The Green Revolution and Economic Development

HUNTLEY H. BIGGS
Colorado State University

The one bright spot in the otherwise rather dark Decade of Development of the 1960's is the notable accomplishments in the field of food-grain production. The Malthusian spectre stalking the globe no longer seems such an imminent threat to the world's population living in the less developed countries (LDC's). While it is true that the Green Revolution has raised hopes for the LDC's, the realization of these hopes is presenting challenges heretofore unimagined by development experts and national politicians. The purpose of this paper is to provide a brief history of the development of the high-yielding varieties (HYV's) (chiefly of wheat and rice) and to review the research problems associated with their introduction that must be solved in order for the LDC's to proceed on the path of total development.

FOUNDATION EFFORTS

The institution most instrumental in the development of improved food crops for developing countries is the Rockefeller Foundation.[1] In response to an invitation by the Mexican government, the Rockefeller Foundation began research operations in Mexico in 1943 as a cooperative venture with the Ministry of Agriculture. Research efforts were aimed at raising the productivity of basic food crops, particularly corn. Under the International Corn Program, researchers collected and assembled maize varieties for classification. The more than 2,000 entries from Mexico alone were the result of domestication of wild maize. Once the collection was assembled, artificial cross-breeding enabled scientists to develop new varieties.

Because Mexico did not have suitable wheat varieties within the country, the Rockefeller project began importing and assembling wheat varieties for cross-breeding purposes from all parts of the world in 1943. The dissemination of wheat strains throughout the world in the process of human migration had led to a multitude of varieties adapted to broad spectra of environmental conditions. Headed by Norman E. Borlaug, a plant pathologist, the International Wheat Program had three primary objectives. The first was to coordinate the growing of wheat varieties in selected geographical locations throughout the world in order to determine the range of soil and climatic conditions under which wheat varieties can thrive. The second objective was to develop single varieties having high yields of quality wheat. This is accomplished by breeding into the best varieties those characteristics that they lack for becoming perfect wheats. The third objective was to train and provide practical experience to individuals from less developed countries so that they might carry out effective research and experimentation in their own countries.[2]

As an outgrowth of its experience and growing expertise, the Rockefeller Foundation further concentrated its efforts on the international scene. In October 1963, the International Center for Corn and Wheat Improvement (CIMMYT, in Spanish) was established in Mexico City to further the work and objectives initiated under the earlier programs. Today, this organization is the focal point of research, information, and dissemination of the HYV's of corn and wheat.

To attack the food problem in other parts of the world, the Rockefeller Foundation sought to set up operations to surmount the problems of rice production in Asia. Early in 1962, the International Rice Research Institute (IRRI) was established in Los Baños, the Philippines, as a cooperative venture. The Philippine government donated the land, the Ford Foundation supplied funds for capital construction, and the Rockefeller Foundation accepted the responsibility for supplying operating funds and providing the scientists to organize and direct the scientific research. The fundamental purposes of this program are to (*1*) improve agricultural materials and methods by experimentation and research; (*2*) help develop national scientists and institutions toward maximum efficiency in agricultural research and education; (*3*) help disseminate the benefits accruing from experimentation and research as quickly and widely as possible, both nationally and internationally; and (*4*) help each country toward independence in the various phases of agricultural improvement.[3] The IRRI staff is both international and interdisciplinary, consisting of geneticists, plant physiologists, plant pathologists, agronomists, economists, and entomologists from many different parts of the world.

RESEARCH RESULTS

The early task of the wheat specialists was to develop a variety that would respond well to fertilizer applications without lodging. In 1935 the Japanese had registered a short, stiff straw variety called Norin 10 that later was incorporated with North American materials by Orville Vogel to create a new variety called Gaines wheat. In 1953 Borlaug obtained some of the Gaines, which he managed to refine for use with Mexican types. From the new dwarf varieties, Borlaug proceeded to accomplish the second major breakthrough by adapting the plants to a wide variety of environmental conditions. Such wheat varieties as Lerma Rojo, Mayo 64, Penjamo 62, Pitic 62, Sonora 63, and Sonora 64 are but a few of the "Mexican varieties" that are rapidly becoming known throughout the world for their properties of high yields, widespread adaptability, and efficiency in fertilizer use. In many countries, local varieties are being crossed with the Mexican varieties so as to develop resistance to local diseases.

