asia	1.93	2.60	1.93	3.72	1.33	1.11
World	2.08	2.70	3.01	4.17	0.93	1.48

Policy Spectrum of HR

In the HR, public policies are playing a critical role in the expansion of area under horticulture, but through a different mode and context. Here the emphasis is not on supplying inputs through public sector or guaranteeing the minimum price for horticultural products; rather it is on removing price guarantees and other policy supports for cereals to correct the relative incentives for horticultural products. In some cases, like in Taiwan, guarantees were provided for the off-season production of vegetable crops (Wann et al. in dynamic of vegetables 2000), but those were isolated examples. The real incentives for the horticulture sector were provision of credit and infrastructure development such as roads, cold storage chain, green houses, etc.; however, most of these developments were provided through the private sector.

Area Expansion not Yield Enhancement as Starting Point

As noticed earlier, the area expansion was the driving force in the HR in contrast to the GR where yield improvement was the main force, although yield improvement also played a role, especially in vegetables during the period 1995-2004. This implies that the availability of improved technologies was not a constraint in the HR; rather, the market or an efficient link between farmers and the market was the major constraining factor. This constraint was removed through favorable policies including the provision of appropriate market infrastructure and knowledge system, and support for farmers' organizations, all of which triggered the expansion of area under horticulture.

Not Just Based on Quantity but Also Quality

The quality of horticultural products in terms of size, shape, and taste is more diversified than in cereals. For example, small-sized onions are preferred in the Philippines, medium-sized in India, and large-sized in Taiwan. For hot chili, pungency in India and Thailand, appearance in China, and freshness in Indonesia and Thailand are the first ranking criteria (Ali 2006). One unique characteristic of the HR is that production technologies are adjusted to meet these local quality requirements.

Another quality criterion is the regular supply of horticultural products, which is normally more seasonal than cereals (Ali 2000). Higher incomes have not only created additional demand for these products, it also has encouraged people to consume them more regularly. Thus, increased incomes have asserted stronger demand pressure on supply during the lean period. The HR has been able to meet this quality criterion both through technological innovations for off-season production, including protected cultivation, and regional and international trade. As a result, seasonal variations in vegetable prices, for example in Taiwan, Vietnam and India, have decreased significantly over time (Figure 8).

Figure 8. Overtime reduction in seasonal prices of vegetables in selected countries o Asia

Role of the Public and Private Sectors

The International Agriculture Research Centers (IARCs) have played a major role in the development and promotion of GR varieties and technologies. More than 35 percent of modern varieties (MVs) released and adopted were based on crosses made in IARCs; 15 percent of NARS-crossed MVs had an IARC-crossed parent, and an additional 7 percent had another IARC-crossed ancestor. The private sector's contributions were limited to "hybrid" varieties of maize, sorghum, and millet. Private sector breeding programs for these crops were developed only after "platform" varieties were developed in IARC and NARS programs. Since 1996, genetically engineered varieties developed by the private sector have been released but adoption is limited to only 3-4 developing countries (Evenson and Gollin 2003). The private sector also played a minimum role in offering input supply and output delivery systems for cereals, as these were mainly controlled by the parastatals.

On the other hand, the international centers engaged in horticulture commodity research (i.e., AVRDC and INIPAB) rarely released advanced breeding lines as such anywhere in the world. It was modified and adapted to the local conditions either by the private sector or by the national programs. Secondly, international and national public sector breeding efforts were confined only to certain commodities, while the major task of releasing and introducing the modern varieties of horticulture crops was taken up by the private sector. The international centers, however, did play a major role in providing germplasm to the private sector. For example, AVRDC distributed over 18,000 packets of germplasm free of cost to the public and private sector during 2004. About 45 percent of the seed companies surveyed during 2002 used or are planning to use the germplasm supplied by AVRDC (AVRDC 2003).

The HR built its success on the prevailing market infrastructure. The inputs were supplied and outputs were picked up by the private market agencies, or farmers' cooperatives without much involvement of the government. Sometimes, marketing agents were involved in forwarding loans, and/or engaging with farmers in contractual arrangements for a specific quantity of outputs, in prescribed quality, at a particular time. The government was involved only in a facilitating role to resolve the key constraint, such as the high cost of cargo of horticultural products in Kenya (Jaffee 2003), covering the risk of off-season vegetable production through the deficiency payment program for off-season vegetable production in Taiwan (Wann *et al*. 2000), etc. Sometimes the key constraint was resolved by the private sector; for example, providing training, necessary inputs including credit and sprinkle irrigation, and assuring output prices for the introduction of asparagus in the Kamphaengsaen district of Thailand (AVRDC 1998).

