A TIME FOR RAINFED AGRICULTURE

L. D. SWINDALE

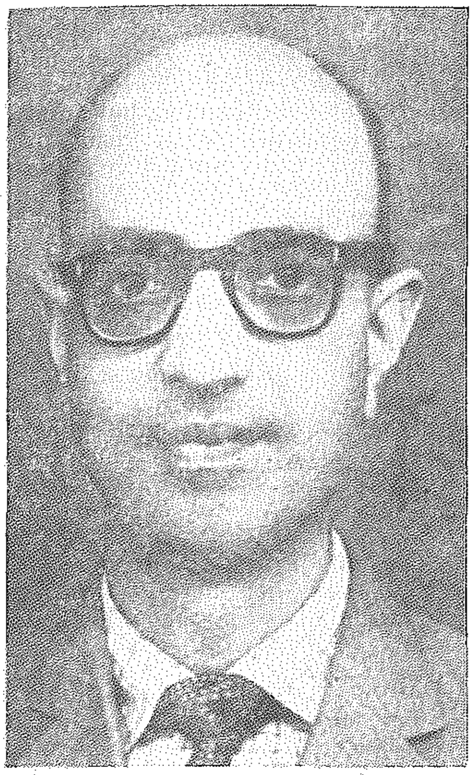
Eleventh Coromandel Lecture this year was delivered by Dr. L. D. Swindale, Director General, ICRISAT, Hyderabad, at New Delhi on December 10, 1981. The subject was 'A Time for Rainfed Agriculture. Sir John Crawford, Chancellor, Australian National University, presided over the function.

The annual Coromandel Lecture instituted by Coromandel Fertilisers Limited, provides a forum for distinguished men of science and letters to expound on topics of contemporary interest, specially relevant to agriculture and human welfare. The earlier lecturers in this series were distinguished names in the field of science and economic thought, such as, Sir Joseph Hutchinson (University of Cambridge), Dr. Norman E. Borlaug, Dr. M. S. Swaminathan, Dr. W. David Hopper, Dr. I. G. Patel, Dr. Sylvan Wittwer to name a few.

The increasing pressure of population on limited land resources in India and very particularly the aberration of weather makes it absolutely necessary to get the maximum food production both from irrigated areas and those that depend on rainfall. In India, out of 142 million hectares of land cultivated, approximately 108 million hectares depends on rainfed agriculture. Such acreage is responsible not only for 40 per cent of the food production but also nearly 80 per cent of our cotton, 90 per cent of our oilseeds, most of our pulses if not the entire pulse production also comes from this region. The concentrated interest in this area arises not only on account of the contribution it makes as described above but also because 50 per cent of the population living in this area live in great poverty and the constant uncertainty which weather brings. Therefore, a study of and effort to promote greater agricultural production and stabilisation, in rainfed areas acquires importance in our agriculture. Dr. Swindale speaks with authority, born of many years of experience in different parts of the world and his experience with ICRISAT which has concentrated on improving crops, basic to life in the semi-arid tropics such as sorghum, pearl millet, pigeonpea, chickenpea and groundnut.

Introduction

The world is aware of India's agricultural miracle. To quote a recent article in the New York Times "India once written off as a hopeless case has almost tripled its food production in the last 30 years and now has a comfortable reserve for future bad years." Dr. I. G. Patel in last year's Coromandel lecture spoke of the anguish of those bad years in the late 60's: anguish because so many people suffered and hungered and anguish at the contempt in which India's efforts towards self-sufficiency in food were held in those unhappy days. Recently, an American writer predicted that India could soon become the worlds number one producer of grain. Quite a change; from a basket case to a bread basket in a few decades. The man we honor today, Norman Borlaug, has become a symbol throughout the world for the potential for improvement in agriculture that does exist in India and, indeed, in most developing nations.