In the case of rice, the problem was likewise to develop a strain that would respond well to fertilizer without lodging and be resistant to tropical diseases. The two major rice types, Indicas and Japonicas, have certain beneficial characteristics, but each lacks essential attributes to support global increases in food supplies. For example, the Indica is disease-resistant and has a taste quality preferred by consumers, but it has relatively low yields. On the other hand, the Japonicas are much higher yielding but are subject to tropical diseases, do

not thresh well, and are not preferred by consumers. Earlier efforts to improve each of the varieties met with only limited success.

The efforts of IRRI plant breeders were aimed at crossing the tall, tropical Indica varieties, the Ponlai Japonica variety, and the semidwarf Indica varieties from Taiwan. By 1965, the IR-8 "miracle rice" was discovered by crossing Peta (a tall rice from Indonesia) with Dee-geo-woo-gen short rice from China. Since that time, IRRI has generated other varieties that are being used commercially throughout Asia, namely IR-5, IR-20, and IR-22. Like wheat, the new rice strains have a short stem to resist lodging under intensive fertilization and are adaptable to many environments. More importantly, the rice strains ripen in 120 to 125 days rather than 180 days for traditional varieties. This shorter maturation makes it possible for farmers to produce more than one crop during the year, substantially increasing total production possibilities.

THE SEEDS AND DEVELOPMENT

Perhaps the most comprehensive single work dealing with the Green Revolution and associated problems and issues is by Lester R. Brown entitled, *Seeds of Change*.[4] In his book, Brown points out that there are a number of complicating problems which must be solved before the Green Revolution can have a broad-based beneficial impact for a wide segment of the populations in the LDC's.[5] The following pages are devoted to indicating the major stumbling blocks that must be surmounted before the new HYV's will have a lasting beneficial effect on total development.

In order to achieve widespread dissemination, certain constraints must be alleviated. Perhaps the major physical constraints to the further spread of the HYV's are controlled water supplies, fertilizers, and pesticides made available at the right time at prices that producers can afford.[6] Because of the limited availability of irrigation water in many countries, the short-run spread of the HYV's is limited to regions where irrigation structures have been constructed. This fact causes problems in terms of disparities in the regional distribution of income and development.[7] On the other hand, many existing gravity types of irrigation structures are not considered the most appropriate for maximizing yields because of their excessive flooding properties and the associated institutional arrangements which cause inflexibility in field application. Very often farmers receive a given quantity of water, fixed according to field size. The water is distributed when the farmer's turn comes. This system ignores the needs of the particular crop as regards quantity and timing of water application.[8]

The desire of farmers to obtain greater control over water supplies to assure timely application has been one of the explanations for the proliferation of private tubewells in India and Pakistan in recent years.[9] Of course without proper drainage works, problems of salinity often accompany excessive irrigation which adversely affect yields. The construction of new irrigation and drainage works to expand the land area being planted under the new HYV's will require rather substantial amounts of fixed capital investments. Where internal savings are insufficient to meet investment needs, government planners

may have to rely upon external sources of funding, creating problems of foreign debt servicing.

The availability of fertilizers is also considered a key constraint to the widespread successful adoption of the new varieties.[10] Lack of local supplies of essential ingredients makes for dependence on foreign suppliers and a drain on scarce foreign exchange holdings. In addition, the internal distribution of these scarce supplies poses many serious problems not only in terms of transportation and storage, but also in terms of equity, since only the more wealthy farmers can afford them or have access to credit for purchase.

Another essential physical input is pesticides. Many of the new strains are not as disease-and pest-resistant as the traditional varieties. Also the planting of a single variety in a field may put the entire crop in jeopardy, as opposed to the traditional system of planting simultaneously many varieties, each being tolerant to particular pests and diseases. Thus, the appropriate pesticides must be available and a program organized to alert farmers against the outbreak of an epidemic, as well as to encourage them to take preventative measures.