Built on the Transformed Market Infrastructure

During the GR, the initial development of rural market infrastructure was mostly the result of the increased output generated by the modern varieties and new technologies in cereal cultivation. On the contrary, sophisticated market infrastructure development drove the HR. The infrastructure, such as chain of cold storage at the farm, around ports, and at retail level, refrigerator trucks and ships, and efficient telecommunication technology reduced the post-harvest losses, and helped to keep the original quality of the products even if they were transported from long distances within the country or imported from abroad (Reardon and Timmer 2005). The long-range commerce also assured the regular supply of seasonal products, especially important for horticultural products. These developments helped to ship horticultural products to niche markets without threatening freshness, low cost, consumption diversity, and consistency of supply.

On the other hand, market integration in the downstream agrifood system reduced the marketing costs of high value products, where marketing margins were particularly high, by removing large numbers of retailers who had low capital investment but high per unit fixed cost and post-harvest losses. This also generated incentives for horticulture producers. Unlike small-scale retailers, the large-scale downstream market chain is more directly linked with producers and processors, not only making it feasible to monitor the food safety regulation at the production and processing points, but also enabling horticultural farmers to understand the nature of market demand for their products. In addition, the large-scale retailers conducted research on consumer demand for food quality and safety. All of this has helped in targeting production to meet demand more precisely, especially for the niche market, and overcome the annual fluctuations in supply and demand of horticulture products, to a certain extent.

Future Challenges

Increasing Costs

Vegetables are input–intensive, both with respect to materials as well as labor. This increases the production costs many folds compared to field crops (Ali 2000-Dynamics-summary). Expensive material costs for mulching, rain shelters and tunnels, staking, drip irrigation, sophisticated machines for land preparation, fertilizer and pesticide placements and irrigation, and skilled labor for planting, harvesting, and grading, all add to the costs of production. In addition, cash costs are two to five times higher than field crops like cereals (Table 5).

Higher production costs are increasingly becoming a binding constraint to the expansion of horticultural production, especially with the recent rise in petroleum prices. The costs are also increasing with the shift of its production from the most productive lands in the periphery of cities to the marginal lands away from cities mostly in upland fragile ecosystems (Ali 2007). Moreover, the labor costs, which is the single most important item claiming a 40-60 percent share in production costs, is on the rise in almost every country, rich or poor. These trends in production costs are more troubling for the horticultural producers as its production is more input and labor-intensive compared to field crops like cereals (Table 5). The greatest challenge of the researchers and policy makers in the horticultural sector, therefore, will be to reduce production costs and make the necessary finance available to further spread the impact of the HR to small farmers without damaging the environment.

High Risk in Horticulture Production

In addition to higher production costs, higher risks may restrict horticultural cultivation to more well-off farmers who can afford these costs and the associated risk (Ali 2002- technical bulletin 27; Ali and Hau 2001; Key and Runsten 1999). This higher risk is due to the variability in production and market prices. The production risk is high because horticultural products generally are more sensitive to the changes in a narrow range of environmental conditions than field crops. The market risk in horticulture products stems from the small production scale of individual crops, scattered farmers on a large area, high sensitivity of production to environments, and lack of government support in price dissemination and farmer coordination. The production risk is much higher during the off-season, while market risk is the major concern during the peak-season.

Although technologies are available to ameliorate the biotic and abiotic stresses and reduce production risks, many of them are expensive, environmentally unfriendly, and have limited adoption. Similarly, institutional arrangements such as contract farming, cooperative marketing, and processing of horticultural products can reduce the market risk. Making these technological and institutional innovations economically viable and environmentally friendly in a wider range of environments and for a greater number of smallholders is a continuing challenge for researchers. This will definitely require more investment in the research and development of the horticulture sector.

Post-harvest losses

During the process of distribution and marketing of food, substantial losses are incurred which range from 1 to 50 percent, depending upon the country, product, and type of losses considered (FAO 1981; FFTC 2004). The causes of loss are many: physical damage during handling and transport, physiological decay, water loss, or sometimes simply because there is a surplus in the marketplace and no buyer can be found. Losses are high in developing countries, because of the inherent difficulty of collecting and transporting small quantities of produce from numerous small farms, and trying to collect these into a large enough quantity for efficient domestic marketing or for export. In tropical and subtropical countries, the warm, humid climate adds more stress and accelerates the decay of tropical produce. The poor post-harvest handling may also become a source of microbial contamination on fresh foods including fruits and vegetables (Black et al. 1982). A recent example is the e.Coli detected on broccoli packages in the supermarkets of the United States. All these post-harvest problems reduce the prices and competitiveness of horticultural products.

