Consultative Group on International Agricultural Research

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Modern Varieties, International Agricultural Research, and the Poor

Michael Lipton
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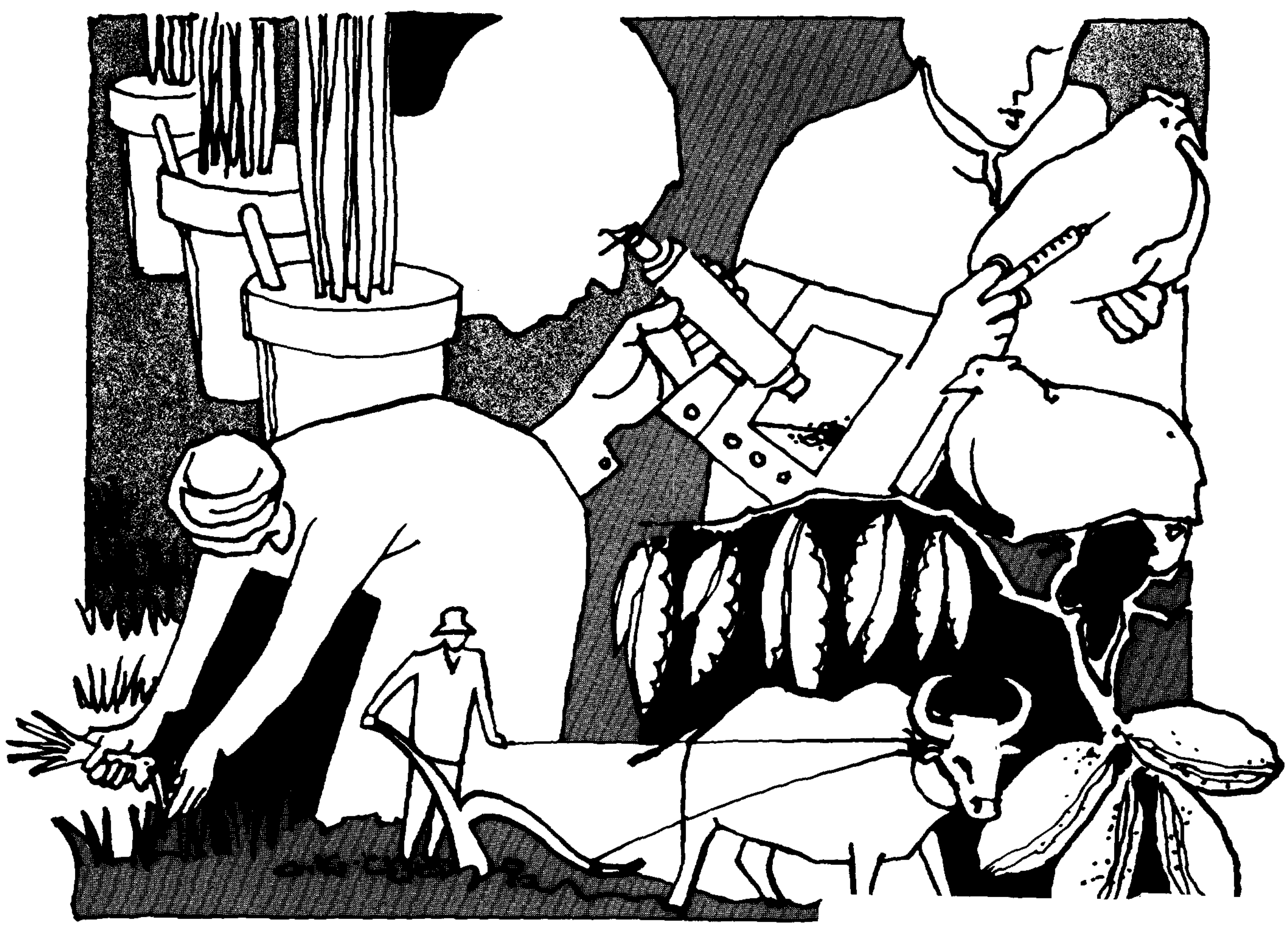

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The World Bank
Washington, D.C.

At its annual meeting in November 1983 the Consultative Group on International Agricultural Research (CGIAR) commissioned a wide-ranging impact study of the results of the activities of the international agricultural research oganizations under its sponsorship. An Advisory Committee was appointed to oversee the study and to present the principal findings at the annual meeetings of the CGIAR in October 1985. The impact study director was given responsibility for preparing the main report and commissioning a series of papers on particular research issues and on the work of the centers in selected countries. This paper is one of that series.

The judgments expressed herein are those of the author(s). They do not necessarily reflect the views of the World Bank, of affiliated organizations, including the CGIAR Secretariat, of the international agricultural research centers supported by the CGIAR, of the donors to the CGIAR, or of any individual acting on their behalf. Staff of many national and international organizations provided valued information, but neither they nor their institutions are responsible for the views expressed in this paper. Neither are the views necessarily consistent with those expressed in the main and summary reports, and they should not be attributed to the Advisory Committee or the study director.

This paper has been prepared and published informally in order to share the information with the least possible delay.

Michael Lipton and Richard Longhurst are professorial fellow and visiting fellow, respectively, at the Institute of Development Studies, University of Sussex, Brighton, England.

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ABSTRACT

Plant breeders select for roots, leaves and stalks, making efficient and stable use of water, nutrients and light. Therefore, in many environments, modern varieties (MV) now produce higher yields of less costly calories and less vulnerability to drought and disease, even without purchased inputs, per ton of food. Physical risks (e.g. the narrow genetic base of some plants, and "soil mining") are real, but have been exaggerated. The bio-economic impact of MVs should be especially favorable to smaller farmers, hired workers, and poor consumers, yet much of this "pro-poor potential" has been lost due to (a) insertion of MVs into social systems favoring urban groups and the big farmers who supply them, (b) demographic dynamics making labor cheaper relative to land, and (c) research structures prioritizing fashionable topics rather than genuine needs of the poor.

Too much research into "how MVs affect the poor" still focuses on small farmers in MV-affected areas. In general these adopt MVs later than bigger farmers, but then attain at least as high adoption rates, intensities, yields, and efficiency. Only exceptionally are they dispossessed before they can gain from MVs. But early adopters, who got better prices, gained more from MVs (see (a) above). Also, most poor farmers in South Asia and Africa are still outside MV areas. As producers they have probably lost from MVs.

Especially in South and Southeast Asia, the rural poor are increasingly laborers rather than farmers. MVs raise demand for labor per acre and clearly resulted in raised employment around 1965-75. More recently, farm employers

have successfully lobbied for cheaper credit, fuel or tractor hire, dealing with labor scarcity more by mechanization than by employing more migrants as previously.

Consumers' gains, from lower prices due to the extra thirty to seventy million tons of grain produced yearly, thanks to MVs, seem clearest and most pro-poor, as poorer people spend much larger parts of income on cereals. However, in many countries, extra MV-based output has mainly displaced imports (or stocks), not increased available calories per person, mainly because rather little extra purchasing-power per person reached the poor. However, higher and more stable output of calories, especially in places hitherto little affected by MVs, should be the top priority. The emphasis of nutrition research on protein, cooking qualities, etc. has done little for the poor.

The above approach "adds up" evidence on effects of MVs on poor people as producers, laborers and consumers. Alternative "holistic" approaches exist. General equilibrium analyses are young, have heavy data requirements, but promise major policy insights. Also promising may be the comparative analysis of agricultural revolutions (ARs). Their effects on the poor - at least when, as with MVs, adoption can be piecemeal and unconnected with rural social change - have depended much more on how they interacted with socio-political power-structures and with demographic change than on their pure economics (e.g. production functions). However, MVs differ from earlier ARs by being locked into big, formal, public-sector, and partly autonomous research systems. Earlier ARs suggest that MVs will help mainly the better-off; yet the bio-economics emphasizes MVs' potential to benefit the poor. Responsibility to investigate and realize that potential (not least <u>outside</u> MV regions) within real-life socio-political systems, therefore, rests especially heavily on international researchers. Only they are relatively immune from pressures to steer research away from the needs of the poor.

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CONTENTS

ABBREVIATIONS

ADB	Asian Development Bank
ADC	Agricultural Development Council (New York)
AER	American Economic Review
AJAE	American Journal of Agricultural Economics
AICRIP	All-India Coordinated Rice Improvement Program
AICSIP	All-India Coordinated Sorghum Improvement Program
AR	agricultural revolution
ARTI	Agrarian Research and Training Institute (Colombo)
BIDS	Bangladesh Institute of Development Studies (Dhaka)
BHP	brown planthopper
CIAT	IARC for field beans, cassava, rice and tropical pastures (Cali, Colombia)
CIP	IARC for potatoes (Lima, Peru)
CIMMYT	IARC for wheat and maize (Londres 40, Mexico)
EDCC	Economic Development and Cultural Change
EC	European Economic Community
EJ	Economic Journal
EPW	Economic and Political Weekly (Bombay)
FAO	Food and Agriculture Organization
GE	general equilibrium
GNP	gross national product
HYV	high-yielding variety
IARC	International Agricultural Research Center
IDS	Institute of Development Studies (Brighton, UK)
IITA	IARC for root crops and farming systems (Ibadan, Nigeria)

ICARDA	IARC for arid-zone research (Aleppo, Syria)
ICRIAT	IARC for semi-arid tropics (Patancheru, India)
IFPRI	IARC for food policy research (Washington, DC)
IJAE	Indian Journal of Agricultural Economics
ILR	International Labour Review (Geneva)
INCAP	Institute of Nutrition of Central America and Panama
IRRI	IARC for rice (Los Banos, Philippines)
ISAE	Indian Society for Agricultural Economics
ISNAR	IARC for national research support (Wageningen, Netherlands)
JDE	Journal of Development Economics
JDS	Journal of Development Studies
JPS	Journal of Peasant Studies
K	potassium
LDC	less developed country
MIT	Massachusetts Institute of Technology
MV	modern variety
N	nitrogen
P	phosphorus
PPS	photoperiod-sensitive
SAT	semi-arid tropics
TFP	total factor productivity
TN-1	Taichung Native 1 (rice MV)
TV	traditional variety
UN ACC-SCN	UN Administrative Committee on Coordination - Sub-Committee on Nutrition
U.P.	Uttar Pradesh State, India
USAID	US Agency for International Development

WCARRD	World Conference on Agrarian Reform and Rural Development (FAO)
WBSWP	World Bank Staff Working Paper

CHAPTER 1 HOW DO MODERN VARIETIES OF FOOD STAPLES AFFECT THE POOR?

If the farmers of the Third World today used the same cereal varieties as in 1963-4, and everything else were unchanged, then tens of millions of people would this year die of hunger. This is a powerful bit of evidence. But it does not suffice to answer the question. Many other things, in fact, would have changed. Also, major technical transformations do not simply slot into old realities; they are used by the people who shape those realities.

There are five main questions, considered in turn in Chapters 2-6 below, about the impact on poor people of modern varieties (MVs). Do the physical characteristics of MVs lead to gains or losses for the poor? Do MVs help poor farmers, absolutely or relatively to rich farmers? Do rural workers gain or lose income, or shares in income, via employment or wage-rates? Do poor consumers gain or lose, nutritionally or otherwise? Does economics, political science, or history help us to predict the interactive effects of all these sequences on poor people, in various social and institutional contexts?

These are complex questions. First, each question suggests ways for MVs to help or harm poor people a) absolutely, b) relatively to the rich, c) both, or d) neither. For example, rural workers' income probably rises absolutely in the wake of MVs, but falls relative to landowners' income. Second, the answers to all the five questions can affect any measure of net benefits to the poor through changes not only a) in its level per poor person, but also b) in its distribution between the poor and the extremely poor, between regions, and between present and future, and c) in its stability and predictability. Third, the questions vary in importance among LDCs by region - most of the poor are urban consumers in Latin America, small farmers in Africa, and increasingly rural laborers in South and S.E. Asia - and by political and institutional set-up.

* * *

No wonder, then, that the question in our title has produced so vast a literature. Merely to "summarize the summaries" -- or to give a bibliography -- would use up my allowance of space. It is a literature pervaded with sharp changes of direction. The "green revolution" euphoria of 1967-70 [e.g. Brown, 1970] was replaced by growing fears that the MVs enriched large farmers at the expense of small, and landowners at the expense of laborers [e.g. Griffin, 1975; Borgstrom, 1974; Frankel, 1971].

In the later 1970s a number of reassessments appeared, suggesting that in MV-affected areas the poor gained absolutely but lost relatively [Dasgupta, 1977; Ruttan, 1977; Lipton, 1978, 1979]. Small farmers adopted after large ones -- but did adopt, and raised yields. Farm workers found that the effect of MVs in boosting the demand for their labor seldom brought much higher wage rates -- but employment rose. Above all, poor consumers gained as food prices fell. The big exception to this rather happier verdict on the MVs was that producers in non-MV areas, often the poorest farmers of all, gained nothing from the new technology', -- indeed they lost, when the extra MV sales from the Punjab (wheat) or Central Luzon (rice) pulled down farm-gate prices in impoverished Madhya Pradesh or Mindanao respectively.

The pendulum has now swung too far. It is being widely asserted that small farmers adopt MVs earlier and more intensively than big ones, that MVs raise the share of labor in income, and that poor consumers gain most of all [Hayami,1984; Barker and Herdt,1984]. The known difficulties of the poor in borrowing money, in taking risks, in moving to new job opportunities, are de-emphasized [Berg, 1980]. Only the problem of "neglected regions" is still generally acknowledged. Thus the increasingly accepted view is that technically appropriate and profitable MVs, by being spread everywhere, will everywhere help the poor [but see Prahladachar, 1983]. Yet we know that the incidence and severity of poverty since the late 1960s have hardly changed in India and Bangladesh, and have worsened in Africa [Griffin and Khan, 1977; Ghai and Radhwan, 1983]. Certainly things would have been even worse but for the activities of the IARCs in developing MVs; and of course they cannot be "blamed" for institutional inadequacy, population growth or (in Asia) inappropriate, labor-displacing mechanisation. But still the new "MV euphoria" needs a critical review. In providing one here, the intention is to make a positive contribution to the debate: partly by looking back at opportunities lost, partly by looking ahead to suggest how research can adapt to rapidly changing circumstance of poverty; but above all by stressing that agricultural research findings, national and international, are inserted into political systems. These systems, at least as much as "production functions" and other aspects of pure economics, determine who gains and who loses from MVs. Researchers can and should allow for such effects in setting priorities for work likely to help the poor.

Why have there been these huge "swings of the pendulum" in regard to the effect of MVs on the absolute and relative position of the poor?

- Part of it is plain optimism or pessimism, often based on changes in climate or oil prices, plus intellectual fashions, intensified by the temptation to pigeonhole the pessimists as "Marxists" and the optimists as "neo-classicals".
- Much of it relates to real changes in the nature of MVs of particular crops. The first "rice revolution" (dwarfing) brought fertilizer-responsiveness, but also, with IR-8 and TN-1, higher requirements for inputs and management, which raised yields but were hard on poorer farmers. The second and third, combining dwarfing with improved disease-resistance and with much shorter duration to avoid moisture stress respectively, were much more "poor-friendly" [Herdt and Capule, 1983]. Similarly the disadvantages of maize hybrids for the poor [Malaos, 1975] have been largely removed by synthetics. But these trends are not uniform; hybrid wheat and rice are upon us.
- Some of the changes in interpretation relate to the effects of time and learning on farmers. Even if big farmers adopt first, small ones usually catch up later, once they have seen that the risks are not too great. But late adopters gain much less than early ones, because prices

have been reduced by early successes [Binswanger and Ryan, 1977; Dalrymple, 1979, pp.720-721].

* * *

This summary will emphasize two fundamental problems with the vast mass of literature seeking to tell us what MVs do to poor people. They are problems not about "swings of the pendulum" of analysis, but about faulty design of the machinery of research.

The first problem is that <u>the wrong questions are being asked</u>. One example must suffice here. "In adopting MVs or supporting inputs, or in getting high yields from them, do small farmers lag behind big ones?" is a question asked by almost all commentators [including Lipton, 1978, 1979] but it is the wrong question, if we are interested in what MVs do to the poor. The poverty or affluence of a farm family is affected not only by its land area, but also by the quality of its lands, its sources of non-farm income, and the number of family members. Yet of the hundreds of studies of adoption of, and returns to, MVs, almost all ask whether small farmers lag behind. The right question, instead, is whether farm families with a low initial endowment of farm and non-farm income sources per member (or, strictly, per consumer-unit: Lipton, 1983) do so.

The second problem is that, partly because of data limitations, <u>only first-round effects are being examined</u>. Again, one example must suffice. Much of the benefit to poor people, rightly claimed for MVs, arises because the higher yield of MVs makes more food available domestically, so that the price to consumers normally falls [Evenson and Flores, 1978]. On this observation have been based several analyses of the amount of consumer benefit [Scobie and Posada, 1978, 1984; Flores, Evenson and Hayami, 1978] and of its distribution to, and nutritional impact, on the poor [Pinstrup-Andersen, 1977]. However, when the food price falls, the real value of consumers' wages rises substantially. Since unskilled labor is in ample supply, and is highly responsive to real wage rises, employers can reduce the money-wage when the price of food falls, and the whole process may well leave employees not much better off. So the gain to poor employed consumers from cheaper food (due to MVs) is much less than the first-round effect, all that is analyzed in the above references, suggests; on the "second round", most of the gain is passed on to their employers, who are seldom poor.

A major purpose of this summary is to suggest new agendas for pro-poor MV research. Hitherto, it has rightly sought to supply MVs (and linked techniques) most beneficial to "small farmers", poor consumers, landless laborers, and, where possible, disadvantaged regions. Our two fundamental questions suggest that this approach, while desirable, may be insufficient. Poor people will be helped by an MV to the extent that it improves their well-being in their total context: as members of families and localities, not just as "small farmers"; as employees, tenants, borrowers, etc., affected by outcomes of MVs after many "rounds" of consuming, investing, employing, etc., not just by the immediate effects [Bell et al., 1982]. General-equilibrium economics [Binswanger, 1980; Binswanger and Ryan, 1977] is part of the answer; but other social sciences, and disequilibrium considerations, matter also, as do the "lessons of history" about what rapid agricultural change does to poor people. We return to these issues in Sec. VI below.

Before asking any of these questions, however, we need to link up the "scientific" nature of MVs with their socio-economic consequences for the poor.

CHAPTER 2 PHYSICAL FEATURES OF MVs: IMPACT ON THE POOR

2.1 Nutrient response

Short varieties are designed to benefit from much higher fertilizer inputs without falling over. Many worries about MVs stem from the erroneous belief that "fertilizers are a sine qua non" [Borgstrom, 1974, p.14]. The belief that without fertilizer MVs give lower yields than traditional varieties (TVs), and are thus unlikely to help farmers too poor to afford, or risk applying it, is so entrenched as to be stated (sometimes with fertilizer response diagrams to match) even alongside the honest presentation of convincing counter-evidence [Wright, 1973, pp.59-60; Hayami and Ruttan, 1971, pp.43, 83, 193]. But the belief is usually wrong. Semi-dwarf MVs (and even tall hybrids) are designed to turn NPK from all sources -- soil, stubble [IRRI, Annual Report, 1972, p.xxvi], manure (even from grazing many years ago: Olson et al., 1972, p.188), legumes from last season, worms, fertilizers -- into more edible grain, per unit of nutrient input, than did local varieties [Swaminathan, 1974, p.36]. Crops usually get most of their nourishment from non-fertilizer sources. Thus even in the early years, most MV wheats [Lowdermilk, 1972, p.243; Kahlon, 1974, p.5] and rices [IRRI Reporter, 3/1973, p.4; Pal, 1972, p.95; IRRI, 1975, pp.19-21] and hybrid maize somewhat outperformed TVs even with zero fertilizer nitrogen. While high nitrogen fertilizer inputs usually maximized expected profits, the expected profit/cost ratio -- an indicator of safety, and thus attractive to poorer farmers -- was highest at zero fertilizer nitrogen for MVs of all five main cereals [Ryan and Subrahmanyam, 1975, pp.11-13]. Newer MVs appear to be more efficient in using P, as well as N, according to recent work by CIMMYT in Brazil. (Work by ICARDA has shown the importance of increasing barley yields).

Most of the more recent wheat MVs, like older ones, if free of pests and diseases, outyield TVs somewhat with no nitrogenous fertilizer. However, the MVs' absolute yield advantages increase as it is added. Also, in field conditions, the greater resistance to pests and diseases increasingly built into recent MVs means that, if the moisture regime is suitable for MVs at all, they tend to outperform TVs substantially even with zero fertilizer input [Byerlee and Harrington, 1982, pp.1-2; Parikh and Mosley, 1983, for wheat in Haryana]. This substantial advantage over TVs at low or zero fertilizer inputs also appears for more recent rice MVs [IRRI, 1978, pp.176-80] -- for IR 36 even under moisture stress [Barlow et al., 1983, p.86] -- and for hybrid sorghums [Rao, in ICRISAT, 1982, vol. 1, pp.49-50].

So is everything fine for poor farmers, in that MVs will do well without fertilizers, so that the IARCs should simply do "more of the same"? It is in many ways not so simple.

First, there is no free lunch. MVs that produce high yields with no fertilizers must be getting nutrients from somewhere. Long-established rotations, manuring and stubbling practices, etc., adequate to maintain N balance with TVs, will -- if continued, without extra fertilizer, for the more demanding MVs -- run the risk (save in truly exceptional soils: IRRI, Ann. Rep. 1973 p.100) of "soil mining". Poorer farmers, because of their higher "time-preference" for present over future income, are especially vulnerable, notably where recommended N fertilizer doses can be reduced a long way (from profit-maximising levels) with little loss of profit and much risk-reduction this season [Mandac and Flinn, 1983]. Such economizing on current inputs may involve big, unresearched risks in a few seasons' time. Without falling into dust-bowl hysteria, the IARCs should consider looking beyond single-season response functions when designing optimal recommendations on rotations, manure, etc., as well as on fertilizers, in the context of the long-term security of smaller farmers. At least, the trade-offs between "more yield with little fertilizers now" and "risks later", and the costs of reducing those risks, should be spelled out.

Second, very occasionally, MVs do perform worse at low fertilizer levels, impeding adoption by poor farmers. For Tunisia, this is true of MVs of bread wheats, though not of durum [Gafsi and Roe, 1979, esp. p.126].

Thirdly, a small grain yield advantage, such as is obtainable at low input levels, may not suffice to make MVs pay, because the farmer may be deterred from adopting by any or all of three problems. a) The MV grain often starts at a price discount. b) The value of straw per acre, as cash or animal-food, is sometimes less for shorter, stiffer varieties, despite the higher plant density [von Oppen and Rao, ICRISAT, 1982, vol.2]. c) The cost of annual seed acquisition may be excessive. Problem c) arises only with hybrids; and a) is less relevant to the extent that poor farmers eat their own grain. However, all three problems do in some cases indicate directions for IARC research into non-adoption.

Fourth, breeding MVs for high grain/N ratios can have drawbacks: a) Unless farmers obtain very large yield rises, big falls in straw per kg. will mean less straw per acre [Johnson, 1970, p.188]. MV straw can be stiffer and less digestible for animals [Lowdermilk, 1972, p.488]. Often it is too short to be useful for thatching. Extra N may improve MV yields enough to cover costs only if enough P is added; for wheat in Chile, this sometimes left TVs preferable [CIMMYT, 1983, pp.136-7]. MVs can also require extra outlays for zinc [Narvaez, 1973, p.269]. c) Extra N raises the yield losses per day from moisture stress; even 20 kg/acre of N did so by 5 kg/ac. for MV rice at IRRI [Wickham _et al_.,1978, p.227]. All these factors -- by raising risk, complexity, need for information, and need for purchases (animal feed, thatch, P, irrigation water) -- may well disfavour smaller farmers via "diseconomies of small scale even though [MVs _per se_ do] not" [Burke, 1979, pp.148-9].

Balanced against all these reservations mentioned above is the fact that MVs have been widely adopted. The great majority of wheat farmers in Mexico use MV wheats. Therefore, to intensify help to poor farmers, IARCs will need to continue the search for fertilizer-efficient, yet high-yielding, MVs, especially under moisture stress, and to explore MVs within intercropping systems, which would have important equity benefits [Jodha, 1980]. Poor people's crops -- millets, sorghum, cassava -- are unlikely to be heavily fertilized even with MVs. High fossil-fuel costs (camouflaged, not changed, by the dollar's surge in 1984-5) strengthen the case, not only for economizing on fossil-fuel feedstock [Herdt, 1981], but also for researching ways (a) to farm MVs that yield well (without soil mining) at low N levels, e.g. by reducing N losses [Craswell and Vlek, 1979] -- and (b) to handle, not only fertilizers (e.g. via IRRI's work on slow-release), but other NPK sources (manure, etc.), to increase N outturn per unit applied.