Unfortunately, little research has been done on the potential harmful effects to the environment which the heavy applications of fertilizers and pesticides along with the HYV's may have. The short-run production benefits may be far outweighed by the long-run cost of a deterioration in the general environment. However, for many LDC's faced with severe shortages of food, the long-run may not even be relevant.

There are a host of problems associated with the marketing of the final product. The dramatic increases in production have taxed marketing facilities to capacity, and in some cases insufficient storage facilities have spelled losses to insects, rodents, and weather. At the outset, the "miracle rice" IR-8 was marketed at a discount because of poor cooking quality and low taste value.[11] Fortunately, some of the problems of consumer acceptability have been overcome through the development of new varieties, such as IR-20 and IR-22, released in 1969.[12]

Another important marketing problem is the pricing of the final product. On the one hand, many governments have introduced price support programs to provide adoption incentives to farmers. While the price incentive has encouraged a positive production response, the larger output has meant heavy government expenditures under the guaranteed price arrangements. Many allege that the withdrawal of price subsidies would decrease profitability and discourage the further dissemination of the new seeds. On the other hand, it is argued that price support may be so high as to discourage efficiency.[13] The allocation of substantial agricultural land to wheat and rice in response to higher relative prices may lead to shortages in the output of alternative commodities, causing inflationary pressures and balance of payments problems. High support prices create the additional problem of artificially raising internal prices so high that exporters are not able to compete on the world market.[14]

Often the HYV's are introduced with the objective of attaining self-sufficiency. Once internal demands for wheat and rice are met, producers may seek external markets.[15] The ability of the LDC's to sell surpluses to the world will depend not only on the relationship between internal and external prices,

but also upon the trading policies adopted by the developed countries. Some of the policies that will be particularly relevant will be those regarding concessional sales and grants, trade barriers to protect domestic producers, the preferential treatment accorded former colonies, and the terms of the International Wheat Agreement.[16]

The impact of the introduction of HYV's on the net foreign exchange and balance of payments situation deserves special attention by development strategists. Assuming that international competition can be met, the marketing of surpluses abroad would have a desirable effect on foreign exchange earnings. It also is obvious that the substitution of domestic production for commercial imports of food implies a saving for foreign exchange. However, if the imports were being supplied under public grants or concessional sales (e.g., the United States P.L. 480 Program), import substitution may have little, if any, effect on foreign exchange holdings. While it is true that since 1966 most P.L. 480 sales have been for dollars and convertible currency credits, these are made on very liberal terms at low rates of interest. Additionally, the P.L. 480 transactions have been a convenient method of generating development funds within the recipient country. Since the inception of this program, approximately 75% of the currencies generated have been for country use rather than for U. S. use and effectively have been a source of internal savings for developmental projects and programs.[17] Efforts should be made to assure the continued generation of development funds as internal supplies are substituted for P.L. 480 imports.

The realization of the yield potential of the HYV's may necessitate direct or indirect expenditures of foreign exchange, chiefly for fertilizers and mechanical equipment. When coupled with controlled water applications, the HYV's of rice and wheat can produce at least 50% more grain for each pound of fertilizer used than traditional varieties.[18] Thus, the potential for fertilizer use has increased by four to five times over the traditional cereals, causing the actual demand for fertilizers to increase markedly.[19] Because most adopters among the LDC's lack the basic ingredients for fertilizer production, they must depend upon imports of either finished fertilizers or intermediate materials for mixing within the country. In some countries, such as India and Pakistan, efforts are being made to increase the domestic production of fertilizers; however, even in these cases, foreign exchange must be expended to support imports of capital equipment used in plants, to meet external franchise and licensing obligations, or to repatriate profits on foreign direct investments.

Below it is indicated that farm mechanization may accompany the introduction of the HYV's. For many nonindustrialized countries this implies the expenditure of foreign exchange on the importation of capital equipment. There are cases where the demand for farm equipment has stimulated local production, such as seed drills in Turkey and tractors in India. However, even these operations usually rely upon the importation of intermediate products and raw materials to sustain production or require outlays of foreign exchange for debt service and profit repatriation. Because of the scarcity of foreign exchange faced by most LDC's planners must weigh carefully the balance of payments impact accompanying the introduction of the HYV's against the op-

portunity costs of foreign exchange expenditures when formulating an agricultural development strategy.