A large number of post-harvest technologies have been documented in the literature (UC Davis 2006; Washington State University 2006; FFTC 2006), but their application is conditioned by infrastructure development and improved links with the markets or such technologies are relevant only for the large commercial enterprises. Longer-shelf life varieties of several horticultural commodities such as tomatoes and onions have been developed. The priorities within the post-harvest sector of developing countries, however, have evolved from a primarily technical focus geared toward the reduction of losses to a more holistic approach designed to link on-farm activities to processing, marketing, and distribution (Mrema and Rolle

2002). In this scenario, new organizational structures for marketing, such as cooperative marketing, contract farming, supermarket, etc. are considered better ways to reduce post-harvest losses. However, such market arrangements either have transaction costs or are biased towards large farmers.

Despite this evolution, fundamental problems and concerns of the horticulture sector have remained relatively unchanged: high post-harvest losses, poor marketing systems, weak post-harvest research and development capacity, and inadequate policies, infrastructure, and information exchange regarding post-harvest technologies still persist. In light of high rates of return, the skewed allocation of funds to production versus post-harvest (5 percent of the total agriculture research funds are channeled to post-harvest) is now questioned (Goletti and Wolff 1999). Although a large amount of post-harvest research is conducted by the private sector, such research is mainly for large-scale commercial market enterprises and have little or no relevance for small-scale farmers and retailers. Therefore, the future success of the HR greatly depends upon the management of post-harvest problems.

Efficient Input Markets

Horticultural production is not only input-intensive but also sensitive to the timing of input availability. In many countries of Africa, Asia, and Latin America, the marketing costs of inputs such as fertilizer, pesticide, irrigation water, and seed is high, and supplies are irregular. For further expansion of the HR to developing countries and to resource-poor farmers to occur, the agricultural inputs should be made available whenever they are needed and at low marketing costs.

Seed is especially important in the HR, because it sets the limit on the productivity of land, labor, fertilizer and water. A competitive seed sector can also promote agricultural business development through the seed industry and related inputs. An efficient private seed sector is important to promote the hybrid seed as many horticultural crops are cross-pollinated and hybrid seeds usually give better yields. The seedling sector is also equally or even more important when nurseries are transplanted rather than direct seeding. This is especially true for fruit trees where the quality of seedlings can be judged only after several years of their planting. Established community seedling centers usually become the focal point for horticulture crop production technology dissemination, as they use the best available seed, apply best nursery raising methods, and advise farmers the appropriate management techniques to get the best output from their seedlings.

Private-public sector collaboration is very important in establishing the efficient seed and seedling industry in a country. The public sector provides information to the private sector on the potential demand of different seeds with different attributes, supplies enough basic seeds of improved varieties, identifies genes for resistance and quality attributes, forges the enabling legal and procedural framework for not only the private sector to operate efficiently but also for the farmers to ensure quality, and provides information and training about the merging scientific methods of varietal development, seed production, and distribution. The private sector multiplies the basic seed in large quantities for commercial distribution, improves the existing varieties by incorporating the identified genes for resistance and quality attributes, and sets up efficient marketing chains for seed and seedling distribution.

Private sector investment in varietal development depends critically on an enabling policy environment of Plant Varietal Protection (PVP) and Biosafety regulations. These laws will open up doors for the flow of new technologies in a country. On the other hand, lengthy procedures of varietal registration, certification and testing, licensing requirements of seed-growers and retailers, unavailability of enough basic seeds, unnecessary restrictions on imports, lack of trained manpower, scientific information, and access to germplasm usually restrict the seed and seedling sector development. It is a great challenge both for the private and public sectors to overcome these constraints on seed and seedling sector to intensify the HR and its impact to the small-scale farmers.

Management Skills

Horticultural products are not only input-intensive, but also management-intensive. Horticultural farmers face uncertain production and market environments. Unlike in cereals, they are not protected by government policies such as minimum procurement prices, price support, etc. They have to make timely decisions in crop selection and establishment, input purchase and application, management practices, harvesting, and output disposals. They have to perform more sophisticated operations, such as the construction of furrows, line sowing, application of chemicals in appropriate dosages and times, installation of drip irrigation and drainage systems, and make financial arrangements to pay hired labor and input suppliers. All of these require sophisticated managerial skills and an understanding of the input-output markets and an ability to match market demand with available farm resources. It is said that if farmers can successfully manage a vegetable farm, they can easily operate a computer shop or any other modern business. The resource-poor farmer usually lacks these skills and is therefore unable to participate in the emerging horticultural product markets. To bring the fruits of the HR to small farmers, their managerial skills have to be improved through appropriate education, training, and extension programs.