2.2 Light response

"Erect leaves to prevent mutual shading" [Peiris, 1973, p.4], and hence improved sunlight-to-grain conversions, were once seen as a major benefit to be gained from MV research. Plant breeders inform me that these hopes have largely disappeared; both theoretical and empirical work suggests a very limited range of photosynthetic efficiency.

However, photo-period sensitivity (PPS) is as important a variable to plant breeders as plant height. Low-PPS plants, the early aim of MV breeders, can thrive despite day-length and cloud cover, and permit growth wherever temperature, water, nutrients, and light (however timed) suffice. This enables seasonal smoothing of food output, work availability and food prices, and conversion of one-season into two-season food agricultures, in many areas [e.g. Bolton and Zandstra, 1981]. Low-PPS varieties are often transferable between areas, as well as seasons [Dalrymple, 1985, p.31]. Since poor people have the greatest problems in carrying stocks, saving or borrowing -- and are thus most damaged by seasonal fluctuation -- they gain most from such PPS bio-engineering.

However, IARCs are not concerned directly with breeding non-PPS plants, but in association with national agricultural research centres with adapting to local priorities and risks. As regards PPS characteristics, this usually means local specificity, not broad adaptability. Some low-PPS MVs do well because they can flourish even if they must be planted on "difficult" dates [Lipton and Longhurst, 1975, p.67; Sen, 1974, p.37]. But if the usual timing of pest attacks leaves sowing dates fairly fixed [Swaminathan, 1974, p.40], then low PPS during the growing season may be the aim. Contrariwise, PPS plants are often wanted [Frankel, 1971, pp.52-3]; often crops must "mature towards the end of the rainy season, when favourable weather for sun-drying occurs" [Beachell _et al_., 1972, p.91]. Low-PPS varieties can readily induce post-harvest innovation that displaces labor [Duff, 1978, p.148].

The poor, the weak and the "tail-enders" are especially vulnerable to unexpected delivery failures constraining timely operations. They want, not merely a low-PPS plant that allows some choice of sowing date, but a plant that can respond to later delays (in, say, water releases or fertilizer arrivals) by adapting its growing cycle, in particular its light responses, without great yield loss. I do not know how feasible that is, nor what the costs (in tons of yield foregone) might be. But plainly the questions need to be asked. IARCs, if they used socio-economists _early_ in research design, would ask: what light-response characteristics will generate most, safest real net income for poor growers, workers, and consumers of our mandate crops, in the major (especially the poorer) areas where they are important? What are the probabilities of achieving key PPS-related characteristics by research? At present the latter question is asked first; the chosen characteristics are (as far as a lay person can judge) brilliantly researched, but the first question, about what the poor want and will benefit from, is asked, if at all, after the research and in a spirit of "what went wrong", not before in a spirit of "what is right".

2.3 Water response

As breeders seek to redesign mostly _height_ to improve N-response, and _leaves_ for light response, so _roots_ are the main target for improving water response. This is at the centre of the MVs' hopes and problems for the poor. If technology and economics were all, the MVs' capacity to use water better than TVs (and recently to resist moisture stress better too) would have helped poor farmers, and in ways that raised demand for poor laborers. Yet many an LDC's polity, especially in regard to water management, has turned the MVs' greater water-use efficiency into a servant mainly of better-off farmers and regions. Specific research planning of the MV-water link, with IARCs possibly in collaboration with IIMI, will be needed to help the poor in such circumstances to reap the potential water-use gains for MVs.

MVs are criticized as "giv[ing] higher yields only [with] extra quantities of water" [Borgstrom, 1974, pp.14, 17], as "less resistent to drought" [Griffin, 1975, p.205], as "requir[ing] controlled irrigation" [Falcon, 1970, p.699], or as "more prone to suffer yield losses" unirrigated than MVs [Palmer, 1972, p.51]. These criticisms are generally wrong.

Even many older MVs usually yielded more in <u>absolute</u> terms than MVs under moisture stress [IRRI, Ann. Rep., 1975, p.156]. They generally matured earlier, and thus avoided such stress by being "not so dependent on the late rains" [<u>ibid</u>., 1968, p.22]. Given total water available, MVs are usually less sensitive to its timing than competing TVs [Palmer, 1972, p.51]. By rendering higher N inputs economic, older MVs also saved water, since fertilization normally reduces water use (per unit of dietary energy produced) by over 35 per cent for rice [Swaminathan, 1974, p.40] and wheat [Borlaug, 1972, p.586].

Recent MVs aim even more clearly at water-efficiency. Even by 1972, IRRI's main goal was better tolerance of moisture stress [IRRI, Ann. Rep., 1972, p.85]. Since then it has sought somewhat less short MVs to improve it [Johnston and Clark, 1982, pp.90-1]. Recently, however, the old belief that dwarfing of shoots, because of its effects on root structure, means less-efficient moisture search has become very questionable [IRRI, 1981]. For maize, while shortness has yet to be combined with really high yields, earliness of maturity, short stature and drought resistence normally go together [CIMMYT, Review 1981, p.32].

Millets and sorghum are bred largely for "more intensive root systems -- to withstand moisture stress" [Swaminathan, 1974, p.29]; by the late 1970s CSH-1 hybrid sorghum was achieving "spectacular" yields at farm level in drought-prone Indian areas and in rather dry years [Rao, in ICRISAT, 1982, vol. 1, pp.49-50]. Wide crosses, such as triticale (to breed rye's drought tolerance into wheat) and maize-sorghum crosses can also help.

Farmers in many unirrigated places have adopted MVs <u>mainly</u> for improved resistance to moisture, and other, stress in the Philippines, Pakistan and Tunisia [Barker, 1971, p.121, and cp. Herdt and Capule, 1983, p.15; Rochin, 1973, p.140; Palmer, 1972, pp.54-7]. This applied also to IR-20 <u>aman</u> rice in Bangladesh. Yet vast areas of unreliably rainfed rice, flood rice, and semi-arid crops remain in TVs. Why?

First, MVs are damaged, even in irrigated areas, by the politics of moisture stress. The improvement of MV over TV rice is less for tail-enders than for users near the irrigation source, and the yield gap for MVs is greatest for them [Herdt and Wickham, 1978, pp.5, 22]. Uncertain water deliveries are to blame. They limited the acceptance of MV rice in some parts of Bangladesh to better-off farmers, who owned water sources or could buy priority for their use [van Schendel, 1981, p.150].

Second, some research stations are badly located to analyze moisture stress [Biggs and Clay, 1981, p.332]. "IRRI is poorly situated for rainfed rice research because of the high [and] protracted rainfall" but it is not clear whether it follows that IRRI should be confined to fundamental research and generation of germplasm [O'Toole <u>et al</u>., in IRRI, 1982, p.217]. Instead, "perhaps more effort should be made ...for farmers [and] scientists to meet" [Vergara and Dikshit, 1982, p.199]. Natural scientists should then be working alongside the village-level research of the socio-economists, and listening to farmers, not lecturing them, about water requirements and choices. ICRISAT irrigates its entire research station -- I believe rightly so -- but maintains close contact with hundreds of individual small farmers in various stressed soil-water regimes.

Third, major problem areas (e.g. semi-arid winter-crops, upland and deepwater rice) remain where, despite major spending, IARCs have not yet achieved basic improvements in water use efficiency. We point out in Section III(vi) that such "neglected areas" (although ICARDA is now giving attention to semi-arid Winter crops) are the core poverty problem, almost unassisted by MVs (except via lower food prices and migration to MV areas), and in some respects harmed by them. Most of sub-Saharan Africa and much of Eastern India suffer from unsure water supply in ways that impede MV spread, especially to poor farmers. It would be absurd to summarize here the problems of improvement in these 8 to 10 quite distinct agro-climatic zones; they are the subject of many specialized publications, and of extensive review elsewhere in this survey. However, some observations may help. First, potentially attractive MVs can induce Governments to support the spread of irrigation to such areas, as in Japan, Korea, Sri Lanka and the Philippines [Hayami and Ruttan, 1971, p.22; Abeyratne, 1973, p.6; FAO, 1971, p.25]. Second, evaporation, seepage, and erosion loss reduction -- not just reduced plant transpiration and better root uptake -- are feasible, perhaps economic, ways to raise water use efficiency in rainfed (as well as irrigated) areas; as a mere economist, I wonder if the IARC's great expertise in crop-related research would benefit from much closer links to the physical sciences.

Third, deliberate development of intermediate varieties may help; in Sri Lanka, H-4, a fairly tall (but stiff and fertilizer-responsive) medium-yield rice, spread fast and far because it was developed in research stations with badly drained soils, enabling researchers to anticipate <u>field</u> problems of water control [H. Weeraratne, pers.comm.].

* * *

At today's yield levels in environments at serious risk of unanticipated and major changes in water timing (including flood and drought), a dilemma faces IARC research. Concentrate on those environments, and expect lower returns to research, lower increases in food supply, and hence dearer food, with the worst effects on the poorest consumers. Or neglect those environments, and (as extra food supplies from favored districts glut the markets) impose losses on the many very poor producers, often immobile, living there [Brass, 1984]. In a sane world, given the huge returns to IARC work, there should be ample cash for IARC work on food production in all major farm areas, and on making such work useful via national adaptive research. In the real world, the agonizing strategic choice remains: how to allocate absurdly inadequate resources between the poorest producers and the poorest consumers; between better water-use efficiency in unreliably watered places, and more food output where water is not a major problem?

Of course, the dilemma can be softened by persuading those few, but excellent, IARC researchers now doing work demonstrably unhelpful to the poor as producers <u>or</u> consumers to change tack (see the discussion of protein research in Sec. V). But can something more positive be said? I believe that neither the "food-population balance", nor the problem of adequate entitlements to buy food, in sub-Saharan Africa and in unreliably watered areas of South Asia, can be tackled sensibly without major improvements in water security. Thus MVs often outyield TVs even under moisture stress (and with, <u>therefore</u>, inadequate nitrogen); but they will not yield enough either to feed growing poor consumer populations, or to get adequate command over basic necessities to poor producers. The MV-watercontrol-fertilizer complex is the only game in town, and in the countryside too.

But the "water security" approach to poverty reduction, in flood or drought areas, has been largely discredited by - vast irrigation (and flood protection) schemes, at forbidding and rising cost per acre, with bad water management, and often no integration between water-planning and crop-mix, let alone varietal research;

- at the other extreme, paternalist and under-researched technocratic efforts to persuade or compel farmers to alter their planting dates, crop-mixes, or entire soil-water management systems, in the vain hope that what is technically feasible in the research plot (or sandbox) will prove safe or profitable in the field.

It may be that the IARC system can offer a third option. Some aspects (not all!) of ICRISAT's micro-watershed development approach point the way. The centerpiece has to be substantially increased water security, and this will usually involve farmer-controlled micro-irrigation, typically a well or low-lift pump system. Into this context might come something like Sri Lanka's "minikit-production kit" approach, in which two or three poor but "progressive" farmers in a village first try out different combinations of MV and fertilizers in a tiny Latin square, then select a combination for larger-scale use. Ultimately and on a wide scale, of course, this is a job for national research and extension. But the IARCs could perhaps "seed" the process, in conjunction with water management experts and national extension systems and after prior consultation with small farmers, in a few trial areas.

2.4 Stability against diseases, pests and weeds

As with fertilizers and water, so is it here, in two respects. First, the critics' claims that MVs make matters worse, especially for the poorest, are ill-informed and represent a sort of fear of knowledge, a sense that natural varietal selection in the field must be better if unassisted by scientific research, than if so assisted. Second, MV research (in its broadest sense of IARC varietal development plus national adaptive research) has neglected key, unfashionable problems that are gravest for the poorest (birds, weeds), and has not selected clear enough priorities for the war on diseases and pests in the context of the needs of the poorest people in their actual environments, socio-economic as well as biophysical.

MVs have been attacked for a "notoriously low threshold of resistance" [Whitcombe, 1973, p.199]; for being "somewhat more susceptible to disease and infestation by insects" [Griffin, 1975, p.205]; for being "sensitive" in direct proportion to their "potential" [Palmer, 1972, p.23]. If true, this hits the poorest worst; they are least able to bear risk, or to afford chemical protection. Some early MVs, indeed, justified such criticism, being selected for yield potential: "TN-1 [rice] in the field is a veritable insect pest museum" [Fernando, 1973, p.2]. Later experiences, however, have been misinterpreted. The tungro disaster of IR-22 in the Philippines shows, not the instability of MVs [Borgstrom, 1974, p.17], but the speed with which a sophisticated breeding program can replace a susceptible variety. The IR26-IR36-PB56 sequence in Indonesia, in which successive resistant varieties were introduced in response to three successive BPH biotypes, tells the same story of wrapping up protection in successive, and for the farmer inexpensive, seed improvements [Herdt and Capule, 1983, p.10]. It is a story far more hopeful for poor or illiterate farmers than reliance in emergency on costly, precision-requiring pesticides. <u>If there is a Green Revolution, it is fast and responsive breeder-farmer interaction, not this or that vulnerable variety</u>.

Not that MVs have been all that vulnerable. Borlaug and many others expected the Mexipak wheats to need replacement after 4-7 years, as rusts mutated; Sonalika lasted almost twenty. IR-20, more resistant than TVs to all major pests and diseases of <u>aman</u> rice in Bangladesh, replaced those TVs in areas where its advantage lay in robustness far more than in yields, and lasted over ten years. At high levels of yield potential, breeding for further yield improvements largely means selecting varieties that resist, or lose little yield from (tolerate), low-level insect or pest attack. Hence, especially as MV work progresses, there is not really a trade-off between yield and disease or pest resistance.

The main failings of IARC pest-disease work, from the standpoint of poor farmers and laborers, are thus completely different from those alleged by the critics.

For poor farmers, the main weakness is that scientists, like economists, prefer <u>interesting</u> problems to <u>important</u> problems, and "sensational" pests (taking 80-100% of crops from 2% of farmers) to damaging pests (taking 5-10% from 100%). Among the most damaging and important pest problems facing the world's poor farmers are rats, birds, and weeds; but these do not at present suggest interesting solutions to most agricultural scientists. There are occasional IARC books about weeds. They are usually pessimistic in tone, stressing the shortage of resources for weed research [ICRISAT, 1983, pp.4, 83; IRRI, 1983]. Often, they are unspecific about which variety of the crop, let alone which farm system or size, is fighting which varieties of (competitive?) weeds, when, in what environment. Very little about interactions between MVs, practices and bird losses, and almost nothing about rats, is to be found in IARC research. "In Africa, at least, the two biggest problems of sorghum growing are <u>Striga</u> and bird pests, yet these were dealt with in only three [of 34 topic-specific] papers" [Jones, in ICRISAT 1982, Vol.2, p.720]. On the other hand ICARDA has started weed related research including the parasitic weed <u>Orobanche</u> that causes damage in legumes.

Apart from this relative neglect of poor farmers' most widespread pest problems -- perhaps because there really isn't much that IARC-type work can do about quelea or rats? -- must be added certain weaknesses in the poverty-orientation of problems that IARCs do tackle in depth. A good example is a standard, clearly highly expert, paper on rice blast control. After expressing (a) great hostility to polygenic resistance (and implicitly to tolerance in general) and (b) hope for systemic fungicides, it advocates a highly sophisticated gene rotation approach, aiming at "eradication of the pathogen" [Crill et al., 1982, pp.143-4]. Clearly, if things go wrong and a super-race appears that can overcome a particular brand of monogene resistance, chemical control is the back-up. That is fine for wealthy and sophisticated farmers; where does it leave poor, illiterate farmers? Probably subject to neighborhood effects, as fungi excluded from the sophisticates' fields concentrate upon poor farmers, with last year's MV and/or no information (or credit) to obtain the right fungicide. Yet the case of Nacozari-76 and leaf-rust resistance breakdown in Mexico in 1981 exemplifies the critical role of outreach -- for research, extension, new varieties, and fungicide -- if poorer farmers are to pull through [CIMMYT, 1984, p.5]. Analogously, relying on costly Striga seed germinators is hopeless for the poor, who have been made more vulnerable to the weed by the very successes of sorghum hybrids in India. Breeding high yields into the already promising striga-resisting sorghums and millets is a far more poverty-oriented stabilizing strategy [Ramaiah, p.53, and Roger et al., p.86, in ICRISAT, 1983].

It is widely recognized [e.g. Dalrymple, 1979, p.37] that the narrow genetic base of MVs in some cereals carries serious dangers, already being realized as the Mexipak wheats in North India and Bangladesh are attacked by mutant leaf rusts. A form of naive ecologism contends that scientists stupidly or wilfully ignore those dangers [but contrast IRRI, Annual Report, 1973, pp.64, 82, and many other IARC documents] and/or that natural diversity is being lost as a wide spread of field races of crops gives way to a few privately patented superraces [Mooney, 1979]. In fact (a) the IARCs have made much the largest ever collections of races of major cereals, (b) such collections are used, and (as with grassy stunt resistance breeding from O. Sativa) even added to with wild races, as never before to fight specific new vulnerability, (c) new dwarfing genes are being sought with considerable success [CIMMYT, 1984, pp.1, 124-7; 1981, p.4], (d) TVs are often so vulnerable as to preclude their use (e.g. tropical wheats to helminthosporium: ibid., p.145). However, the growing similarity of wheat plants over large areas, due to the success of a narow band of MVs, does carry risks of sudden large losses at national level in a single year - even though risks to each local grower, in a normal year, are reduced by the fact that such MVs are bred for robustness.

The general fear that "going for yield" must increase vulnerability (and thus harm the poor) is unfounded. Nitrogen fertilizers help many weeds as well as crops, but the dense-planting and erect leaves of most MVs hinder weed growth. Also, fertilizers increase resistance to alternaria leaf blight of wheat [Saari and Wilcoxson, 1974, p.50] and to tungro virus of rice. "If properly done, irrigation does not increase disease in wheat", except perhaps rust in arid areas [ibid., p.50].

"Going for intensity", however, may increase pest and disease attack, because the unwanted guests receive year-round homes. Especially in unbroken rice sequences (and above all if the varieties in both seasons are genetically similar), hoppers and borers build up [IRRI, Annual Report, 1973, p.74]. It is widely recognized that this is a problem; less widely, that it hurts poor farmers most, because they are least able to find or afford chemical protection (and most likely to double-crop; see Sec.V(iv)).

Nevertheless, despite specific gaps and wrong emphases and despite the threat to genetic diversity, MVs and the network of IARCs and national research systems enormously reduce disease and pest loss and risk. This helps poor farmers, most vulnerable and with least information and cash, more than rich. The risk to poor farmers, indeed, is the introduction of MVs into countries whose national research systems cannot detect and respond to new pests (or new races of old ones) as fast as, say, India or Kenya. ISNAR should seek to fill a major role here.

While IARCs' (and the MVs') role in pest and disease management is clearly pro-poor for farmers, the case is not so clear for laborers. Weed control criteria are solely related to output. Yet if weeds are controlled by transferring 5 per cent of farm income to weeding labor instead of to weedicide firms, even at the cost of losing 6 per cent instead of 5 per cent of output to weeds (unweeded loss being, say, 12 per cent), that cost may be outweighed by the benefits to the poorest. At least the alternatives should be spelt out, and certainly not tipped against the poor by "free" screening, testing, or improving of commercial weedicides by IARCs [CIMMYT, 1983, pp.89-91; 1984, pp.77-79].

* * *

The physical features both of semi-dwarf wheat, maize and rice and of hybrid maize and sorghum, in the great majority of varieties, "ought" to help the poor as laborers, consumers, and growers. Because they are bred mainly for yield enhancement -- short stalks, erect leaves, dense roots, to improve per-acre use respectively of nutrients, sunlight and water -- MVs raise labor requirements per acre, and thus employment. Because MVs produce grains that loom largest in poor people's consumption (and because breeding priority for high grain weight tends to reduce fineness, etc., and to cause most MVs to stand at a price discount), they should be especially important (a) in lowering poor people's cost of living as consumers, and (b) in the output-mix of poorer farmers, for whom the high ratio of marketing-costs to grain- weight is less of a deterrent because they eat most of what they grow. And because MVs are increasingly bred to resist or tolerate pest and disease attack, they should specially benefit poorer growers, who are more damaged by downside risk than richer farmers, and less able to afford chemical controls. Yet the systems into which MVs are inserted often thwart these pro-poor elements; and researchers need to gear their work more towards varieties, practices, and inputs designed for the poor in the various total systems, social as well as economic and environmental, where MVs are used. We return to this issue in Chapter 6.

CHAPTER 3 MVs AND DISTRIBUTION AMONG FARMERS

3.1 Small farmers in MV areas: an over-researched issue?

Perhaps 90 per cent of the effects of MVs on poverty and income distribution are via availability and price of consumed food and via impact on poor farmers in non-MV regions. Yet at least 90 per cent of the literature on "what MVs do to the poor" is about small farmers or tenants in MV regions. It asks: do they adopt MVs? If so, soon or late? Over what proportion of area? With how much support from other inputs such as fertilizer? With what yield, profitability, efficiency, and impact on farm income? In all these respects, how do small or tenant farmers compare with larger or owner farmers?

These are all interesting questions. The discussion below suggests that, on the whole, we now know the answers. But the questions and answers tell us almost nothing about how MVs affect poverty, even among farmers in MV areas. Five obvious reasons follow. They are largely neglected in the massive "size-adoption-yield" MV literature skimmed later in this chapter. They imply a new research agenda for IARC work on poverty impact in MV areas, although, again, we admit the data needs are heavy.

First, even given the crop, the region, and the inputs per acre of labor, fertilizer, etc., "size" gives little indication of a farm's capacity to generate income. Slope [Colmenares, 1975, p.21], terrain [Cutie, 1975, p.23], irrigation or drainage can make vast differences to that capacity per acre -- and to the scale, and impact on that capacity, of MV adoption and yields. Hence "poverty rankings" by farm size and by net farm income from the MV-affected crop ("net" of production costs) differ hugely, as do the two rankings' interactions with MV adoption. An outstanding Mexican study showed that adopters despite having slightly less land per person than non-adopters, had significantly higher land value per person [Burke, 1979, p.148].

Second, on most farms, several crops help to produce net farm income. Yet almost all studies of MV adoption, yield, etc. on "small vs. big farms" ignore what the MV innovation does to non-MV crops. "Poverty ranking", by farm size or even net farm income from the directly MV-affected crop, often tells us little about how poor farm households are in terms of net returns from the system of all farm activities -- let alone about how MVs affect these returns.

Third, even net farm system returns are very far from describing the effect of MVs on a poor household via all farm and non-farm activity. The gains to adopting households from, say, MV rice are overstated if we neglect the income they lose by (for example) diverting labor to it away from (a) other crops or (b) non-farm activity, which typically accounts for one-third of net rural household income in LDC micro-studies [Chuta and Liedholm, 1979]. Conversely, income and information from off-farm activity, apart from making many small farms non-poor, helps them to take risks and to adopt MVs successfully; the proportion of days spent off the farm has been strongly linked to a household's technical efficiency, and hence yield, in MV rice farming [Herdt and Mandac, 1981, p.394]. And many small farm households are spending some time working on other farms; MVs can affect them as employees and as non-farm workers, not just as farmers.

Fourth, net household income from all activity -- or from farming, given off-farm income -- gives very little indication of income-linked poverty, because of different household size. "Income-per-person" and "income-per-household" rankings usually assign people to different quintiles! [Datta and Meerman, 1980]. Households with high total income, farm income, or farm size tend to be big households; yet in total populations, even if we do not hold farm size constant, bigger households tend to be poorer [Lipton, 1983a]. As for MVs, given farm size, lots of family workers ease the problems of management and labor search, but reduce the gains-per-person from each extra ton of produce.

Fifth, even the effect of MVs on income-linked poverty, as measured by income per person or per consumer-unit net of production costs, is a very imperfect indicator of their effect on real poverty, absolute or relative. This is because people have obligations (apart from production costs) which, alongside income, change with farm practice. (a) To adopt MVs or fertilizers, debts are often increased, especially by poor households, at least in initial seasons when the extra purchases precede extra incomes. Yet, in circumstances of excess demand for official and formal credit, it is usually the poorer adopters who must go to moneylenders and incur high interest obligations to reduce their future gains from MVs, even if they adopt and farm better than richer farmers. (b) Informal bribes and obligations to petty officialdom are bid up by the need to acquire MV-related inputs or favors, and loom largest for poor farmers [on Chilalo, Ethiopia, see Cohen, 1975, p.354]. In adopting MVs, it is poorer farmers who are likliest to rely mainly on family members for extra labor; this extra effort is seldom counted into production costs, but requires extra dietary calories, cutting the true net gain of poor people from MVs.