There are two economic problems associated with the Green Revolution that have significant social and political overtones: income distribution and employment. Not only is the possibility of increased regional disparities in incomes a very real concern, as indicated above, but so also is the adverse distribution of income among families within the same region. Most of the adopters are already relatively well off.[20] These are the farmers who (1) are responsive to economic incentives and new technological possibilities, (2) are good agriculturalists that can read and follow the necessary cultivation instructions to guarantee maximum yields, and (3) own relatively large portions of the good arable land. The skew in personal income distribution is further distorted by the fact that only the wealthy can afford the higher cost of the new package of inputs or have access to credit on reasonable terms. It is also probable that in many rural areas the larger farmers exercise influence over the pricing and distribution of the inputs and credit.[21] These institutional arrangements make it difficult, if not impossible, for small farmers and tenants to share in the benefits of the new technology.

There is some evidence that the larger farmers take their profits and purchase more land and machinery.[22] Assuming that economies of scale exist, the larger farming operations will be in a better position to sustain decreases in market prices for the output as larger supplies enter the market than will the smaller ones. Given government support prices, many small farmers have borrowed money in order to purchase the variable inputs required by the new technology (i.e., seeds, fertilizers, water, pesticides, etc.). Although total costs are much higher than for traditional varieties, profit expectations are good in light of guaranteed prices and lower average costs resulting from the dramatic yield differences. In fact, many formerly subsistence farmers may enter into commercial production under the new production possibilities. Should the government release price supports, it is the small operations that will be most adversely affected because of the structure of total costs. Since a substantial portion of total costs are variable on small farms, a slight fall in market prices for the final commodity would make it impossible to cover variable costs, causing a shutdown of operations for commercial purposes.

On the other hand, large-scale operations would have a larger portion of total costs in the form of fixed costs (e.g., machinery, buildings, land). Therefore, these operations are able to sustain the losses entailed by a fall in the market price over a wider range of outputs than are small farmers.

In the longer run, the large operators may actually be able to increase total profits under the lower market prices by increasing the land area under cultivation. In this fashion, average costs can be lowered by spreading the costs of mechanical equipment over a larger total output. Clearly, the market will be increased with lower prices under fairly elastic demand conditions. One of the ways that land area can be increased is through mortgage foreclosures on small operators who are driven out of business by falling market prices. In many cases, the creditors who financed the small operators initially are also large landowners. The return of small producers to subsistence cultivation or the

expansion of a landless peasantry makes the task of effectively integrating these elements into modern economic life more difficult.

Governments find themselves in a difficult position regarding price supports. Higher prices may be important for encouraging total output of needed food commodities, lessening disparities in farm and nonfarm incomes, and encouraging production among small farmers. However, lower prices are essential for expanding markets at home and abroad. The goal of broadening the population base benefitting from economic progress may encourage governments to opt in favor of higher prices. Increasing disparities in the distribution of rural income and wealth creates social and political instability as well as retards general economic progress. Sincere and imaginative efforts must be directed to broaden the population base that benefits from the HYV's and to encourage diversification of production among small-scale producers who may be unable to compete in grain production.[23]

The net effect on rural employment of the introduction of the new varieties is not conclusive.[24] The HYV's do have labor-absorbing qualities, since they require more careful cultivation, water management, fertilizer application, and weed and pest control than the traditional varieties, and since the potential for double-cropping seems to be significant. However, mechanization occurring with the introduction of the new seeds tends to be labor-displacing. Because of the substantial increases in yields and the relatively short maturation period, shortages of labor become particularly critical during the harvesting and seedbed preparing phases of the production cycle.