Demand for Organic Horticulture Food

Increasing consumer awareness of the health consequences of heavy metal residues, processed foods, and food produced by intensive farming systems has created demand for organic food in North America, Europe, and East Asia and an opportunity for small farmers. The demand for organically produced (OP) food has reached US$20-25 billion and is growing at an average rate of 20 percent per annum (Kortbech-Olesen 2003). Fresh foods, especially horticultural products, are the major component of OP food. If this is the future trend in the horticulture sector, how will it impact the sector in general and small producers in particular?

On the demand side, the demand for OP horticultural products has created opportunity for farmers because consumers are willing to pay high prices for these products. For example, over 70 percent of consumers in California were concerned or very concerned about pesticide residues and were willing to pay over a 10 percent premium for pesticide residue-free produce (Collins *et al.*1992). According to my own surveys, all the respondents in Taiwan have concern over high pesticide use on vegetables, and were willing to pay, on average, a 30 percent premium for low-input vegetables. In Hanoi, Vietnam, the vegetables produced organically fetched 30-220 percent higher prices (Ho Thanh Son *et al*, 2004; Vu and Mai 2003).

On the supply side, however, it creates challenges for farmers to meet these demands because organic production increases costs, reduces yield, in some cases reduces net return, and requires more intensive management than traditional production (Gristina *et al*. 1995; Lindner 1989 and 1992; Keipert *et al*. 1990; Brumfield *et al*. 1995; Francis 1990).

The horticulture researchers are facing three challenges to enable small farmers to benefit from this emerging demand for OP horticulture products: 1) reduce the production costs of organically produced (OP) or low-input produced (LIP) products by introducing technological innovations to small farmers to make these products competitive with the traditionally produced products;[5] 2) convince consumers of the authenticity of OP products so that they are no longer

[5] Beharrell and MacFie (1991) reported that consumption of OP increased sharply when the price premium was below 20%.

restricted to specialty stores of consumers' choice (Thompson 1998); and 3) link small farmers with the OP or LIP market by providing technical and organizational support to them. Indeed, the main constraint on the expansion of the OP market is intra-chain supply coordination (Moustier *et al*. 2006).

Meeting the Horticulture Product Quality and Safety Standards

Not only producing, but also proving that farm produce meets the stringent food quality and safety standards is a big challenge for small farmers. Meeting the chemical standards such as low or no pesticide residue and heavy metal contents is equally or even more important than meeting the physical standards in terms of shape, color, or taste. The contamination of heavy metal in horticulture food, such as arsenic, cadmium and mercury, is becoming an increasing concern of food administrators because of the increased intensity of pesticide, fungicide, herbicide, and fertilizer being used in its production, proximity of horticulture production to industrial smoke, and the application of improperly treated city solid waste, animal manure, and wastewater in horticultural production. Although the share of fruits and vegetables in total crop area is only 4 percent, together they account for up to 28% of the global pesticide market in certain years or around US$8.4 billion a year (Dinham 2003). As a result, several studies have confirmed that horticultural foods contain higher than permitted thresholds of heavy metal and use of banned pesticides in developing countries (Thach 1999; Thi 2000; Alam *et al*. 2003; Mansour 2004).

The consumers' perceived notion about the safety aspect of food quality has started playing a strong role in international food trade. For example, during 2000-01 some US$1.75 billion of developing country exports were affected by import border rejections or retentions (Jaffee and Henson 2004); this does not include the restrictive effect of these standards on trade. Other studies showing the restrictive effect of food quality standards on trade are Wilson and Otsuki (2001) and Otsuki *et al*. (2001).

The increased consumer awareness has created demand for some mechanism to assure that the use of harmful metals and contamination are within prescribed limits. As a result, various internationally recognized food quality standards have emerged, including the Good Agricultural Practices (GAP), Good Manufacturing Practices (GMP) like ISO 9000, EUREP GAP, Hazard Analysis Critical Control Point (HACCP), and environmental standards like ISO 14000 standards (Plaggenhoef et al. 2002). To ensure that the fresh food supply meets the required standard, traceability of food, by which the retailing firms trace the history, application, or location of food, is becoming the necessary component of the food production chain to ensure food safety to their consumers.