* * *

Massive research "measures" MV-poverty impact by MV-farmsize indicators. But there is direct evidence that the above five effects invalidate such measurements. First, only in well-watered areas do agricultural households, as their owned or operated holdings increase from zero (landless labor) to 3-4 ha., show diminished risks of falling into the lowest deciles by income-per-person [Lipton, 1985b]. Second, even authors who emphasize the recent evidence that size of operated holding is seldom linked to eventual MV adoption or yield point out that "when the farmer's wealth or economic resource base is considered, those with higher incomes tend to be the main adopters" [Herdt and Capule, p.37, citing micro-studies from India, Bangladesh and Korea]. Third, other income sources sometimes radically improve the household impact of MVs on the poorest farmers [Swenson, 1976, pp.8-10]. Fourth, family size is significantly linked to MV adoption in three out of five studies, and negatively in none [Herdt and

Capule, p.32; Malla, 1983]. This underlines the weakness of inferences from household impacts to poverty impacts.

IARC research on the impact of MVs on poverty should be reorientated (a) from favored areas to omitted areas, (b) from production effects to consumption effects, (c) but also -- among farm, labor, and other producers' families in favored areas -- from replicative studies linking farm size (or tenure) with adoption, yield, etc., to innovative studies linking MV innovations causally to changes in incidence and severity of "poverty". This is best indicated, not by household farm size, but by real income or consumption per person from all sources (net of all production costs, debt obligations, etc.) at various stages in the spread of MVs and linked inputs.

3.2 Adoption, farm size, and tenure

To the extent that "impact of MVs on poverty" does overlap with "effect of MV innovation on the affected crop in small-farm households", that effect depends on (1) their adoption rates, (2) the proportion of land they plant to MVs, (3) their capacity to saturate MVs with other inputs such as fertilizers, (4) the prices they pay and receive, (5) their yields. As for (1), the questions of whether, when and how "small farmers" adopt MVs remains loosely relevant to equity, and, outside areas such as Bangladesh and Java where most really poor villagers depend mainly on employee incomes, especially relevant to a rural society's social cohesion and "parity of esteem": to the sense that all classes advance together towards higher levels of income and technology. Small-farm adoption and yield of MVs tell us far less about poverty impact than we once believed, but a lot, perhaps, about rural societies' long-run prospects of coherence and stability.

In the early years of MVs, until about 1974, the evidence that larger farmers were adopting more, sooner, seemed overwhelming. In the classic PEO/ANU study of India, "For all five crops and in each of the three years [wheat, rice, maize, millet, sorghum; 1967-8, 1968-9, 1969-70, there was] a strong positive linear relationship between the proportion of farmers adopting [MVs] and the farm size" in the great majority of villages in Indian MV areas. Also "in 17 of [20 case-studies by Agro-economic Research Centres this] relationship was statistically significant" at 5%, and no case showed small farmers likelier to adopt [Lockwood et al., 1971; Schluter, 1971; Dasgupta, 1977, p.226]. Early evidence for other countries was similar [summarized in Herdt and Capule, 1983, p.33].

It is sometimes claimed that the positive link between MV adoption and larger farm size had, by the mid-1970s, been destroyed. In thirty villages surveyed by IRRI, small farmers even appeared to have adopted somewhat more and/or earlier than large; though careful inspection shows that this is a fallacy of aggregation, since only one village showed strong positive size-adoption links [Barker and Herdt, 1981, esp. p.94]. In India, the link had disappeared by the mid-1970s for wheat, and for most States for rice; it was doubtful for maize [Dasgupta, 1977, pp.227-8; Barker and Herdt, 1984, p.24]. Wheat MV adoption also appeared to be widespread among farms, irrespective of size, by the late 1970s in the Pakistan Punjab, N.W.Bangladesh, and N.W.Mexico [Byerlee and Harrington, 1982, p.3].

What has changed and why? Are there exceptions? What are the lessons for research and policy?

The first change is that, in many places, big farmers adopted first and small ones caught up [Prahladachar, 1983, pp.929-30, and Harriss, 1977, pp.139-40 for India; Burke, 1979, for Mexico; Ruttan, 1977, p.17]. For Kenyan hybrid maize, early adoption was strongly related to size (and to no other variables tried) -- but "mature" levels of adoption were not [Gerhart, 1975, pp.42]. This means that big farmers obtain the "innovators' rents" [Anderson and Pandey, 1985, p.8; Dalrymple, 1979, pp.720-1; Binswanger, 1980, p.180]. They do so because, especially if net imports are restricted by policy, MV food prices are pushed down (by the early innovators' sales) by the time the poorer, later adopters are ready to sell. But "innovators' rents" are partly a reward for risk; big early innovators also incur the costs of failure, as when downy mildew hit the early hybrid millets [Binswanger and Ryan, 1977, p.224]. Moreover, in one important case in Western India (where the poor consumed much of their extra output), late adoption did not give smaller farmers any "enduring and self-reinforcing disadvantage" [Shingi et al., 1981]. In general, though, late starters finish last, perhaps because if they do well enough to look like overtaking they are first taken over.

Moreover, this catch-up is not happening everywhere. Of twelve quantitative studies in Bangladesh, seven show a positive size-adoption link for rice MVs, and only one a negative link [Herdt and Garcia, 1982, p.3]. With hybrids, the small farmer, reliant on timely distribution of small amounts of seed each year, may suffer long-term adoption and re-adoption lags, with smallness linked to absence of extension visits [Colmenares, 1975]. In India the spread of MVs to the poor falters or fails in areas of greater initial inequality and institutional inadequacy or bias; catch-up is thus "by no means automatic (which seems to be suggested in the evaluations of over-zealous enthusiasts of the green revolution)" [Prahladachar, 1983, pp.930-1]. Cooperation is one form of relevant institution, which enables small farmers to share savings, thus structuring farm capital away from buildings and towards larger, jointly managed irrigation assets. This made a major difference to MV adoption among small Mexican farmers, favoring ejidatarios over small private farms [Burke, 1979].

Second, apart from smaller farmers "catching up" with old MVs, new MVs of some crops may be getting more "smallholder-friendly". New wheat and rice MVs, such as IR-36 rice, appear to outyield local varieties even with low inputs, disease risk, and some moisture stress -- as early MVs, such as TN-1 rice, certainly did not [see Byerlee and Harrington, 1982, pp.1-2, on wheat. Hybrids, unlike composites, need annual replenishment -- a reason for caution about smallholders' capacity to adopt and sustain the upcoming rice and wheat hybrids. In Tunisia, higher smallholder acceptability of MVs of durum wheat, compared to bread wheat, appears to be related to lower risk, especially at low input and management levels [Gafsi and Roe, 1979].

However, small size of farm -- linked with slow, or no, adoption in so many early studies -- is being separated in recent work from many things for which it is a "proxy". Hold constant (1) a farm's topography and willingness to farm pure line stands [Cutie, 1975], (2) the access to credit [Colmenares, 1975], irrigation, fertilizers, and (3) the farmer's education and off-farm income; and, behold! the effect of farm size in impeding adoption vanishes [Perrin and Winkelmann, 1976]. But this may be misleading. Small farm size, as we have stressed, need not indicate poverty; but they are correlated. Poverty both brings farm size down, and impedes education, off-farm earnings, and access to farm inputs. Through these impediments, poverty delays adoption, and ties that delay to farm size. It is a loose connection, and smallholder-friendly institutions and MVs can break it. But to deny the (usual) connection, or its (usual) harm to the poor, is unhelpful.

As for tenure, the results tend to confirm the theoretical exposition [Bell, 1977]. Farmers who own all their land do not show systematically different adoption rates from pure tenants [Herdt and Capule, p.37], except where, as in Bangladesh, the institutions, especially those for credit, gravely disadvantage tenants. There, too [Herdt and Garcia, 1982; Shahid and Herdt, 1982], owner-tenants are likelier to sow MVs on their owned land than elsewhere [Hartmann and Boyce, 1983, p.211].

3.3 Explaining the patterns: proportion of MV land among adopters

Small farmers are often believed to delay adoption for want of access to inputs or credit. Another reason given generally by poor people is that MVs seem risky. Though some empirical studies cast doubt on poor people's greater absolute risk-aversion [Binswanger, 1981], it is generally believed to make sense. Also new techniques, until one's near neighbors have tried them out, seem to raise risk, even if [Roumasset, 1976] many of the MVs do not do so objectively.

How should policymakers sort out whether to reduce risk or to improve inputs, notably smallholder credit, to increase smallholders' MV adoption? One hint [Schluter, 1974] is that risk appears more constraining in unirrigated areas, credit elsewhere.

Another hint is the surprising but well-attested fact, not an "unsupported assertion" [Herdt and Capule, 1983, p.36], that, where MV adoption is slower among smallholders, the proportion of land sown by adopters to MVs, is markedly higher [Herdt and Garcia, 1982; Asaduzzaman, 1980; Dasgupta, 1977, pp.229-32]. One possible reason is that, if you have very little land but have to incur the fixed costs of learning about and obtaining MVs and perhaps associated inputs, you need to plant most of the land to them to justify the costs. This is consistent with the view that, on plausible assumptions, risk-aversion impedes adoption only if there are "fixed adoption costs" [Feder and O'Mara, 1981, pp.60-1].

3.4 Other inputs to support MVs: big farmers and small

There are two problems. (a) Are MVs normally, or causally, linked with labor-displacing inputs such as tractors, threshers and herbicides, which favor bigger farms with ample savings and little family labor? (b) Do MVs require, or disproportionately benefit from, inputs such as irrigation and fertilizers which, while far from labor-displacing, may be easier to obtain for larger farmers, who have cash or are creditworthy?

(a) In the IRRI constraints study of thirty Asian villages, rice MVs were strongly associated with herbicides, tractors, and threshers only in the twelve Philippine villages, and with tractors in Malaysia [Barker and Herdt, 1984, pp.85, 87]. The latter effect appears specific to double-cropping; MV-based technical progress was size-neutral in single-crop areas, but favored larger farms and mechanization under double-cropping in Malaysia [Gibbons et al., n.d., p.221], as in West Java [Lingard and Baygo, 1983, p.54]. In a village typical of Indian semi-arid areas, land/labor ratios on small farms were only 56 per cent of those on large farms. Perhaps, however, this justifies attempts to improve factor markets, rather than to design special labor-intensive MV technologies for small farms.

However, there are relevant variables here for research policy. A short-duration second crop or MV can permit continuation of inexpensive and labor-intensive animal operations. This may justify a considerable sacrifice in yields if a longer-duration higher-yielding second crop or MV would require threshers or tractors. Also, breeding choices affecting timing and canopies can determine the choice between hand-weeding and herbicides. In these and similar cases the value of the MV release to small farmers is affected, via their capacity to operate labor-intensively rather than with scarce cash or machinery.

(b) As for the general problem that MVs are most profitably used with higher input levels than TVs (whether or not those inputs displace labor), the costs to small farmers are reduced if IARCs breed for performance no worse than that of local varieties even at low input levels. But it is implausible that without "soil mining", or a breakthrough in nitrogen fixation research, even MVs could be expected to achieve major yield improvements without artificial NPK. Although clearly not for S.E. Asian rice [Herdt and Capule, 1983, p.33], there are reports of higher per-acre fertilizer levels on large than on small farms. This is often not because small farmers seek to avoid risk [Smith et al., 1983] but because richer farmers are better able to afford timely purchases of these inputs [Hartmann and Boyce, 1983, p.181]. Although irrigation (closely linked to MVs) is not itself biased in favor of large farms, increasing public and private preference for tubewell, over canal irrigation helps big farmers, more than small ones, to acquire water [Dasgupta, 1977, pp.91-2;

Narain and Roy, 1980]; In Maharashtra, for example, construction costs of wells increase with size but at a declining rate, so that larger farmers enjoy lower unit costs in obtaining irrigation water [Ketkar, 1980]. Biases towards big farmers in extension advice and credit, however, may lose importance in later years of MV spread [compare Hewitt de Alcantara, 1978, with Byerlee and Harrington, 1982, on Yaqui Valley, Mexico]. Certainly the findings on "input saturation" of MVs do not show systematic tendencies by big farmers to exceed small-farm levels in the longer term.

3.5 Prices for inputs and outputs

As indicated in Section 3.2, if smaller or poorer farmers adopt MVs later, they usually obtain output prices reduced by their better-off neighbors' earlier successful marketings. Even among simultaneous adopters, the richer often get better prices due to greater scale-economies in marketing, especially when MVs increase sales volume, and greater ability to hold grain off the market until prices improve. In Thanjavur, their need to sell quickly meant that farmers with less than 20 acres sold paddy at 20% less than bigger farmers [Swenson, 1973, pp.77-8, 113]. These factors interlocked in the wake of MVs; 70 farmers with below 2.5 acres obtained only 17.4% more per kg. of paddy in 1970-71 than in 1965-6 in Thanjavur, less than compensating for inflation, whereas 9 farms over 20 ha. achieved a 48% price rise [Swenson, 1976, p.3]. However, since small farmers consume much of their extra MV output, they may escape the effects of market-price downtrends that hit bigger sellers as MV expansion takes hold [Cordova *et al*., 1981; Deuster, 1982]. Another output price effect favoring small farmers is that, as big ones switch to MVs, they may leave premium varieties (e.g. *basmati* rice), and their increasing price advantage, to smaller sellers [Chaudhry, 1982, pp.176-7].

Price advantages for larger operators are clearer for inputs, especially fertilizers. Only at high cost are these "debulked" at retail into the 5-20 kg. packages suitable for really small-plot trials with MVs. Unavailable or costly small packages have proced a major problem in Sri

Lanka, Kenya and Zambia, perhaps inducing later MV adoption by the poor. Credit, too, is affected; in Thanjavur, interest on loans "for paddy production" fell steadily from 13% for holdings below 2.5 ha. to 9% above 20 ha. [Swenson, 1973, p.184] and differentials on informal-sector loans are often much larger than that. Finally, if tenants are usually poorer than owners, land prices in the wake of MVs normally harm the poor relatively, since (a) sharecroppers must hand over 30-60% of the output to landlords, a share (in effect an input price) often raised by MVs, and (b) MVs tend sharply to raise land prices and rents [Cohen, 1975, pp.350-1].

3.6 Farm size, yield, efficiency and MVs

Small farmers' price problems, although perhaps delaying adoption of MVs or fertilizers, do not prevent it. Ultimately, if small farmers keep operating their land (Sec.3.7), they usually adopt as much as large farmers. Since small farmers normally can mobilize more family work per acre, and can more readily reduce the costs of screening and supervising employees, one would expect them to get higher yields from the MVs -- which raise labor requirements per acre -- than large farmers can do. So small farmers, since they enjoy as much adoption, at least as high yields, and lower cash costs, should do at least as well out of MVs, as large farmers. All this is at a given level of efficiency, and is strengthened if small farmers manage MVs better, applying more "management input per unit of land area" to such matters as fertilizer placement. In a Philippines sample, for every extra hectare of land operated, allocative efficiency dropped by .07 from a maximum of 1, and technical efficiency by .09 [Herdt and Mandac, 1981, pp.398-9]. No size-efficiency relationship, however, appeared in Pakistan [Khan and Maki, 1980] or in the Indian Punjab [Sidhu, 1974].

A major controversy, however, concerns what MVs do to yields in different farm size groups. It is well established that in pre-MV agricultures yield per acre-year, in most LDCs and food-crop systems, usually rises as farm size falls [Bharadwaj, 1974, ch.2; Berry and Cline, 1979; Dasgupta, 1977, pp.173-7; Hunt, 1984]. Lower management and supervision costs, and greater need for food compared with leisure, are among the explanations of this "inverse relationship". However, it has been claimed that MVs, by giving advantages to those who can better afford credit or inputs or tractors, remove or reverse the "inverse relationship". Roy [1981] analyzes data to suggest a reversal in some, but not most, parts of the Indian Punjab exposed most intensely to the new technologies. Another study there concluded that in 1974-5, among 1663 sampled cultivators, significant regression coefficients show that the size-yield relationship "stands reversed" only for the main MV crops, rice and wheat, in the most progressive area, Region I, which is the only area where per-acre input use rises strongly with farm size [Bhalla and Chadha, 1983, pp.62-3, 70-73]. In Mexico, small private farms (unlike the semi-cooperative ejidos) also appear unable to attain the post-MV yields of larger farms [Burke, 1979].

Do we conclude from these leading MV areas that, despite small farmers' success in adopting MVs and in managing them efficiently, large farmers' yields per season will remain superior, reversing the position with traditional varieties? No, for five reasons. First, it is yield per acre per year that counts. Higher cropping-intensity and crop-value were always the main components of small farmers' superior performance. Even in "Region I" these remain, and may indeed now be enhanced by the new shorter-duration varieties; even by 1975-6 they removed the wheat and rice yield advantage of large Punjabi farmers [Bhalla and Chadha, 1983, p.75]. Second, higher yields attained by larger farmers via higher outlays, even for a particular crop and season, need not mean better private income or social efficiency per acre-year. Third, even in the Punjab, some small farmers were still in transition from lower to higher (new MV) production functions [Lipton, 1978, p.324; cf. evidence in Chattopadhyay and Rudra, 1976, pp.A-109, A-117]. Fourth, there is evidence against scale-economies from MV areas of Sri Lanka [Herath, 1983], and a large, slightly earlier farm-level survey in India confirms the inverse relationship [Bhalla, 1979], whereas by the late 1970s a strong positive relationship for wheat in the Yaqui Valley, N.Mexico, had been greatly weakened [Byerlee and Harrington, 1982, p.3]. Fifth, the results are very specific. In both a Malaysian and an Indonesian case, MVs were size-neutral on land operated in the main season, but reversed the "inverse relationship" (favored large-farm yields more) on double-cropped land [Gibbons et al., n.d., p.211], probably because of special advantages to tractors and threshers for quick turnaround. In N.Ghana, large units of mechanized MV riceland were set up, registered, and given special access to inputs amid a sea of unregistered small producers [Goody, 1980]; it would be evasive to blame the results on a reversal of the size-yield inverse relationship by MVs!

If "small farms" means those with more hands to work, heads to manage, and mouths to feed [Chayanov, 1966] per acre, then most MV-fertilizer-irrigation technology should increase possibilities and incentives to generate somewhat higher yields, and much higher income net of cash costs, per acre on small than on large farms. If "small farms" means those with little access to education, credit, extension, or timely inputs, then big farms will do better, per acre, out of MVs. The higher person/land ratios of small farms are a fact of life; their lack of access is a policy variable. This suggests that, instead of doing more research on MVs and size-yield relationships, IARCs should investigate how MV packages can accompany appropriate institutional change to improve small-farmer access (e.g. to remedy the failure of institutional credit in Uttar Pradesh, so as to meet the uncertainly-timed cash needs facing small farmers [Subbarao, 1980], so that costly informal credit may in future cease to deter MV-fertilizer use). Alternatively, IARCs might ask how MVs, etc., could be rendered more robust if that access is delayed or denied.

3.7 But will they last?

"Small farmers", tenants, and in general low-income farm households have the capacity to adopt MVs as much, and to manage them at least as effectively for year-round yield, as other farmers in the long term. But will small farmers keep their land into the long term? The two processes alleged to stop them in the wake of MVs are eviction of tenants, as ex-landlords find it more profitable to resume personal MV cultivation themselves, and engrossment as large operators buy up, or rent from, small ones. Unless MVs have economies of scale there is no obvious reason why they should stimulate these processes. Landlords indeed find that biochemical innovation raises land prices, but why should they not capture part of that rise by raising rents, rather than by seeking to turn themselves into farmers? The rise in price of land, too, should discourage large operators from buying or renting in more; if they do, it should enrich the smallholders who transact with them.

There are, however, notorious cases where MVs have been linked with eviction. In Chilalo, Ethiopia, where about half the 60,000 farm households were tenants before the MV-based development program started in 1968, "as of 1971 some 20-25%...had been evicted"; although the survivors raised real incomes by over 50%, this was no help to the "evictims"! One cannot blame the MVs, or the Swedish donors, for the persistence of three Governmental policy errors, probably deliberate: heavily subsidized mechanization (favoring very large scale), grants of big individual land ownership rights, and broken promises of land reform [Cohen, 1975, pp.348-9]. But if MVs are introduced into such a context the effects on tenants can be terrible. It is, after all, the combination of MVs and the policy context that renders it profitable for landlords to adopt their new strategy of eviction and tractor-combine farming.

In the Indian Punjab and Haryana, the spread of MVs has been accompanied less by eviction than by rental engrossment, despite a steady post-1967 downtrend in the proportion of all farmland rented. Middle and big farmers stopped renting out, and middle farmers increasingly rented in from very small farmers. Operational holdings below 1 acre fell from 24.3% to 4.3% of all operational holdings from 1953-4 to 1971-2, while the pattern of owned holdings changed little [Bhalla and Chadha, 1983, Tables 1.6 to 1.8]. This pattern is unique in India; generally miniholdings have risen greatly as a proportion of total numbers and area [Vyas, 1979]. The Punjab's trend, amounting to a conversion of many of the poorest from micro-farmers into micro-landlords-cum-employees at slightly rising real wages [Lal, 1976; Bhalla, 1979] and rapidly rising rents, cannot be definitely linked to MVs. However, since MV adoption initially favors those with better access to inputs, especially reliable tubewell water (and more recently threshing-machines), a causal link is probable.

No general link of MVs to changing tenure or farm size has been established. Too many other things, from person/land ratios to land laws, are changing at the same time. It is, however, essential that programs to introduce MVs be pre-evaluated in the tenurial context where they are to be introduced. Chilalo is not an isolated case, and MV planners (and IARC researchers) do bear some responsibility for such results. In such social conditions, biochemical technologies need to be especially hostile, not just neutral, to capital-intensive large-scale farming.

3.8 Net impact on poor MV farmers: growth vs. stability?

Yet even in Chilalo MVs greatly enriched the poorest farmers, provided they could keep their land. It follows from what has been said so far that small farmers in regions where MVs do well, if they can keep on farming, will usually gain real income, and will seldom lose. Despite some gloomy assessments from the early years of MVs when few areas and very few small farmers had adopted them [e.g. Frankel, 1971], that is the general message of recent work [Barker and Herdt, 1981, 1984; Chaudhry, 1982; Deuster, 1982; Blyn, 1983; Swensen, 1976]. One study even concludes that such analyses "have provided a body of evidence which proves beyond doubt that they [the critics of MVs from the viewpoint of the local poor] are wrong" [Pinstrup-Andersen and Hazell, 1984, p.11]. It must, however, be stressed that:

- For MVs to benefit even those who remain as small farmers, the institutions must be adequate [Prahladachar, 1983].

- Extra farm income from MVs, even if it is distributed no worse than "in proportion to the initial landholding" where (as in the Indian Punjab) "landholdings are...very skewed" compared to income, enriches the rich proportionately much more than the poor and is thus "quite inequitable" [Bhalla and Chadha, 1983, p.160].
- "Small farmer" overlaps imperfectly with "local rural poor".
- The real poverty problem with MVs arises in the rural areas that they leave out.

* * *

Very poor farmers in MV regions, even if their real net income per person goes up, could suffer if that income became much more unstable. The stability issue is dealt with elsewhere in this Report, but its special relevance to poor farmers in MV regions needs review here. It has been shown [Hazell, 1982, 1984; Mehra, 1981; Ray, 1983; Pinstrup-Andersen and Hazell, 1984] that foodgrain output variability has increased in India in the wake of MVs. However, this does not mean that MVs have made farming riskier. Almost all the increased variability is due to increased concentration of output in fewer places which tend to have good (or bad) harvests at the same time. When the analysis is done at a level closer to the individual farmer -- for one crop, across Districts (instead of for total output across States) -- it turns out that 95% of extra production variance for sorghum, and 92% for pearl millet, is due to extra covariance among producing districts [Walker, 1984, pp.6-8]. Some of this rise, as for the remaining 5-10% of extra variance that may really hit the farmer as instability (possibly pest-induced) in individual yield, may be due to narrowing of the genetic base [Hazell, 1984] although more evidence is required. Some, too, may be due to pushing out of MVs into riskier areas [Ray, 1983]. However, it is not proven that greater restraint with MVs would have been a better policy for the poor [Walker, 1984, pp.11-12].

Indeed, changes in "variability of output", i.e. in the coefficient of variation of gross product, are an odd way to measure risk before and after MVs. Such variability can rise, even though "worst-case" output rises too, if normal or best-case output rises by a larger proportion. Even if worst-case output falls -- a rare feature with recent MVs -- output variability for surplus farmers (who may be very poor people, selling MV rice to buy roots or coarse grain) can be compensated by price changes in the reverse direction for the MV crop sold (or in the same direction for items purchased), and/or by changes in the volume of purchased inputs. We know nothing about whether MVs have improved or worsened such compensation.

It is important for MVs to aim at robustness, partly through greater genetic diversity, and thus at lower individual disaster-risk for a poor producer. The authors cited in the last paragraphs avoid the mistake of inferring such increased risk from higher aggregate output variability. So should we.