In order to permit double-cropping and to avoid losses in output that delays in harvesting and planting entail, farmers are encouraged to mechanize certain operations.[25] Seed drills may be introduced, as the depth of planting is critical for obtaining good responses in wheat output.[26] Mechanical rice dryers are being substituted for the traditional method of field drying in order to gain cropping time lost to field drying, to prevent losses from pests and adverse weather, and to prevent sprouting of the new grains that are not photo periodic and thus not subject to a period of dormancy.[27] Threshing equipment allows the quick removal of the larger harvests permitted by the new varieties. All of these operations in themselves are labor substituting so as to overcome seasonal labor shortages.

In areas where there is an abundance of labor for hire, it may be possible to meet the periodic labor shortages by employing more wage labor rather than by mechanizing the operations. However, the notorious lack of supervisory personnel to manage large numbers of unskilled laborers in the LDC's imposes a constraint on this solution. Also, in regions characterized by family farms, there may be a shortage of hire labor so that the need for additional labor inputs can be met primarily by working longer hours. In these situations, the mechanization of specific tasks may prove to offer a viable alternative. While it is true that mechanizing these operations decreases the demand for labor, the elimination of specific bottlenecks in the production process may permit double-cropping and expand total labor requirements over the entire year.[28] However, the introduction of multipurpose tractors and the indiscriminate

mechanization of nearly *all* tasks may have an adverse effect on total employment. Once the mechanical power unit is introduced, farmers may find it possible to further reduce labor costs by purchasing a number of attachments which substitute for hand labor used in tasks where no critical bottlenecks currently exist. Various forms of government subsidies may make such purchases very profitable, from the private point of view, while ignoring the social costs.

Another problem associated with tractorization lies in the fact that multipurpose tractors make it feasible to exploit a large land area. This may cause landowners to seek to expand the scale of their operations. In densely populated areas, this will aggravate problems of rural employment. The displacement of tenants and expansion in the size of operations is a familiar occurrence in regions where HYV's have been introduced.[29] The net effect in these cases is labor displacement, the aggravation of income disparities, and the creation of a rural proletariat.

Thus, government policy should be aimed at selective mechanization to eliminate production bottlenecks and to expand total employment possibilities. Quite often it is possible to eliminate such bottlenecks through the use of animal power, which has advantages over tractorization in that it tends to be labor-absorbing, does not depend upon a complex service component, and does not entail heavy expenditures of foreign exchange.[30] In many cases, simple animal-powered machinery can be fabricated in the countryside, offering increased off-farm rural employment.

The mechanization of specific tasks should take place in response to relative prices that reflect the real periodic scarcity of labor resources during planting and harvesting. However, the general tractorization of agriculture (i.e., the mechanization of all farming operations) often takes place in response to factor prices that do not reflect accurately real scarcities. In most LDC's, characterized by an abundance of labor relative to capital resources, efficiency in resource allocation calls for the application of a relatively labor-intensive, capital-saving technology. However, government policy may be directed toward the tractorization (capital-intensification) of the agricultural sector so as to emulate the United States and Soviet models of "modern" agriculture. The relative factor prices are distorted to elicit such a response by farmers through such means as overvalued and multiple exchange rates, tax write-offs, negative real rates of interest, and minimum wage legislation. The result is that private profits are raised for farmers who substitute capital for labor, but only at the expense of substantial social costs in the form of rural unemployment and rural-urban migration, accompanied by general social and political instability.[31]

Now that the agronomic barriers to greater food production have been surmounted, a host of new problems have arisen that fall primarily in the purview of the social scientist. The increasing number of articles describing social and political unrest in the countryside attest to the unexpected repercussions accompanying the introduction of the new seeds.[32] Larger and larger segments of the population are demanding a share in the benefits offered by the "seeds of change." In order to harness the potential of the Green Revolution and

generate a "take-off" for many LDC's, the social scientists must be called upon to meet these challenges so that historians may label the 1970's as *the* Decade of Development.

NOTES

Partial financial support provided by the USAID Institutional Grant under Sect. 211(d) of the Foreign Assistance Act is gratefully acknowledged. This paper grew out of a multidisciplinary research effort on the Green Revolution in conjunction with the International Development Seminar supported by the above grant. The information and conclusions in this paper do not necessarily reflect the position of AID or the U.S. government.