The challenge of the horticulture sector, especially of the small horticulture farmer, is to meet the traceability requirements and assure retailers that their supply meets the required food safety standards. However, the regulatory environment in the horticulture sector can be an opportunity to gain secure and stable access to affluent and remunerative new markets, which generates large value- adding activities in developing countries. Many successful examples in developing countries have been reported in Hanak et al. (2002) and World Bank (2005). For this, farmers have to be connected with markets through information about the emerging horticultural niches, and the appropriate technologies and training to meet the food safety and quality standards.

Changes in Market Structure

The “commodity” market that sells unbranded and undifferentiated agricultural products with little or no processing has now transformed into a “product” market that sells differentiated products within a commodity with specific attributes, such as organic or not, processed or not, branded or not, variety A versus variety B. This transformation has brought consolidation downstream in the agrifood system (in the processing and retail segments), including the rapid rise of large-scale processors, supermarkets, and food service chains (Reardon and Timmer 2005). Technological innovations in the marketing chain of agrifood systems has helped to improve horticultural products’ freshness, lower their cost, and improve horticultural diversity in food by bringing these products from diverse production environments and making the supply of seasonal products more regular.

These changes in the market structure provided opportunities for horticulture producers, but also create challenges, especially for small-scale resource-poor farmers. They generally fail to benefit from the emerging market opportunities because they do not have the resources, information, or skills to meet the integrated market standards and they are relatively less integrated with markets. The integrated markets also have scale bias towards large farmers (Dolan and Humphrey 2000). However, with appropriate technological, financial, and information support, small farmers can be successfully organized to meet the new market challenges and benefit from emerging opportunities (Hanak *et al*. 2002; World Bank 2005; Neven and Reardon 2004). Such technological and organizational support will be crucial to saving the HR from being hijacked by large and resource-rich farmers and countries.

Research Priorities in the Horticulture Sector

As highlighted earlier, the HR is not based on a single crop or a single technology. It exploits the available niche at the ecoregional level by fitting an appropriate crop and technology. Therefore, researchable issues and constraints of the HR revolution vary across regions. Keeping in view the number of horticultural commodities involved and location-specific production problems in each commodity, the resources available for horticulture research and development are extremely meager. This clearly signifies the importance of a well-conceived prioritization strategy at all levels of research, development and policy planning. Making collaborative efforts through networking can be another way of overcoming resource constraints in horticulture research. Every region or country should focus on the crop in the ecoregion where it has the comparative advantage, and share the experience with other member countries and regions working on the crops and ecoregion that give them a competitive advantage.

As labor is the major input cost and its share is on the rise, demand for mechanical technologies to offset high labor costs, as well as demand for uniform-maturing horticulture varieties suitable for mechanical harvesting, will be high, especially where the wage rate is high or rapidly increasing. However, such trends may aggravate the seasonality in horticultural supply, as most of the harvest may come at the same time. To overcome this problem, the new varieties should be photo-insensitive so that they can be grown and harvested at different times of the year. This will also stabilize yields and reduce the risks in horticultural production. Shortening the duration of vegetable crops may be another priority for research, so that they can fit in the existing cropping systems without replacing any major crop.

In developing research priorities for the HR, we should not repeat the mistake of the GR of concentrating only on the major crops grown in favorable ecoregions. Breeding efforts must target both exotic and traditional horticultural products grown in unfavorable ecoregions, especially in low-income countries. Traditional horticultural products are substantially important for the household food and livelihood security of resource-poor farmers (Cavendish 2000; Weinberger and Msuya 2004). They are also rich sources of important micronutrients, contributing between 30 and

50 percent of iron and vitamin A consumption, respectively, in poor households (Gockowski et al., 2003; Weinberger and Msuya 2004-Katinka paper on horticulture revolution).

The richness of fruits and vegetables in functional properties such as lycopene, beta-carotene and other antioxidants, and their role in reducing the risk of chronic diseases and improving health has already been discussed. Indigenous horticultural products have also been identified for strong anti-oxidization activity, and for high vitamin-C and phenol contents (Sato 2002). Despite this evidence, however, the research has not focused on fully exploiting the potential of horticultural products. Future horticulture research should focus on enhancing the nutrient content of horticultural products, identifying different functional properties in various products, and quantifying the role of different fruits and vegetables in reducing the risk of various chronic infections and diseases. This will not only add to the value of the HR but also increase the demand for horticultural products, thus further reinforcing the growth in HR.