3.9 The real poverty problem: where MVs are not

Even those who are most positive about the effects of MVs on poor farmers and workers in progressive areas and on consumers agree that "backward" areas, especially those with less-reliable water supply, have not done well [Barker and Herdt, 1984, p.48; Ruttan, 1977, p.18; Pinstrup-Andersen and Hazell, 1984, p.13]. "In some countries optimum environments are frequently controlled by the larger and better-off farmers" [ibid., p.13], so that land is less unequally held, and landlessness is less, in villages in backward areas [Dasgupta, 1977a]. Thus regional MV inequality leaves out (a) initially poorer areas (b) areas where prospects for fair distribution of gains are best.

However, while this is the main problem of MVs, it should not be over-generalized. In some important cases (India, West Malaysia), inequality among rural areas is associated with only a small proportion of either poverty or national inequality [Malone, 1974, p.16; Anand, 1984]. In other cases, some of the regional bias in benefits from MV research corrects earlier research biases towards regions suitable for major export crops, especially within West Africa. Also, to some extent, migration can correct some regional biases. Finally, only if there is a price break, i.e. if a national economy is big or remote or partly closed to trade, will more MV grain from, say, the Punjab or Central Luzon reduce absolute income in non-MV regions; even then, net food buyers in all regions should gain (Chapter 5).

Indeed, regional income distribution has improved in some countries in the wake of MVs. Notable is Taiwan, where most cropland is in irrigable MV rice almost everywhere. In Pakistan, with about 40% of cropland in irrigated wheat, and with much spread of MVs to rainfed barani areas mainly on grounds of risk reduction [Rochin, in USAID, 1973], rural regional inequality has fallen since MVs [Chaudhry, 1982]. But in most LDCs initially poorer rural regions have lost relatively to richer regions from MVs. Although in these regions land, being in inelastic supply, bears more of the costs than labor (which may be able to shift jobs), many poor farmers and workers, unable to move readily from nearby land, have lost absolutely from MVs [Binswanger and Ruttan, 1977, ch. 13; Binswanger, 1980, p.187; Binswanger and Ryan, 1977, p.229].

For example, the spread of MVs in Mexico in the mid-1960s was heavily concentrated in the Pacific North. Already in 1960 agriculture there enjoyed two huge advantages: over half the land was irrigated (the national figure was 15 per cent), and farm income-per-person was over 50% above the national average [Tuckman, 1976, p.20]. MV surpluses must have cut output prices, and restrained growth in incomes, in non-MV wheat areas not only for private farmers with a surplus, but also for poor ejidatarios. Such regional damage to Mexico's rural periphery was reduced by rapid growth of urban employment, but this was not happening in most MV countries.

In India, the proportion of workers engaged in agriculture appears to have been constant between 1961 and 1981 [Lipton, 1984]. Yet the spread of MVs and associated yield improvements have "left out" large areas. In the Eastern rice zone, initially India's poorest rural region, average yields rose by less than 25 per cent in 1960-77; proportions of riceland in MVs reached about 30 per cent, and yields reached around one ton per acre. In the SW and NW wheat-rice zones, initially the least poor, proportions of rice in MVs rose to about 60%, and rice yields about doubled, reaching about 3 t/a [Brass, 1984; Herdt and Capule, 1983]. In 1960-1, before MVs, the Punjab already irrigated 54% of net sown area (19% was the all-India figure); by 1979-80 the proportions had moved even further apart, to 85%(27%) [Bhalla and Chadha, 1983, p.12]. Meanwhile foodgrain output, which had grown at similar rates in Punjab and all-India (60%) from 1950-1 to 1960-1, grew in 1960-1/1978-9 by a factor of 3.6 in the Punjab, but only by 1.6 in all-India [Chadha, 1983, p.131].

The interstate coefficient of variation of foodgrain output per person among Indian States, stable in the 1950s, increased dramatically in the 1960s due to the confinement of progress in MV wheat to the North-west [Krishnaji, 1975]. Lagging states did not, as a rule, compensate by relatively better non-foodgrain performance. Since about 1973, however, the take-off in rice and sorghum has somewhat reduced inter-State disparities in foodgrain output per person [Sawant, 1983, pp.493-96]. Nevertheless, the maize and millet areas, the rabi sorghum zone, plus the large, poor Eastern region, comprising Bihar (outside Kosi), Eastern U.P. (except tubewell areas), most of Orissa, and W.Bengal (outside the irrigated Northern wheat zone), remain left out, as do analogous crop-climate zones in other LDCs.

The parentheses in the last sentence give a major warning about regional impacts of MVs upon poverty and inequality. Most data show changing averages for vast States or Provinces with millions of farmers and with administrative, not agro-climatic boundaries. Disaggregation of MV effects often produces surprises, not least for India. Below State level we all know that the MVs did much more for Western than for Eastern U.P. -- but not, perhaps, that their spread, plus that of tractors, etc., was associated with a 1.7% decline each year in per-hectare labor use in Western U.P. but a 0.29% rise in Eastern U.P. [Joshi et al.,1981, p.4; cf. Sec.IV]. At the level of Districts, 81 of them, accounting for 51% of Indian wheat output on 42% of area in 1962-65, had each by 1970-73 raised output at over 10 per cent per year, to provide 67% of output on 52% of area by 1970-3 [Bhalla and Alagh, 1979, pp.95-7].

However, despite the heavy concentration in the Punjab of both high initial productivity and rapid growth of foodgrain output, there is no indication that Districts with slower growth of total farm yield and output were initially worse endowed with good land than those helped by MVs to improved performance. The laggard Districts were areas of low labor-productivity, i.e. of low income per farm-operating or laboring worker. Bhalla et al. [1983, Table 17] compare 74 leading Districts (of 281 surveyed in India), which achieved 51% annual compound rates of all-crop yield growth and 5.6% growth for total farm output in 1962-5/1970-3, with 67 laggard Districts, or rather backsliders (output -2.1%, yield -2.1%, yearly). Land yield in the leading districts in 1962-5 was a mere 6% above the laggards' yield (but 88% above by 1970-3), but output per male worker started 14% higher and ended up just over double. The widening of gaps in labor-productivity means that the regional patterns of Indian growth, in a period where MVs dominated these patterns, almost certainly increased substantially the relative disadvantages of small operators in poor districts. The absence of linkage between growth performance and initial land productivity, however, prevents any ready-made theorizing about just how and why this happened. It is likely to be crop-specific and environment-specific.

For example, the acceptance of sorghum hybrids, which in the 1970s enabled parts of semi-arid India to catch up with the growth-rates (if not to the levels) of the best irrigated wheat districts, is specific to kharif (main monsoon) areas in two States; cropping season effects explain 88% of inter-District variations in adoption [Walker, 1984; Walker and Singh, 1983]. These MVs'requirements are very timebound. "In [several districts] in the drought-prone black soil belt...100-110-day hybrids [able] to stand grain deterioration when rains occur late have taken firm root" [Rao, 1982, p.46]. For MV rices, however, the gain over traditional rices is much greater in non-monsoon, controlled-irrigation areas and at top ends of canals [Herdt and Wickham, 1978, p.5]. Yet in both cases, long before MVs, the lower level and slower progress of output-per-person (or per worker) in second-season sorghum, rainfed rice, and tail-end farming were familiar issues throughout South and East Asia. For hybrid maize in Kenya too, the spread to smallholders in "progressive" areas, viz. those with higher labor income, is in marked contrast to the failure to reach long-neglected areas [Gerhart, 1975].

Even well below district level, inter-village differences in MV offtake and yield appear much greater, notably in ICRISAT studies, than intra-village differences. The very slow progress of hybrid millet, together with the rapid advance of MV wheats, can lead to "patchwork quilts" in areas with water regimes and topography that induce major local variation of the main staple [Sharma, 1981, on Gujarat].

Even where crops and varieties are similar, regional and local gaps in MV results persist. Should we look to "human capital" to explain these gaps, clearly linked to labor productivity, in response to MVs amongst villages, districts, and States such as Bihar and the Punjab [Nair, 1979]? Education, co-operation, and perhaps motivation surely vary locally, and are linked cumulatively [and statistically: Rogers, 1962] to innovation, growth or decline, whether among rice villages or in computer manufacturers. However, the very frequent changes in pattern in desperately poor and long-stagnant places -- e.g. the shift to irrigated MV wheat in N.W. Bangladesh, the bamboo tubewells and MV rice of North Bihar, the MV sorghum takeoffs in much of Maharashtra -- surely prohibit ethnic determinism. Ethnic group and caste, if related to MV performance, are proxies for "income and size of landholdings" [Herdt and Capule, 1983, p.32]. For paddy villages in Malaysia, "the average total Technical

Progress score is exactly identical for the Chinese and Malay villages" [Gibbons et al., n.d., pp.194, 205].

There is thus great localization of regional disparity. Outside the legendary successes like Sonora and Ludhiana, every MV lead district has its backward villages, and almost every laggard (at least in Asia) its successful MV smallholders. Thus it may not be useful to identify vast and disparate "zones", like the Eastern Indian rice zone, where no sensible MV-based strategy is yet available, as appears to have been done at IRRI [Brass, 1984]. By 1978-9 Assam, Bihar and Orissa had respectively 23%, 25% and 30% of rice under MVs and West Bengal 41% [Herdt and Capule, p.49], by no means all in the winter season. The spread of rice MVs (not the very shortest, of course) to rainfed areas in Bangladesh ever since IR-20 has been impressive. Local areas of MV takeoff, inside regions of poor water-control, should be identified. For rice, drainage appears to be crucial, via poor response to nitrogen fertilizer, in deterring adoption [David and Barker, 1978, p.178].

Given the growing feeling that inadequate retained nitrogen, not too much or too little water, is the major constraint on yields in areas without good water control, fertilizer distribution, type and placing may be key issues in broadening the MV impact on backward regions. Accessible and promising regions are well served by competitive private fertilizer distribution, but remoter farmers, often already deterred by water risk from applying levels that maximize expected profits, may also require some public involvement [Ahmad and Hossain, 1984, p.40; Govt. of Bangladesh and USAID, 1982]. African practice in extension and fertilizer supply frequently involves supplying a standard NPK mix (e.g. "Compound D") unadapted to local soils or even crops, a procedure which almost certainly discriminates against areas of higher water risk, especially for smallholders. The CIMMYT proposals to shift wheat research towards stability in marginal environments could also help here [CIMMYT, 1983, p.VII].

* * *

Brass has fairly stated the dilemma facing IRRI and the Indian Council for Agricultural Research) [1984, p.7]. Should one divert "resources to the poor subsistence paddy growers of [Eastern] U.P. and Bihar when production and consumption needs might be better met, and the political dangers of discontented urban populations...warded off", by concentration on irrigated areas? Must one, perhaps, "introduce [more] inequalities into the agricultural economy to prevent the greater evil of an inadequate food supply"? It is not clear that Brass is right in blaming "production orientation" for the delay in attending to lowland rainfed rice at IRRI (a balanced review is Barker and Herdt [1979]). He cites [IRRI, 1979, pp.20, 45] showing that 32% of non-Chinese Asian rice is "intermediate rainfed", and received 31% of IRRI's 1977 budget -- hardly dramatic neglect. Shares in IRRI's research budget shares were and are far below shares in output, farmland, or population for dryland, upland, and deepwater rice [_ibid_.]. The same applies to the share of African national agricultural research outlays devoted to the adaptation and selection of MVs of rainfed foods, especially millet and root crops [Judd _et al_., 1973; Lipton, 1985]. IRRI's emphases represent a decision about research prospects; plainly IARCs do not help the poorest regions by research that produces no economic results. The African imbalance in _national_ research, however, damages the impact on poor areas of IITA and ICRISAT. ICRISAT, _combined with Indian national adaptive research_, has had major recent impact on sorghum, pigeonpea, and finger millet among poor farmers in neglected regions of India. In places without such national adaptive work, "foreign" agricultural research demonstrably achieves less [Evenson and Kislev, 1976]. The work of ISNAR, so far mainly directed to improving the _organization_ of national programs, might do more for the impact of varietal change on the poor if it now turned to their _content_, especially the crop-mix for poorer regions.

Another regional consideration is the urban-rural distribution. Any MV-based breakthrough, even in semi-arid farming systems or sorghum, tends to get a large part of its benefits transferred to fertilizer producers, in towns or abroad [Ghodake, 1983, pp.8, 11, 15; Ghodake and

Kshirsagar, 1983, p.12]. Moreover, most of the gains from widespread MV-based rises in food supply -- except in very open economies, as few LDCs are -- tend to be transferred to urban and other consumers. Some rural surplus farmers, especially those who are in areas unsuited for MVs, can be left worse off [Scobie and Posada, 1978; Evenson and Flores, 1978; and see Sec.V(i)]. In many countries, therefore, research that increases the return to farming in "backward regions" should, in equity, have some priority, even at the cost of somewhat slower progress in bringing down urban food prices than might be achieved by greater concentration on "advanced" regions.

There are also three efficiency arguments for such a switch of emphasis. First, research on irrigated areas, so long the priority, must be running into diminishing returns, compared to work on neglected, generally poorer regions, although specialists engaged to work on one set of problems, and seeking honestly to reinforce the contribution of their special discipline, tend to overestimate prospects for their initial work, as against work in other areas they know less about. Second, under urban pressures, national research agencies tend to favor areas which deliver food to cities; international centers can correct that emphasis. Third, neglected rural areas expel migrants, partly to favored rural areas (but not if all the gains from extra output are transfered to the towns via cheaper food), partly to the towns. This process has done something, but not much, to redress regional neglect, notably in the case of Bihar and U.P., which sent seasonal migrants to the booming Punjab (Ch.4). But it certainly creates serious urban problems of slums and congestion, while often depriving "backward" rural areas of potential leaders.

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Finally on regional matters: what have MVs in developing countries done to international income distribution? I know of no global research on this, but the impact on North-South distribution via lower grain prices, while favorable (since the Third World is a major net food importer) and measurable [Flinn and Unnevehr, 1984], must be small compared to that of the big growth in EEC and North American exportable grain surpluses under the impact of domestic agricultural research and of trade/subsidization policies.

Among developing countries, the few grain exporters lose from MVs, because of the big price cuts caused, both by MVs themselves and by EEC and other Western policies to subsidize cereal production. However, farmers in the Third World who are geared towards food exports, and who are often poor (or employ poor workers), have safeguarded their interests, e.g. (a) by switching from rice to rubber (Thailand), (b) by concentrating more upon premium basmati rice exports (Pakistan).

Most serious, of course, is the failure to date of MV research to have a significant impact on poor countries in sub-Saharan Africa. There are possible exceptions for cassava in a few places [Hartmans, 1985], for rice in a few parts of West Africa, and for hybrid maize in parts of Kenya [Gerhart, 1975] and of two middle-income countries, Zambia and Zimbabwe. Barely 3% of cropland in sub-Saharan Africa is irrigated, mostly in the Sudan, and not much more is fertilized. In the main crops (maize, sorghum, millet and cassava) MVs have not been proved economic in the field, except for maize hybrids released up to about 1970-72. The IARCs have spent more -- per head, acre, or ton of food -- in sub-Saharan Africa than elsewhere, but with limited impact, due to rather ineffective and costly local research backing which is seldom in practice directed towards poorer regions or smallholders. While the sorghum experience has bred caution about adapting Asian seeds to African farming systems, Asian national research and farm policymaking methods and priorities are more relevant to developing MVs for poor African regions than has yet been recognized [Lipton, 1985a].

CHAPTER 4 LABOR AND THE MVs

4.1 Economics, farmers and labor

There is an interesting puzzle, which casts light on the scope and limits of different types of social science to help IARCs in directing MV benefits to the poor. The puzzle is that, although theoretical arguments from economics alone (a) probably cannot show that small farmers gain from MVs and (b) do strongly suggest that laborers do, there is (c) growing (though often overstated) evidence and consensus that small farmers gain absolutely from MVs, while (d) net gains to laborers from the processes involving MVs in their total socio-technical setting are getting less clear, and may in several cases be turning negative [Smith et al., 1983; Smith and Gascon, 1979; Jayasuriya and Shand, 1985].

Economics alone cannot give firm guidance about the impact of MVs on the absolute and relative income of poor farmers in MV regions. Certainly the physical properties discussed in Chapter 2 -- MVs'use of more labour and management per acre, their production of coarser and cheaper varieties favoring self-consumption rather than marketing, and recently their greater robustness -- should be more helpful to small farmers than to big ones. But the societies into which MVs are inserted also influence matters. Their structure of power can divert to the richer farmers even innovations whose economics appear to favour the poorer ones. Moreover, the transfer of MV benefits to consumers and fertilizer-makers clouds the issue. Hence the limitations of economics in predicting impacts of MVs on inter-farm poverty and distribution within MV areas. Hence, too, the very variable, though in general not anti-poor, empirical outcomes.

Economic theory can apparently make stronger and clearer statements about the impact of MVs upon hired labor in MV areas. MVs -- via greater needs for fertilizer, water control, harvesting and threshing, and often via double-cropping -- increase the demand for labor per acre, apparently pushing up labor's share of income [implicit in Binswanger and

Ryan, 1977, p.225]. However, in a large and growing majority of developing rural areas (and especially in irrigated areas, where MVs are especially important), the supply of labor is ample. It can sometimes respond by moving to nearby MV areas if the real wage starts to rise. However, the supply of land is restricted, and cannot rise much in response to the greater demand for it caused by the new, profitable MV farming opportunities.

So employment of labour goes up somewhat, the real wage rate does not go up a lot, and the rewards (price, rent) of land go up a good deal, probably reducing labor's share in income [these elasticity effects are considered in Binswanger, 1980, p.283, and Anderson and Pandey, 1985, p.9]. Although employed laborers find initially that more work is on offer, and is better spread over the seasons (though perhaps not over the years), with MVs than without, this rise in work may be outpaced by growth of the workforce since population is growing. The share of wages falls, because rising land-rents enrich landowners proportionately more than rising employment enriches workers. The real wage bill rises. Real annual earnings per worker need not rise.

As we shall see, this simple economic "story line" corresponds reasonably well with observed facts in MV areas. Two complications, very important in other respects, do not greatly affect this story line, but a third can produce an unhappy ending:

(a) Whatever the proportion of gains from MVs that is transferred from producers to consumers via lower prices, labor per acre in the MV crops is still increased, so the above processes still work. (At lower prices, producers may switch area from MVs to other crops, which could move wage-rates, wage-bills or wage-shares either up or down).

(b) As family farmers' income is raised by MVs, they tend to take it easier -- while still putting more labor into the crop -- by switching from family labor to hired labor, usually more of it. This reinforces the above processes.

(c) Less happily for the poor, MVs are in some circumstances linked to labor-displacing inputs -- tractors, weedicides, more mechanised irrigation or (especially) threshing. (The view that such inputs "on their own" do <u>not</u> displace labor is either "special case" or special pleading; a good review on tractors remains Binswanger, 1978). Some argue that MVs do not "cause" this labor-displacement. Others disagree, emphasizing the incentives to mechanize created by MVs: seasonal labor peaks and the bidding-up of seasonal threshing wage rates in some areas. However, if MVs do "cause" mechanization, etc., and thus labor-displacement, this is a direct result of employers' reaction to the labor-using effects mentioned above, and almost always only partially offsets them; in the absence of the offsets, employment and real wage-bills would rise rather less, and wage-shares would fall slightly more. Real rural unskilled wage rates, except seasonally in the short run, tend to be little affected by either the labor-using effects or the offsets because of the high long-run elasticity of labor supply, and its growth alongside population. These wage rates tend to stay close to subsistence levels until rural population starts to fall, well on into the development process.

Apart from possible mechanization effects, economic theory makes fairly strong predictions about what MVs do to labour. (1) Employment should rise significantly, especially in the short run. MVs not only raise labor use per acre-year. They also raise the proportion of hired labor in total use, for three reasons. First, farm families, unless heavily underemployed to begin with, must meet most of the extra labor requirements of MVs by hiring in. Second, as MVs enrich farmers, they will choose to take more leisure, and to hire in workers instead. Third, because MV systems are often simpler than TV systems, they tend to require less direct family involvement [Kikuchi et al., 1982]. Moreover, (2) stability of employment should rise as MVs increase double-cropping and shift demand for hired labor from casual to permanent employees. (3) However, MVs will raise real wage-rates little, and (4) labor's share in income falls, due to the much greater elasticity of supply of labor than of land. Do the facts support these strong predictions of economics?

4.2 Labor use, wage rate, factor share

As rural incomes rise and as labor shifts from the household to the job market -- processes happening anyway, but much enhanced by MVs -- two main things happen to labor. First, there is a fall in adult "participation rates", the proportions of person-days supplied to the workforce, especially among women. Second, there is also a fall in the proportion of workforce-days spent in employment (or self-employment). Both Indian village cross-sections and analyses of the aftermath of MVs support this conclusion [Dasgupta, 1977, p.172]. The many studies of labor use under MVs hardly ever separate these two effects. Nor do they often separate the role of MVs from that of other factors. Thus studies of unemployment in LDCs almost all show increasing rates [Lipton, 1984], but that is because it is pulled up by workforces (growing at 3% yearly) faster than it is pulled down by falling participation rates. In fact MVs help both to moderate unemployment by requiring extra labor, and to reduce labor supply as better-off families reduce participation rates.

* * *

"Early observers" of MVs often found they raised labor requirements per acre-year by about one-fifth [Barker and Herdt, 1984, p.38]. Village-level increases in such requirements in MV areas for 1968-73 varied from 10% in Orissa and 13% in E.Java to 40% in Suphanburi and 42% in Bangladesh, though incomplete MV adoption in these early days meant that employment rose "much less" [ADB, 1977, p.60].

As MVs spread to less favorable environments, the yield impact fell and with it the direct crop employment effect [Herdt and Wickham, 1978, pp.4-6]. Where rice yield rises were large, rises in total labor use per acre remained clearly linked to MVs [Barker and Herdt, 1984, p.43]. This was less so, however, after allowing for the link between smallness, irrigation, and both yield and labor intensity; the labor-use rises from local varieties are then less marked in Andhra Pradesh, Tamil Nadu and Orissa [Agarwal, 1984a, pp.23-8]. Among 100 rice MV adopters in a block in Eastern U.P., the big rise in labor input per acre from MVs between 1967-8 and 1972-3 had been wholly reversed by 1979-80 [D., V. and R. Singh, 1981]. Worrying and widespread evidence of recently worsening MV-employment relationships comes from some of the very sources that earlier documented strongly favorable effects [Jayasuriya and Shand, 1985, esp. Table 1].

Several reasons are proposed. The key role of (1) migration and (2) mechanization is treated later. As in Central Luzon, (3) rising "full costs" of labor-time, including search and transaction costs as hired workers replace some family labor, may be partly responsible [Smith, Cordova and Herdt, 1981]. (4) As in Java, institutional changes, under pressure of seasonal labor bottlenecks immediately after MVs, may be destroying traditional work-increasing or work-sharing arrangements or technologies [Hayami and Hafid, 1979 , but cf. Hart, n.d., ch.7]. (5) Larger farmers, to avoid MV-related labor costs, may eventually combine with import licensees (and aid donors: Burch, 1980] to obtain subsidies for labor-displacing inputs. More hopefully, (6) in Laguna [Smith and Gascon, 1979], and surely in Taiwan and Korea, growing off-farm opportunities have reduced availability of farm labor. Most worryingly in the long term, (7) the "theory of induced innovation" [Hayami and Ruttan, 1971; cf. Grabowski, 1981] means that researchers face incentives to push down unit costs of factors scarce to rich, powerful users. As research is internationalized, these increasingly come to mean bigger, including Western, farmers seeking mainly to save labor. But such research impinges upon LDC environments too. IARCs need to be very careful to avoid such pressures (notable in, for example, the "IRRI-PAK mechanization program").

* * *

Although the impact of MVs on employment usually remains positive, it has become less favorable. Moreover, "except in Malaysia, the [Indian Punjab and] Thailand, [no] significant rises in real agricultural wage rates have taken place" in Asian MV areas over the past two decades [Jayasuriya and Shand, 1985, and citations there; cf. K. Singh, 1978]. Choice of particular years or seasons for comparison can be misleading, because fluctuations in real wages far outweigh trends [e.g. in Haryana in 1967-78: Kumar and Sharma, 1983]. Even in the areas of very rapid MV-induced growth, the rise in real wage-rates is very slow [Lal, 1976, and S.Bhalla, 1981, for the Punjab; at village level, cf. Leaf, 1983, p.251, and Blyn, 1983, p.719].