1. A history of the Foundation's activities from its incipient operations in Mexico to its involvement on an international scale is recounted by individuals directly involved in those efforts in E. C. Stakman, Richard Bradfield, and Paul C. Mangelsdorf, *Campaigns Against Hunger* (Cambridge, Mass.: The Belknap Press of Harvard University Press, 1967). For other discussions of the development of the HYV's see Louis P. Reitz, "Short Wheat Stands Tall," and Robert F. Chandler, "Dwarf Rice—A Giant in Tropical Asia," *Science for Better Living*, U. S. Department of Agriculture Yearbook, (Washington, D. C.: Government Printing Office, 1968), pp. 236-39 and pp. 252-55, respectively.

2. Stakman *et al.*, p. 275ff.

3. *Ibid.*, p. 305.

4. Lester R. Brown, *Seeds of Change: The Green Revolution and Development in the 1970's* (New York: Praeger, 1970).

5. Many of these problems are concisely summarized in Walter P. Falcon, "The Green Revolution: Generations of Problems," *American Journal of Agricultural Economics*, vol. 52 (Dec. 1970), pp. 698-710. In May 1969 the U. S. Agency for International Development conducted a "Spring Review of the New Cereal Varieties," during which a number of papers was presented over a wide range of topics. The individual papers were published by mimeograph.

6. There have been some empirical studies conducted to estimate the explanatory significance of inputs on variations in output: Randolph Barker and M. Mangahas, "Environmental and Other Factors Influencing the Performance of the New High Yielding Varieties of Wheat and Rice in Asia" (paper presented at the International Conference of Agricultural Economists, Minsk, U.S.S.R., August 1970); Randolph Barker and S. K. DeDatta, "Water Use and Management with Rice" (paper presented at the International Rice Research Conference, Los Baños, Philippines, April 1970); and S. C. Hsieh and V. W. Ruttan, "Environmental, Technological and Institutional Factors in the Growth of Rice Production: Philippines, Thailand and Taiwan," *Food Research Institute Studies*, vol. 7 (Stanford, Calif.: Stanford University, 1967), pp. 307-41.

7. This is a conclusion reached in the following country study: Carl Gotsch, "Regional Agricultural Growth: The Case of West Pakistan," *Asian Survey*, vol. 8 (Mar. 1968), pp. 188-205.

8. United Nations, Economic Commission for Asia and the Far East, "Planning Strategies in Asia and the Far East," *Economic Bulletin for Asia and the Far East*, vol. 20 (Sept. 1969), p. 18.

9. Private tubewell development in West Pakistan is recounted in Walter P. Falcon, "Agricultural and Industrial Interrelationships in West Pakistan," *Journal of Farm Economics*, vol. 49 (Dec. 1967), 1139-53; and Mohammad Ghulam, "Private Tubewell Development and Cropping Patterns in West Pakistan," *Pakistan Development Review*, vol. 5 (Spring 1965), pp. 1-53.

10. K. S. Mann, C. V. Moore, and S. S. Johl, "Estimates of Potential Effects of New Technology on Agriculture in Punjab, India," *American Journal of Agricultural Economics*, vol. 50 (May 1968), pp. 278-91; and James Blume and O. Kelley, "Major Physical Inputs," (presented at the Spring Review of the New Cereal Varieties, U. S. Agency for International Development, Washington, D. C., May 13-15, 1969), p. 3.

11. Floyd L. Corty, "Global Crop Paper—Rice," (presented at the Spring Review of the New Cereal Varieties, Washington, D. C., May 13-15, 1969), p. 36.

12. U. S. Department of Agriculture, Economic Research Service, *The Agricultural Situation in the Far East and Oceania*, ERS-Foreign 315 (Apr. 1971), pp. 12-13.

13. John W. Mellor, "The Role of Govern-

ment and the New Agricultural Technologies," (presented at the Spring Review of the New Cereal Varieties, U. S. Agency for International Development, Washington, D. C., May 13-15, 1969), p. 55.

14. Lyle P. Schertz, "The Green Revolution: Production and World Trade," *Columbia Journal of World Business*, vol. 5 (Mar.-Apr. 1970), pp. 53-60.