Summary and Challenges

The stage has been set for a full blown Horticultural Revolution (HR) in the world since mid 1990s. The forces for this have emerged both from the rapid growth of world economies and from within agriculture. Income and population growth and rapid urbanization have created additional demand for the regular supply of quality and diversified horticultural products, while the need to diversify cereal-cereal production systems has generated additional scope for integrating horticulture into these systems. These forces are reinforced by the freeing of food markets internationally.

These forces have generated the fastest growth in the horticultural sector, among all the raw food sectors in the world. The growth in the production of almost all major vegetables and fruits increased during the 1990s. Among the horticultural sub-sectors, vegetable production increased at a faster rate than the production of fruits. The HR has brought an impressive improvement in its trade, per capita availability, and share in farming system with positive consequences on the foreign exchange earnings, health of the people, and sustainability of the farming systems. This HR is pro-poor from the outset as most of the improvements related to the horticulture sector benefited developing countries, although China claimed the proportionately higher share.

The HR has generated new employment and income opportunities for the poor. It is estimated that vegetable cultivation alone generated approximately 80 million jobs worldwide during 2003, which would have been 53 million less had this area been allocated to rice. A similar amount of the labor force was estimated to be engaged in off-farm activities such as transporting, processing, and marketing. The evidence suggests that additional labor requirements were more often met by hired labor and women, providing them with greater incomes.

The HR improved resource productivity, as measured in terms of a higher return on land, labor, water and financial resources (benefit-cost ratio) in horticultural compared to cereal cultivation. The improved managerial capacity of horticulture farmers also enhanced the farming system efficiency. Horticulture production also instigates agricultural business activities in rural areas such as fertilizer and pesticide sales shops, loaning, processing, grading, sorting, packaging, etc. The multiplier effect of horticulture production on other sectors is much higher than other field crops as the former requires more inputs and sells more outputs to other sectors. The HR can also be a major vehicle in eradicating micronutrient deficiency, which inflicts 2.5 billion people mostly in developing countries and causing billion of dollars losses in terms of forgone human productivity.

Several unique characteristics of the HR differentiate it from the GR. Contrary to the GR, the efficient link of farmers with the market, not the availability of technology, was the major constraining factor in the spread of the HR; once this constraint was removed, expansion in area dominated over the improvement in yield in the HR; the commodity and technology spectrum of the HR is much wider than during the GR; the HR quickly and widely spread across regions and countries; it gets its support from the corrected policy bias for cereals and the provision of credit and infrastructure mainly through the private sector; it meets the local demand for quality and regular supplies of horticultural commodities; private sector breeding has played a dominated role not only in developing varieties (mainly hybrid), but also in resolving the infrastructure and liquidity constraints; the HR is built on the transformed integrated marketing structure which links farmers with markets, makes the long distance transportation of perishable commodities possible, and reduces the post-harvest losses and overall marketing costs. These differential factors for the HR and the GR have provided us with lessons to instigate and spread similar revolutions in neglected crops, such as pulses and course grains.

Like any revolution in agriculture, the HR also faces challenges for its wider and deeper expansion, participation of small farmers and landless people, and sustainability of the production system in which it spreads. Learning from the GR, we suggest policy support in terms of the provision of research and infrastructure through public-private collaboration, rather than provision of subsidies and control of price and export in the public sector. The need for low-cost production and marketing technologies and policies to reduce or curtail production and transport costs, cover market risk, and overcome post-harvest losses is much bigger in sustaining the HR for the poor. Small farmers need to be organized to overcome their scale bias, and marketing arrangements need to be innovated to ensure them input supply especially credit, seeds, and seedlings at reasonable prices and in a timely fashion. Farmers should be trained for the use of sophisticated horticulture technologies, and they should be integrated with markets so that they can benefit from the emerging opportunities in terms of demand for quality, safe, diversified, and seasonal horticultural produce using certified and traceability procedures.

The future success of the HR in reaching out to the poor depends upon the strength of the research system. Only those countries and regions will benefit from HR whose research system will predict the consumers' demand for the quality of horticulture products, suggest innovative and unique solutions to meet these demands, and connect farmers with opportunity markets. Therefore, identifying the niche markets, finding appropriate technological solutions, innovating market arrangements to ensure input supplies and efficient delivery of outputs, and linking farmers with markets should go hand in hand. Not all these can be done in the public sector. Strong public-private sector collaboration can effectively solve the challenges of spreading the fruits of the HR to the poor.

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