This stagnation of rural real wages means partly that MV gains are being passed on to consumers (Chapter 5) and landowners; and partly that farm employers displace labor by tractors, weedicides etc., if it looks like getting more expensive, and can obtain subsidies for such inputs through the political system. But the main reason why wage-rates stagnate, and why wage shares decline, is that with workforces growing fast, extra <u>demand</u> for labor due to MVs meets a <u>supply</u> of laborers prepared (or compelled by competitors) to work at rates barely above subsistence. Without MVs, such rates would probably have fallen further. Moreover, unless all the extra food grown by MVs would otherwise have been imported, food price rises would have implied real wage falls. In view of transport costs, it is naturally in the areas where MVs spread fastest that they did most to restrain local food prices, and thus indirectly to prevent real wage falls [Jose, 1974; Parthasarathy, 1974].

Since population growth, as the mainspring of workforce growth, is largely responsible for the disappointing impact of MVs on real wages and underemployment rates, it is natural to ask: do MVs affect the rate of population growth? Is it higher or lower in MV areas, or after MVs have spread? Unfortunately, these are almost wholly unresearched issues.

* * *

Farm labor's falling "factor share" (wages x employment, divided by net farm output) in MV areas has been dominated by (1) the rise in rental-to-wage ratios and (2) the drift of extra MV gross farm incomes to suppliers of inputs. The rental-wage ratio in Thanjavur doubled between 1971-2 and 1980-1 [Rajagopalan et al., 1983, p.427], though with many fluctuations; a good (bad) year usually led to much higher (lower) rents next year. A falling wage share in farming factor income, due to the rising price of land relative to labor -- alongside rising absolute real wage bill as MVs pushed up labor use -- is confirmed elsewhere in India [Prahladachar, 1983, p.938] and in Mexico [Burke, 1979, p.150]. So scanty is the impact of MVs upon labor income that new farming systems for semi-arid areas are commended because labor gets even 9% of extra farm income, as against as little as 1% reported for previous MV impacts in the Philippines (while gross farm revenue rose by 70%), and 2-5% elsewhere [Crisostomo et al., 1971; Ghodake and Kshirsagar, 1983b, p.9]. In these new farming systems, dependence on MVs and fertilizers means that most projected income gains from extra production go to urban or foreign producers of inputs, especially of fertilizers, often leaving both land and labor with a smaller share in gross revenue, despite a rise in the real rental and the rent/wage ratio [ibid., p.12]. A similar process transfers extra gross farm incomes to producers and repairers of machines, if these are linked to MVs [Ahmed and Herdt, 1981].

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With rapid population growth and scarce land, the position of landless labor is much worse without MVs, as village comparisons show [Hayami and Kikuchi, 1981]. MVs seldom raise real wage rates, or prevent falls in the wage share. But they do bring higher employment and a rising real wage bill. There are four cautions, however.

First, these benefits usually have to be shared among a growing number of labor households. Thus employment and hence wage receipts <u>per household</u> rise less, or may even fall. This is not usually "because of MVs" but because of population growth. However, a part is also played by developments that may sometimes be linked to MV-induced changes in landholding structure (Chapter 3). The possibility was established in some Bangladesh villages that due to early MV innovation "with their extra resources and relatively increased power the village rich were [better placed] to push the poor off their land" [van Schendel, 1981, p.245].

Second, very little is known about the effect of MVs on <u>wage-rates or employment on other crops or off-farm</u>. In Bangladesh the shift from jute to MV rice is labor-displacing [R. Ahmed, 1981; Harriss, 1978, 1979; see next section].

Third, no research has been done on the effects on <u>laborers in non-MV areas</u>. Such workers benefit as consumers (Sec. V) and as migrants to MV areas (Sec. IV(iv)). But they lose as MV output cuts relative grain prices, and hence the incentive to employ them at home.

Fourth, apart from the "average" fate of labor, <u>particular groups</u> of poor people (and in bad times many such groups) may gain or lose from processes involving MVs. This crucial impact has two aspects. In Chapter 4, Section 3, we ask how MVs have changed the structure of labor use, e.g. among family, permanent, and casual workers; men, women and children; farm operations; peaks and troughs. In Chapter 4, Section 4, we ask about the effects on workers of possible longer-term responses to the extra labor needed by MVs -- migration by laborers from non-MV areas, labor-replacement with machines or weedicides, etc. Of course, one cannot assume that these processes are necessarily linked to MVs.

4.3 Structure of labor use

(a) Hired vs. family: Numerous Indian studies concur that with MVs "the employment of family labor increases [less than that] of hired labor" [Visaria, 1972, p.184]. This is widely supported from other countries [Barker and Herdt, 1984, p.39; Kikuchi et al., 1982; Smith and Gascon, 1979]. Quite often a post-MV rise in hired labor input per acre outweighs an actual decline in family labor input [IRRI, 1978, pp.73-5, 91, 101, 126, 396].

Is this good for the poor? Clearly so in the main irrigated MV areas, where a little land confers a much reduced risk of poverty, so that laborers are significantly poorer than landholders. The only clear exception arises where, as sometimes in Indonesia [Lluch and Mazumdar, 1981], landed households with slightly different seasonal peaks give one another preferential work on a more rewarding MV crop and employ the landless on other crops at lower incomes. In many unirrigated areas, where landless labor and smallholding give very similar risks of poverty [Lipton, 1984a; cf. Ercelawn, 1984], the anti-poverty advantage of "hired labor bias" in extra MV work is less clear. Also, we must not conceptualize people as either laborers or owner-farmers; most of the rural poor are a bit of both, often concentrating on employed labor when young and on own-farm work after inheriting land.

(b) Casual vs. long-term: Usually real annual wages have risen somewhat in MV areas, while real day-wages have stagnated [Leaf, 1983, p.268; Blyn, 1983, p.711]. If a fairly constant proportion of laborers (probably well over half) prefers longer contracts, this probably means that demand for labor is shifting from casual to longer-term. This is plausible, given the greater amount and lower seasonality of MV labor requirements plus the reduced participation of families enriched by MVs. Remaining seasonal peaks, however, would suggest rising demand for male casuals at harvesting and threshing time. Such demand in India is strongly correlated with the proportion of rice in MVs [Agarwal, 1984a].

Although there is little direct evidence, partial "decasualization" of laborers is almost certainly an effect of MVs. If laborers are the poorest people, is it desirable? Certainly, it is for those laborers obtaining job security together with the direct interest of the employer in feeding well those persons he expects to employ in the longer term, so as to raise their productivity. However, especially in the slack season when work is hard to find, shifts in labor demand towards permanent laborers reduce the prospects of the remaining casuals, who are presumably less strong or able. Partial post-MV decasualization, therefore, might well reduce the <u>numbers</u> in poverty by pulling permanent workers above the poverty line, but increase the <u>severity</u> of poverty for the remaining casuals.

(c) <u>Men vs. women</u>: There are some village-level data suggesting that MVs reduce women's share in income, partly via the switch from family to wage labor [Ahmed, 1983, for Nigeria; D., V. and R. Singh, 1981, for Eastern U.P.]. The only systematic survey, however, shows that total female labor use is positively related to proportion of area in rice MVs in all three Indian States reviewed, and significantly at 5% in two [Agarwal, 1984, 1984a]. The results for wheat, if available, would probably be less favorable, as the greater cropping intensity of MVs creates more work that is "traditionally female" in rice than in wheat.

Once more, it is not clear what, as "friends of the poor", we want from MVs here or how IARCs can be guided in a specific sense. This well exemplifies the problems of IARCs in aiming at outputs for specific groups. The same germ plasm is used or adapted by many different national research systems. The resulting MVs may reach wealthy men in one country, poor women in another, etc. However, it would be a bit evasive to say that

IARCs should leave entirely to national systems the task of focusing on poor groups, on women farmers, etc. Some physical characteristics and timings, which vary among crops and varieties, are almost everywhere especially helpful to participation or benefit by such groups.

A further problem, specific to the sex balance of benefits from MVs, concerns the work requirements to be aimed at. Some tasks, such as weeding and rice transplanting, are more usually female than others. Should MVs aim at more or at less work in such tasks? The proportions of women, and of female-headed households, with very low household income per person are seldom significantly above the proportions of men, and of all households, respectively [Lipton, 1983]. If women are discriminated against inside households, or ought to get a larger share of household benefits because they are likelier than men to pass them on as food to children at nutritional risk, it is not at all clear whether higher or lower proportions of work, casual or family, are an effective means to improve women's status, power, or retained income. Slack-season risk of undernutrition of children is apparently reduced by maternal earnings only if they are obtained from self-employment, e.g. with MVs on the owned farm, not in hired employment that may involve leaving children at home [Kumar, 1977].

(d) Operations and seasons: Various operations with MVs tend to increase and stabilize the demand for labor. This is a major service to the rural poor from the IARCs. Although much of their work underpins this excellent result, unfortunately some does the opposite.

At sowing, if MVs are to approach the economically feasible yield, higher densities are usually required [CIMMYT Review, 1981, pp.31-32]. This raises demand for sowing labor, and in the case of rice for (mostly female) transplanting labor leading in some cases towards direct-seeded rice, or the development of a multi-row rice transplanter, which may well "save transplanting labor". Is this a proper goal for researchers paid for out of foreign aid? Possibly, if poor consumers gain more, from extra rice not otherwise cultivable, than poor transplanting laborers lose. Is that proven? Could other research priorities avoid undermining the favorable impact of MVs on poor people's income from sowing employment?

Since MVs increase the returns to fertilizer, extra labor inputs are also required to place it. But many small farmers cannot at first get credit or afford fertilizers, although small farmers, eventually, often come to use no less fertilizer per acre than big [Herdt and Capule, 1983]). Moreover, most farmers, being risk-averse, use less than profit-maximizing levels of fertilizers. IRRI has led the way in researching mudball techniques, deep placement, sulphur-coating and other forms of slow-release, increasing the incentive to use fertilizers and ancillary labor. Indeed, deep-placement of urea may be constrained in the Philippines by labor scarcity [Flinn and O'Brien, 1982]. But does this not make such methods especially suitable for the deficit family farmer, able to switch labor from hired work to his or her own enterprise?

Similar issues arise for weeding. Dense planting and erect leaves somewhat reduce MVs' requirements for weeding, but are usually more than offset by higher fertilizer levels. Much IARC research appears to be directed towards developing MVs, timing advice, etc. that reduce weeding requirements [CIMMYT, 1983, pp.89-91; 1984, pp.77-9]. This would be a desirable feature of MVs if it were costless, but would not the research time and land be better used to raise yields or stability in ways less likely to reduce employment? Some IRRI work [IRRI, 1983, passim] appears to go even further, by assuming that aid-financed research resources should be used to test, select, improve, or develop recommendations for commercial weedicides. Even where there is a case for this, e.g. with perennial sedge in dwarf rice where hand weeding leaves weed tubers in the ground [IRRI Reporter, 2/1973, p.1], should not IARC resources aim to shift timings rather than to "save the labor" of poor rural women?

Since MVs increase yields, they increase harvesting labor. A natural economic response is to save labor, for example by the switch from ear-by-ear harvesting in Java [Hayami and Hafid, 1979]. Clearly, if migration can be encouraged or varieties selected so that harvest time shifts to a less labor-constrained period, that is better than "unemploying" labor via reaper-binders. Fragmentation inhibits early harvesting of MVs if the remote plots must be reached through fields of standing crop [Pal, 1978]. Consolidation, too, can thus permit a more "labor-spreading" and hence employment-creating approach to the MV harvest.

In post-harvest operations, we have suggested that some MVs or related IARC research might displace labor. The attempt to develop an "IRRI thresher" [Jayasuriya and Shand, 1985] is surely an inappropriate activity. Threshers were much the most clearly labor-displacing piece of mechanization in Ludhiana District [Oberai and Ahmed, 1981]. Even if it is the only way to permit double-cropping in a few places in S.E.Asian economies, which is not proven, it constitutes, if successful, an aid-financed subsidy towards reducing the cost of labor displacement elsewhere, e.g. in Bangladesh. As for rice milling [B.Harriss, 1978], some MVs tilt the balance towards displacing labor from traditional hullers via "intermediate" (Engelberg) systems towards modern rice mills. Finally, since MVs are bred above all for a high grain weight relative to other dry matter, and therefore often have thin husks, care needs to be taken to screen varieties for storage characteristics. Altogether, MVs should increase post-harvest labor requirements, which (except for drying) can mostly be deferred to a suitable time, and which are especially likely to employ women and the landless. It is important that misdirected "labor-saving" research not destroy these possibilities.

All these warnings apply to environments where there are many poor rural people relying on employee income. They might apply much less to MV research for Zaire or Zambia, where the decision to use or reject a "labor-saving" process is usually in the hands of a poor, but cultivating, beneficiary. Also, the warnings are not advice to prevent <u>efficient</u>

labor-displacing innovations that raise food availability. The advice, rather, is to avoid using aid-funded research to ease the path, in land-scarce countries, towards innovations that unemploy the rural poor.

* * *

Given the post-MV pattern of extra operational labor requirements, "natural" responses by farmers, and researched inputs that may also save labor, how have MVs affected the seasonal pattern of labor use? First, one should underline the major role of short-duration varieties in permitting double-cropping, which both increases and stabilizes year-round labor requirements. There may, however, be a ratchet effect. Equipment, which becomes a paying proposition to overcome labor-constraints during the period when late operations on one crop overlap with ploughing for the next season, can then be cheaply used to displace labor at other times of year. This may explain much of the apparent fall in the gains to labor from MVs [Jayasuriya et al., 1981] and the tendency, in the Western U.P. wheat-rice system, for the fall in labor-inputs due to mechanization to pull ahead of the rise due to MVs [Joshi et al., 1981]. The research implication is to increase emphasis on short-duration (compared to full-duration) second-season crops, even at some cost in yield, in conditions where only these varieties will allow the economic continuation of labor-intensive harvesting, threshing and/or ploughing methods between crops.

Generally, however, MVs reduce fluctuations affecting seasonal labor, e.g. in real wage-rates in the Punjab [Dasgupta, 1977, p.336], employment in the Philippines [Barlow et al., 1983, p.42], and earnings in Kanpur district, Uttar Pradesh [Singh and Kanwar, 1974, pp.66, 84-5]. In Bangladesh, the growing importance of MV boro rice and wheat plainly reduces seasonality of labor use. This is the general pattern, with MV sorghum, mainly a kharif crop, an exception [Rao, 1982].

* * *

What do MVs do to year-to-year fluctuations in poverty among laborers? We have seen that MVs probably raise the coefficient of variation of national-level output of "their" crops, but nevertheless normally raise absolute output levels for most adopting villages even in a bad year. In such a year, therefore, farm employment is normally raised by MVs, even if by less than in a good year, unless associated labor-saving changes bite hardest in bad years. This is unlikely, since the main such changes are in harvesting and threshing, activities which are less important in bad years, when they are heavily reduced irrespective of technology. Well before farm employers realise that the year will be bad climatically, they have taken on hired workers for most operations, so that the associated income for the poor has mostly been generated -- in activities such as planting and water management, which are less affected by possible labor-saving pressures in the wake of MVs than are the post-harvest operations. The post-MV shift towards longer-term contract workers, moreover, may somewhat reduce employers' scope for laying off harvest and post-harvest workers in bad years.

An interesting analysis from semi-arid South India [Walker et al., 1983, p.21] suggests that direct year-to-year stabilization of MV output would be an inefficient way to reduce poverty, especially among laborers. Perfect stabilization of crop labor income, generated by crop output, over the five crop years analyzed, would have reduced the average landless household's variability of total income by only 0%, 5% and 5% in the three villages, as compared to 34%, 20% and 55% respectively for perfect stabilization of labor income. However, stabilization of income from crops -- and thus of local spending by farmers -- would have indirectly stabilized labor income. It is thus doubtful whether [ibid., p.36] "emphasizing crop income stability for small farmers [and landless] in India is a misguided means to an end".

4.4 MVs and the laboring poor: mechanization vs. migration

There is very little doubt that most mechanization -- not only four-wheel tractors [Binswanger, 1978], two-wheelers [Jayasuriya et al., 1982] and threshers, but also the shift to more mechanized irrigation technologies [Joshi et al., 1981] -- is on balance labor-displacing. Animal care, and hoeing or animal ploughing, use much more hours per acre than tractor care and tractor-ploughing respectively [Farrington and Abeyratne, 1982]. In some cases, these labor-displacing effects of the shift to tractors are offset because the reduced herd size permits former fodder land to be sown to MVs, which would raise labor use per acre; however, in Asia most beasts are now stall-fed, or grazed on stubble, roadsides, etc. Claims that tractors and threshers allow higher cropping intensity usually collapse when the inputs of MVs, fertilizers, and water are controlled for [Jayasuriya et al., 1982; Agarwal, 1984, 1984b]. Indeed, the labor-displacing effect of tractors may be more in double-cropped than in single-cropped systems because replacement of animals is more complete [Cordova et al., 1981]. Where mechanization pays in land-scarce economies, the reason is usually that it is cheaper than labor (even at a subsistence wage), not because it raises output [Binswanger, 1978]. Most analysts concur, however, that "labor-saving effects of mechanization have been more than neutralized by the labor-increasing effects" of MVs [Dasgupta, 1977, pp.323-4].

However, there is major controversy over whether MVs and associated factors have caused not only this effect, but also the "very high and significant correlation between tractor use" and MV adoption [ibid., pp.96-7]. Some analysts explicitly assert that "there is no sign that tractor adoption was accelerated by the dramatic diffusion of MVs" [Hayami, 1984, pp. 393-4 (cf.1981,p.174; Kikuchi and Hayami, 1980]. Others speak of MVs as embedded in "essentially a 'package' of technical improvements including...tractors" [Gibbons et al., n.d.], or claim that the MV inducement to double-cropping intensifies the pressure to mechanize [Byres, 1981]. A balanced account [Barker and Herdt, 1984, pp.85-7] reveals the environmental specificity of the tractor-MV relationship -- strong in the Philippines and Malaysia, modest in India, Indonesia and Thailand, and with tractors arriving first in Pakistan.

How might MVs be linked to labor-displacing machines? Does IARC research help to forge that link, or to weaken it?

A very low-yielding farm cannot afford to tractorize. The hourly costs of tractors in many parts of Africa would exceed value-added on the land that is ploughed in an hour. Even at higher yields, fuel and hire costs at normal rates can exceed the saving of ploughing labor. By raising yields, MVs render tractorization and threshers feasible.

But why should they make them profitable? The main reason advanced is double cropping, first because it enables the machines to be used for twice as long each year, and second because they can permit timely sowing of the second crop. A subsidiary reason is that machines, hired profitably for the peak between monsoon and second crop introduced by MVs, are then available cheaply in other seasons and undercut labor there also. However, such reasoning is often buttressed by subsidies to labor-replacing equipment [Binswanger, 1978; David, 1982; Gill, 1981; Farrington and Abeyratne, 1982; Jayasuriya and Shand, 1985] and by direct IARC work, e.g. at IRRI to develop and test mechanical threshers and reapers. The reaper was judged to be "a highly profitable investment", reducing harvesting labor by some 80 per cent [ibid., citing Moran, 1982].

The supporters of the IARC system need to ask what, exactly, is the role of such research in it. Answers will not be the same everywhere. Sometimes, tractors introduced alongside MVs probably clear new land, which would otherwise have stood idle and employed nobody (cf. hybrid maize in Zimbabwe and Zambia). Sometimes -- probably far less often than claimed [Farrington and Abeyratne, 1982] -- tractors or threshers can "make time" to improve water management, which is highly complementary with MV use and with double-cropping. At ICRISAT [Mueller and von Oppen, 1985] apparently justified caution to avoid labor displacement has created seasonal labor bottlenecks impeding new farm systems that would otherwise have boosted year-round employment. Sometimes "effort-saving" innovations might reduce drudgery or human energy-costs without reducing employee time much. And sometimes fairly egalitarian access to land rights is sufficiently safe that farmers, if they hire or buy labor-displacing machinery, reveal a preference for rest over income without destroying employee livelihoods.

Such things are possible, but rare -- increasingly so in view of current advances in population, individualization of land tenure, and "Northern" cost-saving research on machinery. It is surely almost certain that, for example, the IRRI threshers, reapers, and "IRRI-PAK mechanization programs" harm poor workers, though far less than IRRI's new varieties have helped them. Just as IARCs now breed and time MVs to "avoid" periods of disease or moisture stress, so they may need to breed and time MVs, and (as at ICRISAT and IITA) farming systems, to avoid creating incentives for labor-displacing mechanization.

* * *

A major alternative to mechanization for easing seasonal labor peaks is seasonal migration, especially in big or diverse countries. Usually workers readily return to their homes after the peak, often to handle different peaks there. On the other hand machinery, even if acquired mainly to ease genuine shortages of peak labor and thus to permit double-cropping with MVs, stays on hand in slack seasons to displace grossly underemployed labor at very low marginal cost. How has migrant labor responded to MV options? Can policy increase the likelihood that farm employers will meet seasonal labor shortages by recruiting migrants, rather than by installing labor-displacing machinery?

There is much evidence of seasonal migration to MV areas [Dasgupta, 1977, p.326], often given by commentators who fear that outsiders in these jobs are easier for employers to manipulate [van

Schendel, 1981]. In fact such migration is a powerful way to spread MV benefits to the neglected regions. This is not only because their workers obtain extra income away from home. Also, MVs in advanced regions strengthen workers in backward regions unaffected by the MVs, by reducing labor supply there when migrants from backward regions move to MV areas instead of to other backward regions with different seasonal peaks [ibid., pp.230, 142-3].

In assessing MVs' capacity to generate migrant incomes for poor workers, we must recall that it is unequal, progressive, and food-surplus villages, whether in MV areas or not, that tend to produce two sorts of migrant: the moderately well-off, moving to known urban work or education; and the poor, usually searching for seasonal farmwork [Connell et al., 1976]. A study in a Punjabi village suggests that MV-based development increases emigration for the first group, but reduces it for the second [Leaf, 1983, p.268]. The Punjab's MVs have attracted many seasonal immigrants from remote, poor areas of Bihar and Eastern U.P., although not enough to prevent a considerable rise in seasonal peak real wage rates in the early 1970s, which may have accelerated labor-displacing mechanization later. Mechanization in the wake of MVs, indeed, can induce net emigration by the poor. In the lead district of the Punjab, Ludhiana, emigration has exceeded immigration plus return migration, and the proportion of net emigrants comprising scheduled and low-caste people has gradually increased [Oberai and Singh, 1980].

Should not IARCs know more about the impact of alternative crops, varieties, linked inputs and farm systems on such migration, and about its impact, in turn, on wage rates, incentives to mechanize, and subsequent employment and labor-income? If there is no effective land seasonal peak real wage rates in the early 1970s, which may have accelerated labor-displacing mechanization later. Mechanization in the wake of MVs, indeed, can induce net emigration by the poor. In the lead district of the Punjab, Ludhiana, emigration has exceeded immigration plus return migration, and the proportion of net emigrants comprising scheduled and low-caste people has gradually increased [Oberai and Singh, 1980].reform, an MV system may spread income lastingly to labor only if it generates sufficiently long, spread-out peaks to attract enough immigration to prevent a large rise in real wage-rates seasonally, and thus to maintain the incentive to employ. Paradoxically, in view of hostilities between immigrant and local laborers, the latter can probably gain longer-run employment in threshing and ploughing seasons from MVs only if the former come in sufficient numbers to moderate real wage-push then.

* * *

Year-round, MVs raise labor demand, employment and real wage-bills. However, the real wage-rate shows little long-term uptrend, and the wage share in farm income falls, because there is plentiful labor but scarce land. Therefore, rent/wage ratios rise. So does the part of farm income that goes to fertilizer producers.

Seasonal peaking of extra MV labor requirements, especially the peak from main-crop harvest through second-crop weeding time, can have two effects. It can pull in seasonal migrants, sharing the benefits, and moderating even peak-season real-wage increases. Or it can first pull up local wage rates in the peak season, but thereby stimulate the hire or purchase of tractors, threshers, mills, and transplanters. These machines not only flatten the seasonal labor peak. Less happily, they are also available to displace very poor slack-season workers, at low marginal cost to employers.

The year-round rise in income that MVs bring to poor rural employees, some of them migrants from backward areas, is partly to the IARCs' credit, although the rise has been hidden by other factors, such as population growth and cost-cutting "Northern" research on labor-displacing equipment and inputs. Unfortunately, several IARCs have lost some of that credit and may have set back labor income. Directly, they have sometimes pursued research policies, especially in agricultural engineering, that encourage the labor-displacing rather than the migrant-employing response to <u>seasonal</u> MV labor peaks. Indirectly, the IARCs have not sufficiently researched the crop options that might make it more attractive, even in peaks, for farmers to employ rather than to mechanize.

Finally, three points need emphasis. First, despite MVs' possible link with <u>ultimately</u> labor-displacing inputs in some places and times, MVs help labor by <u>initially</u> raising demand for it (hence the link!), and by making food cheaper.