15. The international trade implications of the Green Revolution were the central focus of a conference held by the Southeast Asian Development Advisory Group as published in: Southeast Development Advisory Group, *Agricultural Revolution in Southeast Asia*, Vol. I: *Impact on Grain Production and Trade* (New York: Herbert-Spencer, 1970).

16. Falcon, "The Green Revolution," pp. 702-04.

17. U. S. Department of Agriculture, Economic Research Service, *P.L. 480 Concessional Sales: History, Procedures, Negotiating and Implementing Agreements*, by O. H. Goolsby, G. R. Druer, and C. Santmyer, Foreign Agricultural Report No. 65 (Washington, D. C.: U. S. Government Printing Office, Sept. 1970), p. 31.

18. Robert d'A Shaw, *Jobs and Agricultural Development: A Study of the Effects of a New Agricultural Technology on Employment in Poor Nations* (Washington, D. C.: Overseas Development Council, 1970), p. 12.

19. Blume and Kelley, p. i.

20. Clifton R. Wharton, Jr., "The Green Revolution: Cornucopia or Pandora's Box?" *Foreign Affairs*, vol. 47 (Apr. 1969), p. 467; and U. S. Department of Agriculture, Economic Research Service, *The Impact of New Grain Varieties in Asia*, by Joseph W. Willett, ERS-Foreign 275 (July 1969), p. 20.

21. U. N., Economic Commission for Asia and the Far East, p. 26.

22. Shaw, p. 24.

23. This is the theme iterated in John W. Mellor, "Policies for Broadening the Desirable Income Effects of Rapid Growth in Agricultural Production," Department of Agricultural Economics, State University of New York at Cornell University, International Agricultural Development Monograph No. 33. The International Wheat and Maize Improvement Center is sponsoring a program entitled the "Puebla Project" with the goal of raising maize productivity on small farms in the Mesa Central area of Mexico.

24. In a recent IRRI study conducted among rice growers in the Philippines, it was revealed that the net labor input among adopters of the high-yielding rices was unchanged compared to raisers of the local varieties. Although labor requirements were greater during the growing period for weeding, cultivation, etc., the introduction of mechanical equipment for threshing and plowing decreased labor inputs.

25. It is reported that rice farmers face a loss of 30 pounds of rice per acre for each day that the land lies idle between crops (Brown, p. 106).

26. Warren Kronstad, "Global Report on the Introduction of Semi-Dwarf Wheats to Less-Developed Countries," (presented at the Spring Review of the New Cereal Varieties, U. S. Agency for International Development, Washington, D. C., May 13-15, 1969), p. 18.

27. Blume and Kelley, p. 22.

28. See I. Inukai, "Farm Mechanization, Output, and Labor Input: A Case Study in Thailand," *International Labour Review*, vol. 101 (May 1970), pp. 453-64.

29. Shaw, pp. 24-25.

30. The following analyzes alternative combinations of tractor and animal power for the mechanization of agriculture in West Pakistan: John Cownie, Bruce F. Johnston, and Bart Duff, "The Quantitative Impact of the Seed-Fertilizer Revolution in West Pakistan: An Exploratory Study," *Food Research Institute Studies*, vol. 9 (1970).

31. The question of private profits and social costs is dealt with in H. Kaneda, "Economic Implications of the 'Green Revolution' and the Strategy of Agricultural Development in West Pakistan," *Pakistan Development Review*, vol. 9 (Summer 1969), pp. 111-43.

32. The following are examples: David C. Anderson, "A Squabble Over 'Green Revolution'," *Wall Street Journal*, Oct. 6, 1970; "The Green Revolution Yields Bitter Fruit," *Business Week*, Nov. 21, 1970, p. 84; Wolf Ladejinsky, "Ironies of India's Green Revolution," *Foreign Affairs*, vol. 48 (July 1970), pp. 758-68; Harold Munthe-Kaas, "Green and Red Revolutions—India," *Far Eastern Economic Review*, vol. 60 (Mar. 19, 1970), pp. 321-24; and "Madras is Reaping a Bitter Harvest of Rural Terrorism," *New York Times*, Jan. 15, 1969.