Second, although 70% of Asians and 80% of Africans live mainly from agriculture, labor displacement is a "problem" only because land rights are unequal, so that many agriculturists must get most of their living as employees of others. If a big farm, or a collective of owners, displaces assetless workers with machines or weedicides to break a seasonal bottleneck, then <u>the poorest compulsorily lose their income source</u> and must look, in hope, for others. If family farms or co-operatives (embracing all village cultivators, so that none must live mainly off hired farmwork) decide to hire a tractor or buy weedicide, they <u>voluntarily take their own welfare as leisure instead of labor income</u>.

Third, we have discussed only the effects on farm labour of MVs. The greater the prospects of off-farm employment, the less important are such effects. Even in traditional villages, about a quarter of working time and about a third of income are non-agricultural [Chuta and Liedholm, 1979]. Yet there is almost no research into the effect on such working time and income of MVs or of farmers' reactions to them.

Labor displacement is a problem to the extent that there are population pressures, undiversified farm employment, and unequal land (no land reform). Into these three realities the IARC's research, and the MVs, must fit. Such fitting is a matter partly of tailoring MV research, releases, and systems to help laborers and small farmers within those realities. Partly, however, it is a matter and partly a matter of researching how _different_ land distributions, work diversifications [Bell _et al_., 1982; Hazell and Roell, 1983], and person/land ratios could interact with the pay-offs from MVs to the laboring poor. Ultimately, this may involve IARCs in some difficult tasks of "speaking truth to power" about land and population policies. However, at present IARCs and other researchers know little about how

MVs affect the prospects for rural population growth or for policy towards the distribution of land.

CHAPTER 5 POOR PEOPLE'S CONSUMPTION AND NUTRITION: IMPACT OF MVs

5.1 More food, lower prices - or fewer imports?

It is poor people who are most seriously at risk from hunger. Also, the poorest one-third of people in Asia and Africa use 60-80% of income to obtain food. Thus the MVs' main potential advantage to the poor is that they grow more food, and thus moderate its price.

This is even more important to the poor because in developing countries, several factors are driving up food prices, both absolutely and relatively to other prices and to income. First, population growth, at 2½-3½% yearly, raises demand for food and thus its price. Second, so does growth of income per person, especially among the better-off. Third, this also diverts land towards "richer people's foods", especially meat and dairy products, which need five to seven times as much land per person as cereals. Hence the average cost of dietary calories comes to include more land, and therefore their price is pushed up.

Fourth, population pressure renders land scarcer, and costlier to bring into production. In much of South and East Asia, and in increasingly many parts of Africa, there is hardly any "plausibly cultivable" land left unfarmed. Rising costs of marginal land help drive food prices up.

Could LDCs rely on imports rather than MVs to keep consumer prices tolerable? Alas, the famous food surpluses of Europe and North America are of limited use to poor LDC consumers. The surpluses have always been unreliable, and are increasingly used for feed in producer countries. Worst of all, they dwindle in times of greatest need such as 1972-3. Often LDCs, facing foreign-exchange crisis, cannot afford commercial food imports, yet find that long-term dependence on food-aid imports undermines domestic incentives, probably to farmers, certainly to agricultural policymakers.

Since 1973, a fifth factor has driven up food prices in LDCs, and has made food and fertilizer imports especially costly. Each barrel of oil in 1985 costs LDC oil importers five times as much of their typical export products as in 1972. The costs of both transport and nitrogenous fertilizer include large components of fossil fuels. The price explosion of such fuels, therefore, greatly raises the cost to LDCs both of shipping foodgrains from the West, and of fertilizing them at home.

How much have MVs done to moderate this massive "price threat" to the nutritionally vulnerable poor? This depends on (a) what MVs have contributed to output in LDCs, (b) whether that extra output has raised food availability to consumers (as opposed, say, to reducing imports), and (c) the effect of the extra food availability, if any, on prices.

(a) The contribution of MVs alone to annual outputs of rice in developing countries in the early 1980s has been estimated at 10-27 million metric tons, and of wheat at 7-20m. [Pinstrup-Andersen and Hazell, 1984]. Sorghum, millet and hybrid maize must add at least another 3-5 million metric tons. Extra output due to extra fertilizers and other inputs induced by MVs probably raises these figures by at least 50%.

(b) Yet in India, despite extra output due to MVs estimated at 5-7 million metric tons of grain in 1970-1 [Rao, 1975, pp.6-9], and surely over 12m. tons today, food availability has barely outpaced population growth. This is because almost all the extra MVs have been used to replace imports or to build up stocks, leaving poor people's consumption and nutrition almost unchanged.

(c) Some economies have operated trade policies "fixing" net food imports. There, the effect of "extra MV output" on domestic food prices and hence on consumption, overall and for the poor, can be isolated. In Colombia, households with below $600 in 1970 appear to have gained 12.8% of income, because rice MVs grown in Colombia restrained food prices [Scobie and Posada, 1978], while better-off households gained proportionately much less. Assuming little effect on net imports, the new IRRI varieties are claimed to have enriched South and East Asian consumers by about $160 million in each year in 1972-5, plus a further $400m. yearly from new national rice varieties [Evenson and Flores, 1978]. Assumptions about just how open the economy is, and how much trade would have occured <u>without</u> MVs, are crucial in calculating such numbers [Munchik de Rubinstein, 1984, p.20].

Of course, producers initially lose some part of what consumers gain from these price effects. That part is estimated in the above studies at 50-60%. However, this loss is offset by the various factors increasing the demand for food, and by producers' ability to switch into other crops if prices of MV crops fall "too fast" relative to production costs. <u>Poor</u> producers may also "internalize" many of the consumption gains by eating more of their own produce as MVs boost it, thereby reducing extra marketed supplies and shifting some benefits from pure consumers to poor growers [Hayami and Herdt, 1977]. Benefits to poor urban consumers as well as rural semi-subsistence producer-consumers are even greater when the MV affects "inferior goods" like cassava meal in Brazil [Lynam and Pachico, 1982]. In the Philippines, a 7-8% real rice price fall would now allow the lowest income group to escape under-nutrition [Gonzales and Regaldo, 1983]; since a 30% real fall was achieved in 1975-80, this seems feasible. Unfortunately, there are limits to this story of major consumer gains via the "price effect" of MVs.

First, to the extent that income growth favours the better-off, the extra MV output is likely to displace food imports, rather than to cut domestic food prices. The poor lack the purchasing power to add greatly to their existing food purchases. Extra MV output, however, has contributed to lower real prices at <u>world</u> level [Flinn and Unnevehr, 1984] with benefits to domestic price restraint in the major rice importers, viz in Indonesia, the Philippines and India [Siamwalla and Haykin, 1983].

Second, if food prices to employees come down, employers can respond by cutting money wages, leaving real wages (and therefore food consumption) almost unimproved. This is especially likely where LDCs, partly because their populations are growing rapidly, face increasing unemployment among unskilled (poor) laborers already. In this case the benefits of cheaper MVs may be passed on from producers not to poor consumers, but via them to employers. None of the above estimates of "poor people's gains from MV price effects" allows for this crucial possibility.

Third, although "small farmers" in MV areas may at last be sharing significantly in MV gains, very poor farmers and laborers elsewhere have in many cases lost consumption power from MV expansion (Ch.3, sec.9). Such losses are perhaps not so important in middle-income countries, for example in Colombia, where there are many more poor urban consumers, who gain when food prices fall, than poor upland rice farmers, who seldom get MVs yet suffer from the price decline as other farmers sell MV outputs [Scobie and Posada, 1978]. However, in low-income countries such as India, such lost consumption power by poor cereal growers and their employees in non-MV areas looms much larger, and there are relatively fewer urban poor to enjoy offsetting gains. Millions of not very mobile rural poor in Rajasthan and Madhya Pradesh are selling small wheat surpluses (often to buy cheaper cereals) at prices "undermined" by the burgeoning MV wheat surpluses of the Punjab. IARCs should help to fill the vacuum in empirical research on MVs' impact on poor people in non-MV rural areas.

Fourth, MV research strategy has unduly concentrated on protein and on food "quality" (Ch.5, sec.6). This has eroded the great advantage of MVs to the poor consumer: the provision of his or her greatest need, cheaper calories.

5.2 The nutritional background

The development of MVs has nevertheless been the main means of moderating food prices, generally with net gains to adopting producers, and thus of enabling poor people in LDCs to improve their incomes, consumption and nutrition. In that context improved nutrition is not only a desirable byproduct of MV research; it should be the central objective.

How to reach this objective must depend on who is vulnerable to undernutrition, where, when, by how much, and with what trends. If MVs can reduce the vulnerability of these families, what routes (a) would be most cost-effective if achieved, (b) will not increase the vulnerability of others, (c) puts scarce research resources into strategies whose achievement is likely? The "price effects" show that MVs have helped the nutrition of the poor. But this is despite most nutritional MV research, which would have been better allocated to alternative approaches.

Recent research has clearly identified the main problems of those who suffer or die from nutritional problems. The major nutritional deficit is energy. The major vulnerable group is the very poor, especially under-fives and pregnant and lactating women. They eat mainly coarse grains, root crops and cheap varieties of wheat or rice. Vulnerability is most acute in specific seasons, and in bad years [Schofield, 1974; Chambers, Longhurst and Pacey, 1981; Longhurst and Payne, 1979; Lipton, 1983].

The "ultra-poor" at nutritional risk, among whom persons aged under five are heavily over-represented, comprise six groups: the landless in irrigated areas of Asia; the landless and very small farmers in unirrigated Asia; small farmers and increasingly the landless in Africa; and the urban poorest.

These facts suggest MV research targets in terms of production, consumption, regional and commodity mix, and varietal priorities. The choice of targets can either improve or worsen the massive impact of MVs discussed in Sec. 5.1, in restraining food prices for poor consumers. MV nutrition research has over-concentrated on protein quality, consumer acceptability (palatability and cooking characteristics), and storage.

Such research would have been better directed to other topics, and indeed may have raised the costs of energy intake for the poor. MV impact on poor consumers has been immeasurably improved, not by such things as high-protein maize, but by producing more (and more stable) dietary energy.

5.3 Commodity choice and production strategies

The large increases in rice and wheat production have prevented major deterioration in consumption for the poor in Asia. Yet in most of Africa and parts of Asia and Latin America wheat and rice remain the foods of rich consumers, and are less readily expanded into the marginal soil and water environments of poor growers than are sorghum and millet [Jodha and Singh, 1982]. The poor in Kenya, Zimbabwe and Latin America have benefited from the advances in maize production. Despite major growth of sorghum and finger millet MVs in India [Rajpurohit, 1983], much slower progress has been made in farmers' fields with these crops in Africa, with millets and root crops in most LDCs, and since the early 1970s with maize. Hence poor consumers have gained little in rainfed (or "rainparched") countries of Asia and Africa.

One effect of the progress in wheat has been a replacement of pulse acreage [Ryan and Asokan, 1977], although this did build upon an earlier trend [Grewal and Bhullar, 1982]. This switch has been deplored by some, but must be analysed in the framework suggested in Chapter 5, Section 2. Land will yield more and cheaper dietary energy in wheat than in pulses, with little protein loss. Often even the protein yield of MV cereals per hectare exceeds that of grain legumes. Since 90-95% of undernourished people lack energy, but do not lack protein -- or do so only because energy shortage compels them to divert protein foods to energy uses -- the switch means a clear gain in nutrition. However if "nutrition research" raises the aesthetic qualities of MV wheats (currently 10-15% cheaper than traditional wheats) they will probably cease to be cheap energy sources for the poor.

None of the IARCs is able to provide precise information on how its yield-increasing programs affect human nutrition [Ryan, 1984]. Inferences have to be drawn from data on MV adoption and resulting extra production, combined with estimates of demand parameters. Urban and landless rural consumers have clearly gained nutritionally on balance, as MVs have restrained the price of food, due mainly to increases in yields of rice and wheat in irrigated areas of Asia. Small growers and their employees have lost from these price restraints, but have been compensated by higher self-consumption and lower unit costs. In unirrigated Asia, poor producers may be eating worse due to MVs; their production has benefited less from MVs, while they face lower prices for their output with large increases in supply from adjacent irrigated areas. In semi-arid areas of Africa, the shift from millets and sorghum to improved hybrid maize has raised average energy production and consumption, but also its year-to-year riskiness.

Wheat consumption by the rural poor has increased in India following the introduction of MVs, but partly at the cost of other foods; National Sample Survey and National Institute of Nutrition work shows no net gain [George, 1980]. Indian urban consumers have also benefited; wheat prices have risen less than other cereal prices.

High-yielding, mosaic-resistant IITA cassava varieties, as and when they get into farmers' fields on a large scale, must improve self-consumption among the rural poor in Africa. However, weanling children dependent on cassava do have special protein needs which require research. For Brazil, a CIAT study indicates that the calorie consumption of the poorest 25% of the population could be increased by 45 calories per day by improved cassava production technology. In the rural Northeast of Brazil 20% of the calorie shortfall in the diets of the poorest 25% would be alleviated [Pachico, 1984; Lynam and Pachico, 1982].

Apart from a Colombian urban study [Pinstrup-Andersen, 1977], the work on maize and rice MV nutrition impacts remains hypothetical. In that study, price responses of pre-MV consumption bundles are used to infer what "must have happened" when MVs changed prices. For rice overall, IRRI concludes that MVs must have increased consumption more among malnourished households, because of their higher income and price elasticities of demand for rice [Flinn and Unnevehr, 1984].

Potato is sometimes consumed as a low-cost staple. A recent study from CIP [van der Zaag and Horton, 1983] shows that consumers are highly responsive to potato prices and that consumption levels are correlated with income levels. Breeding MV potatoes for high quality rather than for calories, therefore, will harm the poorest if they are found mainly among potato eaters, but help them if they are found mainly among potato growers or their employees.

Research on legumes -- chickpea at ICRISAT, and lentils, chickpeas and faba beans at ICARDA -- is often cited as favorable to the nutrition of the poor. But this depends on their spending patterns and on the type of their nutritional deficiency. In the usual case where deficiencies are not primarily protein -- and even where they are, but legumes are not a cheap protein source -- legume MVs can do little for nutrition unless (a) undernourished growers sell them to better-off buyers and (b) demand is price-elastic. Protein per unit of land or labor input may in any case be higher with cereals. In India, replacement of pulse area by MV wheat taken in isolation led to more and cheaper protein as well as calories for the poor. This was so even between 1961-5 and 1971-3, when changes in the crop-mix were offset by other factors so that poor people's total calorie intake per person stagnated [Namboodiri and Choksi, 1977, p.33]. Legumes can make diets more diverse or less vulnerable to drought, and can assist vulnerable groups, such as weanling children and their mothers, but the nutritional role is quite limited. It appears to be necessary that ICARDA identify nutritional target groups, whose nutritional needs can be shown to be most cost-effectively helped by its research activities [Somel, 1984].

5.4 Variability

Surprisingly, MVs have somewhat increased the year-to-year variability of cereal production, though this does not mean that in "bad" years particular small producing areas, and thus the people who live there, obtain lower output or consumption than would have occurred without MVs (Chapter 3, Section 8). But even slight extra production variability substantially increases the riskiness of consumption by vulnerable groups in towns and in non-MV areas [Murty, 1983]. Since small growers try to meet family food needs first, they cut sales in bad years more than in proportion to output. Therefore, yearly cereal price instability increases more than in proportion to the increase in yearly output fluctuations in the wake of MVs, leaving the poor even more vulnerable.

Extra imports or stock releases can modify or remove these price risks to consumers. But LDC governments often cannot afford the imports. Stocks carry high costs, too. The 20 million tons of grain typically stocked by the Indian Government, through the Food Corporation, tie up, as working capital alone, almost three months' worth of India's net investment. Moreover, central stocks and international trade seldom deal much in root crops or coarse grains for human food. These are sold in remote areas, where markets are "thin", i.e. release a small proportion of normal output most of which is consumed by growers. In such cases, as with sorghum in India (which absorbs 10% of consumer budgets, much more for nutritionally vulnerable poor groups [ibid.]), moderate rises in variability of these "coarse" outputs, due to concentration of MVs in a few covariant areas, can greatly increase risks to undernourished groups, because slightly below-average harvests mean much smaller marketings, and hence very expensive food for consumers [Walker, 1984]. The African shifts from millet to annually vulnerable maize MVs often occur in countries with only one peak per year of seasonal output and thus are even more serious.

Although MVs may have worsened, or raised the cost of avoiding, year-to-year instability of output -- and therefore of prices, and of consumption by vulnerable groups -- they have reduced seasonal instability. MVs raise output more in the subsidiary season, owing to controlled irrigation, than in the less certain conditions of the main rainy season, when most grain is produced. However, the costs to poor consumers of yearly price instability, induced by MVs especially in coarse grain, suggests somewhat higher priority for stabilizing MVs' output and/or spreading them to climatically more diverse environments. In Africa, appropriate drought-resistant millet/sorghum MVs are an urgent need, to compete with the high-yielding but drought-prone and consumption-destabilizing maize MVs.

5.5 Vulnerable groups

Much of this report has discussed the impact of MVs on the poor. Within "the poor", however, those at greatest risk of lasting damage from undernutrition are pregnant and lactating women and pre-school children. Their particular vulnerability can be ascribed partly to special physiological need. However, it is still legitimate to ask what MVs can do for them.

They are heavily over-represented among the poor [Lipton, 1983a] because of very high birth-rates and infant and child mortality rates in the two lowest deciles of households by income per person. Traditional nutritional interventions for these groups have therefore tended to assume that at-risk pregnant and lactating women and under-fives benefit more or less automatically if poor families can grow or buy more or better food. This approach, however, overlooks the fact that the proportion of extra income and food, allocated by a household to women and children, depends on their status, prospects, and power, all seen in the specific socio-economic context, which interacts with their physiology to cause nutritional problems. For instance, small girls in poor households are clearly worse fed than small boys in North India and Bangladesh, but not elsewhere. This is probably because in these areas cropping patterns, religious traditions, and socio-economic structures all tend to depress female earnings, and hence to make little girls, tragically, less valuable than little boys to the future survival prospects of the family as a whole [Lipton, 1983]. An appropriate nutrition intervention from the side of MVs, in such a context, might best concentrate on raising not only food output but also demand for farm activities likely to generate extra income for women. Major innovations in food and work patterns, such as MVs, need to be selected with an eye to their likely effect on vulnerable groups in their actual socio-economic contexts.

Some of the nutritional problems of small children and their mothers are due mainly to economic pressure on the family as a unit. If this is relieved, so will be part of their difficulties. Therefore, their nutrition is influenced by the "consumer effects" discussed in the earlier section of this chapter. Where MVs have been adopted, more and seasonally stabler calories and cash will reach adopting farmers and their employees. This improves household food security and annual returns to total household effort, and permits households to reduce the work and time pressures on women. However, a search for MV strategies with more direct benefits for women may be desirable (a) in those limited areas, especially North India and Bangladesh, where their nutritional status is clearly inferior to men's [Schofield, 1979; Lipton, 1983], (b) more generally, where women's overall status is such that, nutritionally or otherwise, MVs are otherwise likely to bring them few economic gains due to male dominance and (c) where women, even if adequately fed themselves, require more food or less hard work if they are to feed and look after children adequately.

In few locations have MVs been women's crops, such that they control the output or income. MVs have spread very little in Africa, where most female producers are located -- even to such crops as rice in the Gambia. Although raising level of women's incomes is potentially the most direct means of improving child nutrition, with MVs the shift to cash crops may have raised men's share in household income [Ahmed, 1983] and the shifts to hired labor and to shorter-duration crops may have intensified the seasonal labor demands on women's dietary energy. Both factors would reduce the amount of time and "calories to spare" that women have for their children. Recent evidence suggests that the time allocated to children by their mothers is an important determinant of nutritional status [Tripp, 1981; Popkin, 1978; Wolfe and Behrmann, 1982]. Where women grow MV crops there is a possibility that child nutrition will be improved "by the back door", i.e. without being filtered through the family unit, which should be balanced against the negative impact that mothers will provide them with less care.

This is important because extra nutrients are often maldistributed within households [Carloni, 1981; Longhurst, 1984]. Pregnant and lactating women earning outside the house may fare worse, and feed children worse [Schofield, 1979; S.Kumar, 1977; Lipton, 1983]. Although it is probable that more MV output does usually help child nutrition, we know very little about how MVs contribute to their special nutritional needs: high energy and nutrient density, more frequent ingestion, enhanced nutrient absorbability, nutrient complementarity, nutritional availability in terms of ease of preparation, and favourable interactions with infection.

Despite some welcome recent shifts in a few institutions, IARC research has not been planned explicitly enough to discover how MV outputs or work inputs affect the nutrition of these vulnerable groups, whether directly, through changes in casual sequences such as the relative power of women in households, or through changes in the ecology of nutrition and infection. Even recent, innovative research has generally been confined to the <u>proximate</u> problem of "getting more food to infants and women", rather than enquiring how MV options might actually reach vulnerable groups in the prevailing family and social structures. More worryingly, most "nutrition research" at IARCs has concentrated on issues such as protein quality, which are quite unrelated to this.

We do not pretend here to answer questions about how MVs might best help vulnerable groups. We merely raise the questions, which should perhaps have been raised in the IARCs before they began nutritional research. In the total food-work-infection context, what is the impact of different varieties of a main staple on a pregnant woman and the foetus she is bearing? Do different crops, (e.g. cassava vs. millet) make any significant difference? What is the differential impact on the volume, absorbability and quality of her breast milk? Can the nutrition of sucklings be influenced in this manner? Rather more is being done in some IARCs on the energy density, fibre content, and absorbability of staples used as weaning food. Is such research avoiding the pitfalls of costly efforts to breed or screen for nutrient quality? Similar questions need to be asked about varietal differences in the context of bulk, absorbability, and quality of weanlings' total intake.

Do crop or varietal nutrients, and work inputs, interact, for vulnerable groups, with the type and timing of infection and the building of mechanisms of immunity? Varietal and crop-mix priorities, including the seasonal timing of food flows, may not make much difference, but they should be further investigated.

There are differences among crops and varieties in energy density, fibre content and antinutritive factors. Are they significant, and are costs of improvement justified by benefits in terms of the impact on target groups? Conversely, could some MVs increase the work required of women, perhaps at times when they are already hard pressed to muster enough dietary energy for child care? Is research important that reduces preparation time and firewood costs or increases energy density of food eaten by vulnerable groups? Might research that improves palatability raise the attractiveness of the commodity to non-poor buyers, and hence the price of calories to the poor?

5.6 Nutrient quality and palatability

Most research on how MVs affect consumption and nutrition, by IARCs and others, has sought to "improve" nutrient quality and palatability. This is the inappropriate menu of conventional MV nutrition research. Of this, the improvement of maize amino acids, via the opaque-2 genes, has taken most resources. Yet extra dietary energy, not extra amounts of protein or of a specific amino acid, is the overriding need for almost all vulnerable humans. They do not live on maize alone, and get their balanced amino acids by supplementing it with beans and other foods. (Storage pests do live almost entirely from the grain stored; a balanced-protein MV, with all amino-acids well represented, does wonders for storage pests [Sriramulu, 1973; Rahman, 1984; Podoler and Appelbaum, 1971].) There is an enormous scientific literature on protein improvement, however, and attempts to justify it continue to the present day, albeit with some defensiveness [Valverde et al., 1983].

CIMMYT believes that appropriate varieties of high-lysine opaque-2 maize give yields equal to ordinary MVs, store and cook as well, are available in acceptable non-floury form, and improve the nutritional status of children under two years of age [Ryan, 1984; Tripp, 1984]. But these claimed properties, and the last is highly questionable, were made possible at the huge cost of diverting land and researchers from yield improvement and stability towards amino-acid enrichment. That cost included calories and even proteins foregone. Many poor children are calorie-deficient, while few are protein-deficient. Of those few, most would have enough protein if they were not forced to burn it up for want of calories. Only where root crops and bananas are main staples, with very few pulses added, is protein research likely to do much for human nutrition.

Protein quality analysis and breeding have been carried out to a lesser extent with barley at CIMMYT (now abandoned), for sulphur-containing amino acids in potatoes at CIP (Peru) [Valle-Riestra, 1984], chickpeas at ICARDA, cassava and beans at CIAT, coarse grains and pulses at ICRISAT and rice at IRRI. These emphases have dwindled due to direct trade-offs between protein content, yields and stability. ICRISAT has found that the major dietary deficiencies in their sampled villages were energy, calcium, and vitamins A, B-complex and C, not proteins and amino acids [Ryan, 1984]; yet the world's leading sorghum breeder advocates research to improve absorbability of sorghum protein [Doggett, in ICRISAT, 1982].

* * *

Research continues on consumer acceptance - palatability and cooking characteristics. This has been summarised as follows [Ryan, 1984]: (a) improvement of potatoes at CIP, viz. selecting for increased specific gravity to improve transportability, shape, colour, size, eye depth, culinary and processing characteristics; (b) improvement of chickpeas at ICARDA with respect to taste and cooking time; (c) improvement of cassava at CIAT with respect to storage characteristics; (d) improvement of beans at CIAT for seed size, colour, thickness and cooking time; and evaluation of rice breeding materials at IRRI for milling percentage, grain size, shape and appearance.

IITA has concluded that in view of the low elasticity of demand for roots and tubers, processing improvements must accompany production increases if consumption levels are to be maintained as incomes rise [Okigbo and Ay, 1984]. ICRISAT continues to advocate its vigorous consumer preference studies program [Doggett, 1982] and most IARCs have paid attention in their breeding programs to screening out anti-nutritional factors such as tannins and trypsin-inhibitors.

* * *

Overall, the allocation of scarce research funding to these activities must be viewed in the context of what causes malnutrition and how far they lift constraints on its improvement. If poor people sell a crop to rich people, it makes sense to improve its market value rather than its caloric value, since poor consumers get more command over calories that way. But most MVs are _either_ grown and eaten by the poor _or_ sold to the poor by farmers at little nutritional risk themselves. In these much more usual circumstances, a great advantage of most MVs to the poor consumer is their 10-15% price discount. Breeding for stability and quantity maintains this discount, and does most for poor consumers. Breeding for "quality", palatability and gourmetry harms them, by raising prices. Both this and protein emphases divert scarce IARC resources from their primary functions of providing poor people, especially in hitherto neglected areas, with high-yielding and stable crops that they can grow and/or consume cheaply.

CHAPTER 6 PUTTING TOGETHER THE MV-POVERTY MYSTERY

6.1 Adding up to a problem: holistic solutions?

The problem is: why have MVs, apparently good for the poor, not improved their lot much more? We showed in Chapter 2 that the biological features of MVs were good for the poor as farmers, workers, and consumers, probably increasingly so as IARC and other research responds to their problems of pest and water risk, stability, and input-cost. Chapter 3 showed that in most MV areas "small farmers" (often after a time-lag) adopted no less widely, intensively, or productively than others. Chapter 4 showed that MVs increased labor use per acre-year, and especially hired employment (albeit less so recently than in the late 1960s), raising the real wage-bill, even though real wage-rates rose very slowly if at all, and labor's share in income usually fell due to increased returns to land and fertilizer. Chapter 5 showed that poor people's consumption and nutrition were better and cheaper with MVs than without them.

At each stage there were major qualifications and reservations, both about the findings and about the poverty orientation of some IARC research. "Small farmers" are not the same as "households of poor people", and have not been helped by MVs in non-adopting areas of the Third World, which are very large and often very poor. The impact of MVs in "adopting" areas on small farmers elsewhere has been neglected by researchers. The link between MVs' success in creating work and labor-income through double cropping cannot always be separated from the less happy side effect that such crop intensification may later encourage labor displacement, first at new seasonal peaks but later year-round, via tractors, threshers, weedicides, etc. Research has sometimes supported the wrong way of meeting MV-related peak labor demands -- mechanization rather than migration. There must have been gains to poor consumers from MVs, but the supporting calculations are purely hypothetical. In some major cases (such as India) big MV-induced rises in food output have displaced food imports and raised stocks, but have not increased food availability per person. Most IARC nutrition research has diverted plant-breeding resources away from increasing yield and stability of output of cheap calories, towards issues of proteins, amino-acid balance, and palatability that at best are second-order, often are unreal, and at worst make staple foods dearer.

Despite these serious reservations the balance of advantage to poor people from MVs appears large, taking the effects separately at the level of the individual farmer, worker or consumer. Yet in most of sub-Saharan Africa there are few MVs, and the poor have become poorer [Ghai and Radhwan, 1983]. In South and even some East Asian countries or sub-regions, massive spread of MVs has been consistent both with clear, significant growth of real income per person, and with movements of annual unskilled labor incomes (and of real income per person in the poorest two household deciles) that, while controversial, certainly show no clear uptrend [ADB, 1977, p.63; Griffin and Khan (eds.), 1977; Ahluwalia, 1978; Lipton, 1983]. How is this possible? Part of the answer is that the MVs have had to contend with opposing anti-poor factors, notably rising person/land ratios, and unequal land-systems as land got scarcer [Hayami, 1984; Hayami and Kikuchi, 1981]. But this is not a complete explanation.

I shall suggest three linked answers. They come from different and usually hostile parts of the spectrum of social analysis -- standard general-equilibrium economics, political economy, and comparative history. All three suggest "holistic" methods of analyzing how MVs affect the poor within "whole" social units. All three concur that, because a national or village society or economy is a complete and interacting set of parts, the adding-up approach implicit in almost all the analysis of how MVs affect the poor, including Chapters 3-5 above, is at best seriously incomplete and at worst dangerously wrong. This approach takes the effects separately at the level of the individual farmer, worker or consumer and adds them up algebracally.

The holistic critiques should not be overstated. They do not invalidate most past IARC work. However, they contain enough force to suggest important changes in IARC procedures. These changes would affect both agrotechnical and socio-economic research priorities.

6.2 "General equilibrium" in economics and the MVs

Very few economists in the standard Western tradition have tried to assess total MV-poverty interactions, and these have mostly used the adding-up approach [for outstanding examples see Hayami, 1984; Barker and Herdt, 1984]. Yet uneasiness about that approach is surely called for. Calculations of the gains to consumers from lower MV prices in economies with restricted imports [Scobie and Posada, 1978, 1984], or in large regions with little net grain trade with other areas [Evenson and Flores, 1978], show those gains well above the GNP gains from MVs on most assumptions, implying net losses to producers of MV-affected crops. Since not all these income losses are likely to be to non-MV areas (or to non-poor farmers in MV areas), some losses go to adopting, surplus, but still poor MV growers. How do we "add up" this finding from the consumption studies of MV effects, with the many production studies, claiming that such farmers gain?

* * *

(a) Neo-classical General Equilibrium : There are three sets of mathematical methods called general-equilibrium (GE) in standard "Western economics", which are in principle usable to analyze how MVs affect the poor. The first, originated by Walras [1902], allows us to analyse how changes in demand or supply lead to new sets of price incentives to producers and consumers respectively, and hence to new equilibrium levels of prices, wages and outputs. Such Walrasian GE analysis assumes that land, labor and equipment are fully employed, that all prices are competitively set, and that labor and other non-land current inputs are perfectly mobile in search of higher incomes, while land can shift uses freely but not, of course, location.

These assumptions are used to analyze the equity effects in GE of different forms of technical progress in agriculture, such as the labor-using, land-saving and fertilizer-using MVs, in two notable papers: Binswanger [1980; see especially the assumptions on p.195 and p.210] in the context of distribution between labor, land and capital in one "agricultural" and one "non-agricultural" sector; and Quizon and Binswanger [1983, especially p.526] in the context of distribution within the agricultural sector between labor, land, capital and regions. These models are developed for economies with and without foreign trade; if and only if the Government allows variable levels of foreign trade "and the country or region is [too] small [to affect world] commodity prices, [they] are given from the outside" [Binswanger, 1980, p.195], and are not affected by technical change in agriculture. MVs can still shift wage/rent ratios, but not food prices.

The flavor of the difference between adding up the effects of MVs and Walrasian GE is best given by citation. Adding up "neglects GE effects such as the effect of [MVs] on the demand for output (and hence inputs) of other sectors via price [e.g. MVs bid up demand for fertilizers] and income effects [e.g. richer landowners buy more clothing]. Neglecting GE...is unimportant if a sector or region is very small, but it may become unsatisfactory when we consider very large sectors...In [adding-up approaches] all factors in one sector or one region either gain or all lose, whereas in GE one factor will always lose and another one will always gain" [<u>ibid</u>., pp.195, 210]. That is because only by GE can we allow for feedback effects of factor migration on regions of origination as well as destination.

GE analysis of the effects of MVs is at an early stage. Results change drastically as models are refined. "Most troublesome [is prediction of effects of technical change, etc., on] income distribution [between] landowners and laborers. A complicated interplay across markets for different commodities, land and labor prevent[s] easy generalizations except that in all cases labor-saving technical change adversely affects labor" [Binswanger and Ryan, 1977, p.230]. It would follow, conversely, that "in all cases" technical change raising demand for labor per unit of land, such as MVs, would benefit labor. Binswanger [1980, pp.203-4] confirms this: MVs, as a "labor-[using] technical change, will always [improve] the growth rate of labor incomes and [worsen] the rewards of capitalists and landlords, compared to neutral technical change". In this respect "there is not much difference between partial and GE analysis and between the open and closed economy". Yet once land-labor-capital interactions and the special features of agriculture are allowed for more fully, the result evaporates [Quizon and Binswanger, 1983, p.532]: "When [technical changes that save or use labor] occur at the expense of inelastic land...no definite signs can be proved", so that the effect on real or money wage-rates or shares can go either way. "Intuitively [this is because an innovation that uses more labor per unit of land usually also uses more] capital relative to land, but it [saves] capital relative to labor...the net effects are unclear".

It has indeed been found that labor's share falls in most MV areas. This is inconsistent with the 1977 and 1980 GE predictions, but consistent with the 1983 GE doubts. The non-GE adding-up approach has a simple explanation: with MVs either "neutral" (i.e. cutting by the same proportion the amounts of land and of labor needed to grow a ton of grain) or labor-using and land-saving, there would be "large price rises for [land] in relatively inelastic supply and only modest price rises for [labor] in relatively elastic supply" [Binswanger and Ryan, 1977, p.228; cf. Anderson and Pandey, 1985, p.9]. Perhaps, indeed, since full employment and mobile labor and capital are assumed in GE, "where unemployment is large and [mobility slow], the [adding-up] models will do better at predicting distributional outcomes for...5 to 10 years". [Binswanger, 1980, p.211]. However, the following claim that Walras-style "GE forces...will tend to dominate in the long run", determining the ultimate impact of, say, MVs upon labor-land distribution, depends on at least a tendency towards full employment. In LDCs, especially with rapidly growing populations, the tendency is in the opposite direction [Lipton, 1984a].

Nevertheless, work to develop computable Walrasian GE models could be very useful, ultimately providing IARCs with much more reliable guidance to impacts of MV options upon laborers and on backward regions than is now available [Quizon and Binswanger, 1983, pp.533-6]. However, numerical predictions of equity impact will not be useful without much more work. Such work could usefully be done in association with specifications of the inputs and outputs expected of a pending MV-based technology, as partly attempted in Ghodake [1983] and Ghodake and Kshirsagar [1983a]. The work will need to disaggregate farm products at least into MV-foodcrop and other sectors, to clarify the products and factors of the non-farm sector and their role for agriculture, to introduce the possibility of responsive changes in investment, and to relax the assumptions of perfect competition, notably full employment and instantly mobile non-land inputs. Also such "Walrasian" work, on GE in factor and product markets with flexible prices and mobile non-land factors, needs to be integrated with two equally valid GE approaches to the total effects of MV options on the poor: the approaches implicit in the work of Keynes and Leontief.

(b) Keynesian GE: Keynes's own work is mostly about disequilibria, or else underemployment equilibria, in the whole economy, as affected by the balance between national aggregate planned savings and investment, mediated by changing expectations. However, at least one of Keynes's tools, the multiplier, is valuable for GE analysis of the impact of sectoral changes such as the MVs. The multiplier has been disaggregated to estimate how changes in income among any one set of persons (e.g. groups of workers, farmers or consumers, in the wake of MVs) get transformed into changes in demand, and therefore in income, for a second set of workers, farmers and capitalists who supply the changing demands; for the further set of workers, etc., who supply the changing demands of the second set; and so on. This process converges on a new set of incomes for workers, capitalists and landowners making each main commodity [Goodwin, 1949]. In the classic Keynesian case of widespread spare capacity, free competition, and mobile unemployed labor, the increased demand can generate extra output from domestic suppliers, further extra domestic supplies to meet the new consumer demand of those suppliers, etc., with rather little extra imports, or price inflation for either products or factors. In reality, some of the extra demand may leak abroad, or raise prices of domestic inputs or outputs. Insofar as this happens, the extra domestic money income does not correspond to extra domestic real output.

Obviously this process of successive rounds of demand, converging on a "Keynesian GE", is at the heart of the MVs' effects, especially on non-farm income and employment. Unfortunately, unlike the Walrasian GE, the Keynesian GE poses massive data requirements for computable estimation. One major estimate has been attempted. It follows out the effects on demand of the income expansion initially due to irrigation, fertilizer, and MVs in Muda, Malaysia [Bell, Hazell and Slade, 1982]. It shows that each $1 of extra income generated for food staples producers in the MV context, when it is again spent, generates a further 80c. of extra local incomes. The authors show how this demand benefits local households in various income-groups. However this is only a "first-round" effect; the spending of the 80c. generates extra incomes which are not analyzed. Also the extra 80c. is not broken down between real income and inflation effects.

An attempt to use the Muda results, and parallel work on the Funtua project in Northern Nigeria, to choose between alternative policies for the distribution of MVs has been made by Hazell and Roell [1983]. This relates (a) income per person in the group of households who <u>initially</u> obtain income-enhancing innovations such as MVs to (b) the effects of its extra spending upon income of the poorest, second-poorest, etc. deciles of households in the project area. $100 of spending out of extra MV income, if it goes to big farmers, appears in both Muda and Funtua to generate more demand for products from (and hence income for) the poorest local households than if they had got the extra MV income themselves.

But one cannot infer [Anderson and Pandey, 1985, p.10] that distributional effects of allowing MVs to benefit bigger farmers first are better when GE effects are considered than they appear to be from the adding-up model. The approach looks only at the first round of local consumer spending towards a Keynesian GE. Since non-locals do not gain direct project benefits, it is strange to assume that local spending of such benefits is better for income distribution than non-local spending. Also when rich farmers get extra income from MVs, even if they devote higher proportions of their extra consumption towards local products of poorer households (usually towards direct labor services like domestic work), they devote a much smaller proportion of extra MV income to any sort of consumption than do poor farmers. Further, even if rich farmers' consumption behavior is more pro-poor than small farmers', their production behavior -- which is not considered in Keynesian GE analysis -- involves lower ratios of outlay on labor hire to outlay on fertilizers, tractors, etc.

Furthermore, these models tend to blur three sorts of choice: between allocating MVs, fertilizer, credit, etc., to (a) big or small farms, (b) households with big or small total income, (c) households with big or small income per person. The overlap between these choices is known to be extremely imperfect. For example, "How do the smallest 10 per cent of farms use extra income?" is quite a different question from "How do the poorest 10 per cent of rural people use their extra income?" MV policy choices usually relate to the first question, but Keynsian GE models (and the supporting household surveys) relate to the second.

A multi-round tracing of spending by MV beneficiaries is a very important part of the total picture of MV-poverty relationships. But so far we have not got far in this direction. For example, estimates of impact on welfare via self-consumed vs. sold MV-crop output for each income-group, along lines indicated in Hayami and Herdt [1977], would need to be included in any complete model of Keynesian GE distribution impacts. So would (a) non-local consumption effects for rich and poor, (b) allocation between effects in raising price, imports, and real domestic incomes (requiring integration with the Walrasian GE approach), and (c) Leontief effects, dealt with below.

Yet these effects are not small nit-picks. They may totally overthrow the conclusions of the adding-up approach. Some Keynesian GE results therefore need to be used in forming a reliable picture of what MVs have done to the poor. As with the Walrasian GE, the studies cited get us from Square Zero to Square (or Round) One, a long way, but as yet far from Square 64. Maybe "a little learning is a dangerous thing", and we do better to stay at Square Zero with the adding-up approach. Square One may be further away than Square Zero from what we would know at Square 64. Nobody, right now, has the slightest idea.

(c) Leontief GE: Here, for good or ill, we are at Square Zero. As "Keynesian" GE traces poor and rich people's incomes from spending of successive rounds of cash, so Leontief's "input-output analysis" estimates their incomes from successive rounds of production: incomes from making extra grain via MVs; from providing the extra irrigation water, fertilizer, pesticides, etc. to grow the extra MV grain; from providing the extra feedstock, etc., to make the fertilizer, etc.; and so on. The assumptions are in some ways the opposite of those in Walrasian GE. There, the extra fertilizer can be made only if labor and other inputs move, from other work, to "saturate" fixed equipment with higher levels of variable factors. In the move to Leontief GE, all the raw materials, types of labor, etc. in making fertilizers can and do increase by the same proportion as the rise in fertilizer offtake due to the extra production of MVs, without any reduction in other production lines.

No attempt has been made to examine how the production inputs for MVs generate growth of off-farm or urban income and employment in a Leontief model. It would be feasible to examine jointly the two converging series of effects of MVs by combining Leontief and Keynesian paths to GE: supplies to make supplies to make...to make MVs, and supplies to meet consumer demands out of income from extra consumption out of income...from extra consumption by producers of extra MV output. In essence this can be done by using the Social Accounting Matrices (SAMs) introduced by Richard Stone. In practice there is not yet nearly enough disaggregation of sectors and technologies in the many Third World SAMs to permit this, nor enough information.

One day the three standard GEs may be put together to analyze MV impacts on the poor. Neo-classical Walrasian GE has mobile factors, variable factor proportions, and flexible prices (unless "set" by world prices to a small, freely trading nation), but suffers from extreme assumptions, e.g. about full employment, and from production relations to which are too complicated to handle many regions, products, or groups of people. Leontief and Keynesian GE models can handle many products, but fix both factor proportions and prices in an implausible way. Obviously, when MV crop output grows, all three sequences of production and income-generation -- in response to direct market signals, to the requirements for producer goods at given prices, and to consumer spending -- must occur and will affect poverty and employment. Currently our primitive adding-up methods take inadequate account of any of these three GE paths.

6.3 Interactive responses to MVs via the State, society, and classes

(a) Reaction to food price changes: Recently Lance Taylor [1983] and to some extent Irma Adelman and Sherman Robinson [1978] have been approaching intersectoral responses to technical change very differently from any of the three standard GE models. There are two strands to their argument.

The first runs via effects on the Government budget. In many LDCs the Government is a major buyer or seller of food staples on home or foreign markets. If major progress with MVs leads to a large change in volume and perhaps price of these transactions, there is a big change in the fiscal stance. In the short run, there are effects on aggregate demand, and hence on prices, net imports, and/or domestic output. A little later, Governments correct their tax and spending patterns to allow for the change in their revenues and outlays caused by the arrival of MVs. All this can have large effects on employment and on absolute and relative poverty. So far, the "Taylorians" have computed such effects mainly from a "first cause" of changes in farm-nonfarm terms of trade. However, it is feasible and probably necessary to ask what a major MV innovation would do to the poor via the fiscal balance.

The second element in "Taylorian" models is the analysis of how food prices affect wage rates in the formal sector, and via these the levels of welfare and activity for different income-groups and sectors. This, too, has yet to be aplied to the assessment of poverty impact of MVs.

(b) Micro-systems: A few distinguished sets of materials from village studies consider MV impacts [Hart, n.d.; van Schendel, 1981; Franke, 1972]. Also, both IITA [Hartmans, 1985] and ICRISAT [Ghodake and Kshirsagar, 1983] have sought to develop appropriate farm systems analysis that covers MVs, as does Collinson's work for CIMMYT. However, very little IARC or other analysis looks at the effects of MVs on flows and balances of income, power, and status in total systems.

For example, although an ICRISAT economist has lived in and examined each of six semi-arid Indian villages in great depth for ten years [Mueller and von Oppen, p.4], Dr. Epstein and I found in 1983 that the main moneylender was not in the sample in the village we visited, and that ICRISAT's inquiries about credit did not establish whether he was the source. Therefore the impact of MVs upon a possibly very important determinant of relative income and power had been excluded. This is not a silly mistake by ICRISAT! It reflects a model where socio-economic outcomes are additive, impersonal, and individualistic. "The system", in essence, is the marketplace. Maybe this is a misguided view -- the key role, in adoption of a proposed new dryland farming system, of the presence or absence of a local toolbar monopoly [Ghodake, 1983, pp.23-5] suggests so -- but it is a view.

One step forward is to see extra MV benefits in the context of a "farm system" [Collinson, 1982; Byerlee et al., 1982a; Maxwell, 1985]. This way, at least the effects of MV options on the poor via labor for other crops, straw for cattle, etc. get examined. But nobody lives only in a "farm system". Not just non-MV crops and animals, but also off-farm production, post-harvest processing, and leisure and consumption activity have relations of competition and complementarity with MV inputs and outputs in various seasons.

Also, no real family's production-consumption system is closed, except that of [Crusoe, 1719, before Friday]; yet it is Crusoe who provides the standard economist's model, at least of consumer behavior. The poverty impact of MVs on a farm-based family depends on what happens to other families and institutions with which it transacts. Does the moneylender find his interest income reduced as the borrower is enriched by MVs, and if so does he try to impede them [Bhaduri, 1973], or to switch from lending to investing in production with them? Do MVs accelerate or retard a switch from sharecropping to owner-occupancy? Where do they bring absentee urban landlordism, or accelerate local self-assertion? Classic anthropological work, mirrored in Goody [1980], does seek to answer such questions. Many economists produce studies of how MVs affect sampled individuals in villages, not studies of intra-village relations as affected by MVs, and hence as affecting savings, employment, extra-economic power, and the other components of the societal systems that make people poorer or richer.

(c) Political economists, disequilibria, discontinuity: The GE models "are not capable of handling...disequilibrium phenomena, such as the differential adoption" [Quizon and Binswanger, 1983, p.526] of MVs by farmers facing similar prices and production conditions, but with different assets and access to credit. What fascinates is the concept of disequilibrium here. Imperfect markets in information, credit, or insurance do indeed, technically, create "disequilibrium" in a GE model. But most people who are not standard economists would look for something a bit more dramatic. Do MVs change the structure of wealth and power in a society, leading to a qualitative change in it? If so, the impacts on poverty will dwarf even the "very long run" Walrasian GE effects.

Most economists have given very little consideration to such effects. Natura non facit saltum (Nature does not make a jump) was the motto of the greatest work of standard economics [Marshall, 1890]. But for a village, though not for a nation, some big agricultural changes are huge jumps, not just in technology but in the associated power-structure. Probably MVs seldom entail this sort of change (see Section 4 below). Certainly their massive spread appears to have been consistent with quite different macro-politics, from China to Mexico. But at least the question needs to be asked. Political economists, including Marxists, try to ask it. There has been a general failure to distinguish between Marxist analysts of MVs (such as Cleaver [1972], Byres [1972, 1981], Gough [1977], Rudra [1978] and Patnaik [1971]) and what might be termed general whiners about MVs.

The Marxist analysts are seldom plaintive. They see MVs as part of a process that destroys "reactionary" pre-capitalist formations by formalizing wage contracts, by reducing the role of sharecropping, by strengthening owners of capital against landowners, by polarizing peasants and turning them from "sacks of potatoes" into clearly differentiated large capitalist farmers and landless rural proletarians, and by commercializing and monetizing transactions in grain, leaving the new capitalist farmers with reinvestible surpluses. There is a lively controversy about the "mode of production" in Indian agriculture (for an excellent summary, see Thorner [1982]). Some of the more eclectic Marxists such as Rudra have changed their positions drastically, no longer asserting that MVs in the Punjab were a major component of the transition to capitalist agriculture.

In my judgement, like their predecessors [Engels, 1894, esp. pp.394-5; Lenin, 1899; Kautsky, 1899], most Marxist commentators on MVs err by implicitly assuming that there are great and cumulative advantages for larger farmers over smaller ones, and for owners over tenants, in adopting, intensifying, and getting high incomes from agricultural innovations such as MVs. If that were true, and if pre-MV agriculture really had been fairly equal and pre-capitalist, then the argument that MVs brought capitalist polarization would have force. Marxists have also been greatly influenced by the Punjab, but have not always appreciated that repossession of tenancies, polarization of size of holdings, and tractorization all largely preceded MVs there [Randhawa, 1974; Chadha, 1983].

However, these are serious contributions, and non-Marxists, including standard economists, have been in creative dialogue with Marxists in the Indian mode-of-production debates. Apart from such contributions, however, there is also a sort of bastard Marxism. On the basis of one or two endlessly repeated anecdotes, it is claimed that the Green Revolution (whatever that is) will turn red (whatever that means). Careful scholars [e.g. J.Harriss, 1977a, esp. p.35] have found no relation between the incidence of violence and the spread of MVs. The Naxalite rebellions in India were in very backward agricultural areas. The Punjab's recent troubles have been unrelated to agro-based class conflict. Careful Marxists stress that it is specific to a region and its history whether MV-induced polarization hastens "class action"; in India this happened in Thanjavur, but not in the Punjab [Byres, 1981].

6.4 Lessons from history and from historians

(a) Our methods and theirs: Historians, looking at the effects on poor people of big agro-technical changes like the Neolithic Revolution or US farm mechanization in the 1850s, seldom use the adding-up approach. Such big changes combine with other technical, socio-economic and political changes to affect jointly the poor, the rich, and social relations among groups. MVs in a few isolated villages, or an innovation raising farm output by only 1%, might be "near-decomposable" from all these other causal links, so that the effects on poor groups could be analyzed in isolation [Ando et al., 1963]. MVs in major regions, raising farm output by perhaps 40% and drastically changing techniques and input-mixes, simply cannot be "decomposed" from other big changes affecting rural and urban people of all classes.

This is the objection of most historians to the hypothetical method and to econometric history. One cannot take one big event, such as the abolition of slavery or the spread of railways in the USA, and ask what its non-occurrence would have done to "the poor" if all other events had proceeded unchanged. The US railroad map would have looked quite different without the events of 1861-5. The rapid spread of agricultural machinery in 1830-60 [Edwards, 1941, pp.221-9] cannot usefully be treated in isolation from accelerated farm-factory migration in the USA. In exactly the same way, if one "took out" MVs, it is invalid to assume that all other major sequences since 1965 in India -- mechanization, population growth, land expansion and distribution, and even political structure -- would, with their effects on the poor, have been unchanged, or changed only in ways predicted by the maximizing assumptions and equations of short-run micro-economics.

This is the complaint of the historians. Economists try, all the same, to understand what MVs do to the poor via:

(1) The adding-up approach. We hope that, even if the impact on poor groups in India of MVs cannot be decomposed causally from that of other great events, the impacts of rice MVs on consumers in Delhi, of MV wheats on farmers in Ludhiana, etc. can be, and that we can then add up all the separate effects, still ignoring (say) population growth. If one man pushes a five-ton telegraph pole, the interaction with the prevailing wind can be ignored; not so if twenty do.

(2) GE. Our analysis of the several GE approaches shows that the equilibrium is not general at all. Even if we managed to combine neo-Walrasian, Keynesian and Leontief GE analysis of "directional effects" of MVs on the poor, larger "historical" interactions of MVs with the State, class structures, population change, and land distribution would be left out. And such interactions may be the main way that, in the long run, MVs affect the poor.

So what? It does not suffice to develop MVs that would help the poor as consumers, farmers or workers, if only such MVs could be isolated from other great currents of history such as population growth. MVs, and associated methods and "farm systems", have to be poor-friendly in the real world, in the actual, evolving historical contexts of the adopting country. We now look at what historians have said about other "agricultural revolutions" that could help us to assess MVs and research priorities.

(b) What is an Agricultural Revolution? Historians identify four:

(1) The Neolithic Settlement, when hunter-gatherers became agriculturists, spread slowly SE-NW in Europe during 3500-700 BC [Piggott, 1981, p.30]. Yet any one settling group experienced drastic change. This might even involve invasion, as in Wessex [ibid., p.33].

(2) The medieval AR took from 600-1200 A.D. to cover Europe, but for any one village or manorial farming system there had to be several sudden, linked changes [White, 1962].

(3) Faster, though less fast than ws once believed, was the "18th-century AR" (1650-1850!) in Northwest Europe [Mingay, 1968, p.11; Jones, 1974, pp.78-9].

(4) Finally comes the "green revolution" since 1960.

There are other candidates, mainly for temperate zones. The mechanical innovations of 1830-60 [e.g. Edwards, 1941] and the biological innovations from Peruvian guano through chemical fertilizers in 1870-1915 were clearly evolutions. Bio-engineering and N-fixing cereals may yet be tomorrow's AR. But in what follows it will suffice to see what (1)-(4) have to teach us about MVs and the poor in "total" historical contexts.

* * *

Four criteria are usually suggested for ARs: (a) accelerated and sustained growth of farm output or "productivity", (b) sharp technical discontinuity, (c) technical change requiring or required by (or, weakly, easing or eased by) social or political transformation, and/or (d) major change in mass poverty. We return to the first three below. Historians say little about (d) directly, not because they ignore the poor, but because sharp discontinuities -- or, with the first two ARs, very long time-periods at national level even if each community changed suddenly -- render poor people's conditions "before" and "after" non-comparable [Piggott, 1981, p.31, on Mesolithic hunters and Neolithic farmers].

Economists of MVs, unlike historians of earlier ARs, do often assess (d) directly: data and statistical tools are better, the victims of poverty (and agencies funding research on them) live around us, and nation states now both proclaim "poverty focus" and pay for MV development. Above all MVs unlike earlier ARs, have advanced quickly enough, yet with little enough sharp change in life-styles, for direct comparison of household poverty "before" and "after" to make sense, at least if sufficiently localized [cf. Aggarwal, 1973, chs. 6-7, on Ludhiana]. But we have not learned from historians that MVs' systemic effects on the poor can dwarf direct economic effects on the poor, whether "added up" or in partial forms of GE. These systemic effects can operate as MVs permit policy changes, which may induce faster GNP growth and lower food imports; or via transformed technologies and associated changes in skills; or via socio-political change induced by or inducing MVs and associated innovations. Systemic effects of MVs will normally involve interactions with other great changes such as population growth or, in much of Africa, privatization of land rights.

(c) How much is an AR? Geography and inequality: An AR attracts attention only by affecting a biggish area. This implies two things.

First, a series of sudden sharp ARs, each in a village or a clan, may take a very long time to change a nation's agriculture much. A village may need to adopt swiftly, as a package, or not at all. This seldom applies to MVs [Lipton, 1979], but did apply to the medieval AR, which involved horse-ploughing, improved horse-collars, larger ploughed area, horseshoes, oats, and rotations. For any manorial system or village, it was a revolution of accelerated growth, of discontinuity in most techniques, and of power-structure (sec. 6.4.f), whether as cause or as effect of the technical change. Yet for England the changes took centuries [White, 1962].

Second, as a result, ARs will leave most of a nation behind, while transforming areas of villages or clans. Areas "selected" may have human or physical advantages for the AR, but, once a few villages have demonstrated the gain from transformation, it is their near neighbors that are likeliest to learn, follow, accumulate, and move further forward. The Punjab led South Asia not only in MVs, but in agricultural innovation at least since the risk-reducing canal irrigation in 1859-1900 [Spate and Learmonth, 1967, p.522; Singh and Day, 1977; Randhawa, 1974; cf. Lowdermilk, 1972, pp.15-16]. Similar prolonged innovation leadership preceded MVs in NE Mexico and Central Java [Franke, 1972, pp.63, 189]. Compare Norfolk, in the van of technical progress even in the thirteenth century [Campbell, 1983; Parain, 1966, p.179] and leading the adoption of most eighteenth-century AR practices [Riches, 1937, pp.8-17, 34]. But leaders imply laggards. For the poor in areas left behind by the Norfolks, such as Northern England in 1750-1850, absorption by labor-intensive industry was an option. That is far less plausible in countries with rapid population growth and modern capital-intensive industry. Mindanao, Madhya Pradesh and Pacific SW Mexico feature rapid population growth and no obvious absorbent for extra workers, yet their food production lags far behind MV development in Luzon, Punjab and Sonora respectively. Since the message of historical work, though not of adding-up or even GE economics, is that regional advantage from AR cumulates, this is very serious [Myrdal, 1958].

(d) ARs, poverty impact, and the nature of science: But what can be done? Isn't an AR a prolonged growth acceleration that "saves" a scarce factor, with innovation and research "induced" to lift the blocking constraint suddenly, leaving income distribution to the gods [Hayami and Ruttan, 1971; Boserup, 1960]? In normal times of steady change in techniques, we may expect such consequences of "normal science" [Kuhn, 1973]. History suggests that the supply side of science is not so completely determined during ARs.

For example, did the UK's agricultural changes in the eighteenth century release labor for industry? In 1700-50 UK farm output rose by an unprecedented 26%, at least two-fifths of it in the 1740s. Yet since the workforce grew as fast, the output growth was almost wholly land-saving [Deane and Cole, 1967, p.52]. Recent research suggests that growth was even faster and more concentrated into 1730-60, and even more yield-based [Overton, 1979, p.375; Turner, 1984, p.225]. From 1690 to 1831 the application of science to agriculture, far from being induced by economic incentives to save labor and release it for industry, showed no sign of dramatic falls in labor-intensity. For example, the ratio of landless farm labor to farmers increased only from 2:1 to 2.5:1 [Mingay, 1968, p.26, citing Clapham].

Land in England was saved by eighteenth-century innovations, not because it was getting sharply scarcer relative to labor (on the contrary), but because the spread of discoveries old and new, such as marling, horse-hoeing, four-course rotations, etc., made it profitable to apply more labor to land. The eighteenth-century and subsequent enclosures, partly responding to the supply of new science, also responded to the new, profitable chances to <u>increase</u> labor per acre [<u>ibid</u>., p.25]. Of course, later mechanical innovations did release large numbers of workers, but the story of England's 18th-century AR, and of most growth accelerations, owes at least as much to earlier discoveries which were not obviously responsive to factor scarcity, but rather to what was most readily discovered, tried, and spread.

In Japan the opposite happened in 1877-1919. Labor supply was growing quite fast, about 1.3% yearly. Yet the acceleration of agricultural growth, a precursor of industrialization like Britain's "AR" of 1730-60 was labor-saving. Labor productivity rose at 2.6% yearly and land productivity at 1.9% [Ohkawa <u>et al</u>., 1970, pp.6, 13, 180-1]. Of course there is a massive amount of literature scholarly about what happened in Japanese agriculture in 1877-1919, but the figures do not seem to be consistent with the view that inventions are mainly responses to factor scarcities [Hayami and Ruttan, 1971].

Accelerated growth as such often happens in agriculture with no sharp change in organization or techniques, e.g. in UK wheat in 1936-66. Growth <u>per unit of a factor</u> does accelerate sharply in most ARs, but the factor saved need not be the obviously scarce one. Instead, it may be the one that science has made it more profitable to save (Mendel did not work on sweet peas to respond to land/labor ratios in Asia.) There is scope for human action to affect not just the scale of technical change, but also its path, and in particular the extent to which it reduces poverty or "saves labor".

(e) <u>Discontinuous technical change</u>: The quality of inputs, or of the skills or methods with which they are combined, is often measured as total factor productivity (TFP) or as "residual" productivity. TFP accelerated sharply in Punjab and Haryana, but not elsewhere in India, between 1958/61-1963/5 (0.5% yearly) and 1963/5-1969/71 (13.4%) [Mohan, 1974, p.A.98]. Similar TFP explosions happened in Japan in 1880-1910, and in the USA in 1885-1900 and 1938-60 [Hayami and Ruttan, 1971, p.116]. But there are many problems with TFP and residual productivity measures.

They may indicate technical progress, omitted factors [Schultz, 1964], economies of scale, or merely a "coefficient of ignorance". Anyway, nobody would call all the four TFP accelerations cited "revolutions".

In asking how ARs affect the poor in total systems, however, we are surely looking for, among other things, the effects of discontinuous technical change. Can we find an objective, testable indicator of it that does not -- as TFP and residual productivity do -- come laden with dubious economics and statistics?

An AR (or any revolution) is the exception to "natura non facit saltum". Techniques, at least, jump. AR innovations are <u>not seriable</u> [Shackle, 1952]; in other words, they must be tried out on a farm system (and change it), because piecemeal experiment is infeasible. They are <u>not separable</u>; the package cannot be unpacked. They are <u>not single-unit</u>; adoption involves relationships with neighbors and/or authority structures.

All four so-called ARs -- Neolithic, medieval, 18th-century, MV -- meet the criterion for an AR of dramatic acceleration in rural growth. Indeed, each was quicker than the last. But the key fact about 'effects on the poor' is that only the Neolithic and medieval revolutions were technically discontinuous and therefore, as we shall see, strongly associated with a transformed structure of power. Unlike these ARs, the 18th-century and MV experiences, although so much more rapid in their impact on GNP, could be taken gradually, piecemeal, and individually at farm or village level. The poor must anticipate that this smooth, gradual process will "feed" MV benefits into <u>existing</u> power-structures. To understand what that means, we should look at the opposite: the truly non-seriable, multiple-unit, discontinuous ARs, Neolithic and Medieval.

For reasons of security, scale-economies in land clearance, and simultaneous tasks, Neolithic settlement involved several families, not single-unit decisions. It was non-seriable too, in view of the labor and time costs of clearance, the food foregone, and the scanty stocks in pre-settlement hunter-gatherer societies. Also it was non-separable, involving a package of practices: all European establishments carbon-dated as Neolithic were "stone-using and all showing the essential features of cereal cultivation (wheat or barley) and animal husbandry based on cattle [plus?] sheep and/or goats, pigs and dogs in variable proportions" [Piggott, 1981, p.31]. Animals and stone tools would have been needed to clear, and to plough, heavy hardpan soils.

The medieval AR was also non-seriable; a community needed to be held to a rotation, balancing fodder crops (so animals could over-winter and plough) and food crops. Since the seigneur's "demesne...was made up as a rule of various fragments...mixed up with" peasant lands, he too had to observe the three-field rotation. In many areas "collective grazing rights over the stubble, and the compulsory rotation..., were binding on all, often even the seigneur" [Bloch, 1966, pp.242, 276]. Unless farmers synchronized their rotations, animals would more readily eat standing crops, and farmers' access to their fields at harvest-time would be impeded by the immature crops of others. Farmers could not try out this community system serially! Also, it was non-separable [White, 1962]. In an equicentric package, horses replaced oxen and permitted more land to be ploughed, but needed more fodder cropland. From this package, the three-field rotation of fodder, food and fallow, which spread cultivation across seasons and area, was inextricable. For horses to plough the extra land, this AR also required (in heavier soils, anyway) blacksmiths to work iron into horseshoes, and increasingly into improved ploughs with mouldboards or wheels, and leatherworkers to make improved harnesses with breast-strap and stiff collar [Parain, 1966, p.144]. Plainly this medieval AR, which required social control of rotations, grazing, and (where markets were primitive) availability of leather and iron work, must have been non-single unit. What a contrast with the separable, seriable, evolutionary non-package of inputs [Lipton, 1979] and practices around MVs!

Similarly gradualist were the technical changes of England's "eighteenth-century AR". Hundreds of years of gradual farm enlargement, probably with only a minor contribution by enclosures [Mingay, 1968, pp.15-17], created large capitalist farms, often well before the acceleration of technical change around the 1740s. These farms could take decisions as single units, and thus could often act as lead innovators. Moreover, the alleged "package" comprised practices suited for different environments, or alternatives in the same one, as with horse-hoeing or marling to reduce seed-rates [Riches, 1937, pp.5, 16, 77-81]. Also four-course rotations, turnips as a clearing crop, etc. were separable and each could be tried, serially, on a tiny area. Historians increasingly see this "AR", even for one farm, as continuous, technique-by-technique, in essence evolutionary [Jones, 1974, p.88; Mingay, 1968, p.11].

The MVs may transform GNP, imports, and hence economies and the position of the poor in them, but technically they too are evolutionary. They rest on long histories of "pre-MV" seed releases, and waves of seed innovation [Hayami and Ruttan, 1971, pp.158-9, on Japan; Dalrymple, 1985, on Japan and Taiwan; FAO, 1971, p.6, on the Philippines; Kaneda, 1973, p.169, on Pakistan; Saxena and Jadawa, 1973, p.65, on India]. Importantly for the poor, many "pre-MV" rices rested for their main appeal not on dramatic yields but on robustness: against wind damage for ponlai for Taiwan in 1911-24 [Carr and Myers, 1973, p.32], or overall in the early 1960s for H-4 in Sri Lanka [Peiris, 1973, pp.2-3] and ADT-27 in Tamilnadu [Frankel, 1971, pp.90-1].

MVs themselves are seriable; for instance, with Sri Lanka's "mini-kit", a farmer tries out several variety-fertilizer combinations, then plants the best widely. MV-linked inputs are thus also separable. A precisely mixed and timed package of practices and inputs would make life very hard for poor farmers and unskilled laborers, but is fortunately mythical. Appropriate input-mixes vary with soils and terrain, although even the myth of a non-separable package may harmfully delay adoption among the poor [Lipton, 1979]. MVs and linked inputs are also single-unit. Unless a farmer depends on others for timed water, his or her net gains from MVs are seldom much affected by neighbors' decisions. Thus MVs neither represent technically, nor (by increasing the discipline that each adopter expects from his neighbours) require from social systems, a sharp discontinuity. This eases adoption for poor people and places. But it also increases the chances that existing social systems will steer the fruits of MVs largely to the entrenched better-off. So we should expect, in MV areas, that inequality increases but absolute poverty declines.

(f) ARs, power-structures, and the poor: In my increasing unease with our bitty approach to the question of how vast technical changes, such as MVs, affect the poor, I have been pushed from the "adding-up approach", via GEs that turn out to be partial, to less rigorous but more realistic historical accounts of "general disequilibrium": of how major changes in total agro-rural technosystems, as related to political and social structures, affect the poor. The paradox is that progressively "faster" ARs from the viewpoint of national-level output effects -- Neolithic, medieval, Eighteenth-century, MV -- have involved progressively "smoother" (more seriable, separable, single-unit) technical progress. Faster output change would seem to raise, but smoother technical change to lower, the prospects of radical changes in power relations that affect poor groups. What in fact happened?

If a technical AR was either one-way cause or one-way effect of a new power-structure, there would be no room for incremental policy, let alone for fine-tuning the MVs. The view of an AR as one-way cause of a new policy is criticized by Anderson [1974, p.183] as a "fetishism of artefacts". Institutional gaps meant that 200 to 300 years elapsed "between [the] initial sporadic appearance" of improved ploughs and harnesses (to simplify horse-ploughed three-field rotations) and "their constitution into a distinct and permanent system". Indeed [Dodgshon, 1980, pp.2-3] "manors and villeinage [were] present during the earlier...Saxon settlements" and cannot have been simply caused by the need to organize "plough technology".

Just as unacceptable is the view that a new policy, or ruling class, must arise to consciously cause an AR. The Neolithic Settlement was "in no sense a conscious exploitation of resources by means more effective than those of the hunter-gatherers" [Pigott, 1981, p.35]. Nor, later, were the medieval AR's field systems "consciously contrived institutions of field layout and husbandry...It was not a case of early communities [deciding] how they might best farm their lands, and then devising [field systems] as the answer" [Dodgshon, 1980, p.viii].

However, though technical change is seldom simply either cause or effect of institutional change, the two are closely linked. All very equal societies, some observable still, seem to be pre-Neolithic and non-settled hunter-gatherers. Agriculture and authority emerge and grow together, for four reasons. (1) Settled societies are "delayed-return systems" with investments made before harvests, even before sowing. These societies therefore need "ordered, differentiated, jurally defined relationships [to secure] binding commitments" [Woodburn, 1982, pp.431-3]. (2) The shift from nobody's to communal property rights requires increased authority [North and Thomas, 1977, pp.229-31], even if Kennedy's [1982] caveats are correct. Indeed, (3) the growing need for group security for standing crops and settled investments, and hence for property rights "to be sustained by...public and collective goods...defense...dispute regulation, law enforcement" [ibid., p.384], also advances authority, agriculture and "States" (even if village-States) together. (4) The complex of non-separable, non-seriable, multiple-household processes of settlement and clearing pushes a clan towards formal structure of authority, valued as a "public good" and thus able to secure widespread consent when it extracts surpluses to reward well those high up in the structure, thus encouraging them to maintain both it and the new technosystem. To reap the benefits from the new rotations, each peasant required manorial counts and enforcement officers to compel his neighbours to observe those rotations. It thus paid each peasant to give up some surplus in order that the legal system should be paid enough to work well.

Settlements, and much later complex and integrated rotations, vastly increase and reward such hierarchies. However, no "law" tells us whether the technical transformation precedes or follows the new social structure. Interactions matter. The matrix is not near-decomposable [Ando et al., 1963] into "social" and "technical" equations. (One ideologue's "simultaneous determination" is another's "dialectic".)

Whatever the causality, settlement and structure came together. Settlement, with ploughing, spread in Wessex before about 2810 B.C. A complex hierarchy from clan chiefs to provincial chiefdoms has been inferred from carbon-dated implements, burial grounds, and ceremonial places [Renfrew, 1973, pp.597-8]. At this time elsewhere in England, where hunter-gatherers had not yet settled, only "presumptive small kinship groups" are traceable [Piggott, 1981, pp.55, 58; Case, 1969].

The medieval AR further rewarded centralized power, but seigneurial and not slave systems were needed for efficiency with the new farming [Bloch, 1966]. "Regulatory authority" in policing rotations had to be combined with non-slave incentives to efficient work [ibid., p.276]. "Disciplinary assemblies, notably manorial courts" were required to regulate not only three-field rotations, but aso use of the shrinking common claims upon grazing and stubble, and also timings, partitions and disputes resulting from intermingled lands [ibid., p.242; Dodgshon, 1980, pp.17-18, discussing Thirsk's work].

Compared to MVs, the medieval AR strengthened "authority" more, because the innovations were not seriable, separable, or single-unit; less, because they covered nations more slowly; and, on balance, more at local level, often associated with a transition from slavery or communality to seigneurial systems, and less at national level. Neither medieval nor

MV innovations involved economies of scale; the medieval AR "increased productivity on the small units [giving] them an advantage over the larger estates" [Parain, 1966, p.125], just as today's MVs should, via labor-intensity, favor small family farmers with lower search and supervision costs. But just as Mexican small farmers do better with MVs when they have co-operative ejido institutions to finance and manage common irrigation investments [Burke, 1979], so small medieval farmers required shared institutions of law and settlement. Now, as then, requirements for packages with precise timing or fixed proportions, for water from central suppliers, or for non-competitive deliveries of credit or fertilizers, could increase the vulnerability of poor farmers to rural and urban extractors, seigneurs, and other recipients of economic rents, tributes, or bribes. This is not about big *vs.* small, or public *vs.* private input supplies. Rather it is about competitive or farmer-controlled supplies *vs.* external non-competitive ones.

Unlike Northwest Europe's Neolithic and medieval ARs, the AR in eighteenth-century England is technically very like MVs. Both the latter sets of changes bring rapid growth in agricultural output, but are seriable, separable, and single-unit. At local level therefore, these two ARs seem ideal for "standard" economic analysis of the effects on the poor, because the institutional impact or requirements seem relatively small. In both these ARs the local structures of power do not need to change, indeed are reinforced as richer farmers gain from adopting the AR innovations. Yet this view is too local! The eighteenth-century AR generated four major pressures towards industrialization, and hence changes in *national* structures of power: cash surpluses to invest in industry, food surpluses to feed it (though output per farmworker did not usually outpace output per acre), regions with increasing comparative disadvantage in agriculture, and (because four-course rotations, marling, turnips, etc. did not save labor) pressures to mechanize later on. Northwest Europe and North America now -- with their massive food surpluses; with well below one in ten workers in agriculture; with capital, labor and politics largely urban; yet with rural bias, even rural veto -- embody political transformations initiated by the take-off in agriculture in England around 1730-60. There are several countries in Latin America and South-east Asia where MVs appear to be the mainspring of similar ongoing political changes at national level, although these are complicating factors: power is much more urban and population growth much faster than in eighteenth-century Europe.

Today's AR may be affecting the poor most, not via adding-up effects (except in non-MV areas!) or GE economics, nor by inducing new local structures of power (as is argued by participants in the mode-of-production debate), but by feeding new resources into those old local structures, while changing the <u>national</u> structures of work as well as power.

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We have tried to show that, some major reservations (which suggest new directions for IARCs), without MVs the Third World's poor would in the short term have fared worse. However, to help poor people get and stay significantly less poor, research must seek sets of innovations which help them to gain options, assets, or power in their changing and differing political contexts. In Bangladesh, most poor people are employees; in Kenya and much of semi-arid India, they are small farmers; in most of Latin America, they are townspeople. Efficient pro-poor innovations will need to be more sharply pointed towards these groups. Thus in Bangladesh a suitable innovation in many areas is the hand-pump, which is likely to be substantially used and owned by employees [Howes, 1982]. In much of semi-arid Karnataka, India, MV finger-millet is well designed to help poor subsistence farmers [Rajpurohit, 1983]. In Colombia, MV corn and cassava pinpoint the consumption requirements of the urban poor [Pinstrup-Andersen, 1977].

International research institutions such as the IARCs are a new fact in history, unknown at the time of the earlier ARs. Their greatest comparative advantage is relative immunity from the balance of national pressures for research to respond to the factor scarcities [Grabowski, 1981] and crop priorities, not of the poor, but of the powerful. (Their only absolute disadvantage over national researchers, perhaps, is excessive closeness to the international scientific establishment, rather than to the local needs of poor peasants, workers or consumers). But IARCs, though new as makers of AR history, need to learn its lessons if they are to serve the poor. The innovations of Northwest Europe in 1740-1820, like the MVs, raised labor requirements per acre, and did not possess economies of scale. Yet their main benefits, for many years, accrued mainly to those who held political power, rather than to laborers and small farmers. Now as then, mere passive reliance on the pro-poor micro-economics of particular innovations is no substitute for selecting and designing sets of MVs, other inputs, methods, and outputs that the poor can own, use, or control.

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