DR. R. S. MURTHY WINS BORLAUG AWARD 1980

Dr. R. S. Murthy (b. December 12, 1925), presently Director, National Bureau of Soil Survey and Land Use Planning at Nagpur, has been selected for the prestigious Borlaug Award for 1980. A devoted researcher and a born leader who has spent over 25 years in the field of soil science research and land use planning. Dr. Murthy is concerned with the important task of conducting survey of all soil types present in India and preparing a Soil Map of India. Dr. Murthy's contributions in the area of resource inventory is of seminal value for efficient utilisation of soils as a basic resource.

Dr. Murthy's work in transfer of agricultural technology to dryland farming areas is well recognised and his investigations in remote sensing for quick and reliable assessment of a variety of resources is important to evaluate land-use patterns, geomorphic units in relation to soils and soil mapping.

Dr. Murthy had a distinguished academic record and secured his Ph.D. from the Banaras Hindu University in Soil Science and Agricultural Chemistry. Starting his career with soil survey in the Ministry of Irrigation and Power, he shifted to the Indian Agricultural Research Institute in 1954. Dr. Murthy had a brief period of training in U.S.A. in the Soil Conservation Service. He has to his credit over 125 scientific papers. He is a member of many learned scientific societies. Dr. Murthy has travelled widely in U.S.A., Soviet Union, Europe, Canada, Africa, South-East Asia and participated in international seminars and workshops.

Dr. Murthy is the President-elect for the Agricultural Sciences Section of the 69th Session of the Indian Science Congress Association to be held in Mysore in January 1982.

The National Bureau of Soil Survey and Land Use Planning has been entrusted with the responsibility of preparing the Soil Map of India on 1:1 million scale. Dr. Murthy has been coordinating this project through the Regional Centres, Soil Survey Organisation at the Centre, the State Soil Survey Organisations and the Agricultural Universities. The Soil Map with appropriate definitions of legend classified in the international classification system will be ready for issue by February 1982. In addition, a publication on the Benchmark Soils of India containing morphological, micromorphological, physico-chemical and mineralogical characteristics of about 65 Benchmark Soils selected on an all India basis and their potential land use will be brought out.

Land use planning forms an essential research programme activity of the Bureau. Districtwise soil survey reports with soil maps and land use plans are being regularly put out by the Bureau. The country's production levels are low because of the per-acre yield which is much below the world average. Considering the high rate of population growth, proper land use planning has become imperative in order to raise farm productivity.

The Borlaug Award, instituted by Coromondel Fertilisers Limited in honour of Dr. Norman E. Borlaug and his contribution to the advance of wheat production in India and elsewhere is annually awarded to Indian scientists for their outstanding contribution to agriculture and research. Dr. R. S. Murthy joins the illustrious and dedicated band of those scientists who have previously won this prestigious award and have earned international acclaim for India and are presently working in far off places like Nigeria, Thailand, the Philippines, etc.

The Borlaug Award carries a handsome gold medal, a cash prize of Rs. 10,000/- and a citation.

The success that has been achieved here has been accompanied by improved agricultural infrastructure and supply of inputs and the development of an adequate market structure. We can believe that a reasonable rate of progress will continue, that periodic droughts will be withstood and that an agricultural base for the improvements of other sectors of the economy now exists. The manner in which the country weathered the 1979-80 drought described by many as the worst drought of the century illustrates the solidity of the existing agricultural sector. In my travels around the world, I have on several occasions amazed people by informing them that India sustained the worst drought of the century in that year. They did not know, had not even heard. There was no starvation, no catastrophe, no massive food aid from foreign sources. The world press, finding nothing bad to write about, wrote nothing and the world stayed unaware.

This is not to say, of course, that the worst drought of the century passed without trace. We well know in this country of the many problems that were caused—the draw down in food stocks, the loss of hydroelectric energy, the reduced utilization of industrial capacity, and severe inflation. Further droughts in several areas of the country in 1980-81 aggravated the problem and lengthened the recovery period. The prospects for this years harvest seem good and this may complete the recovery and consign the 1979-80 drought to history. A brief smile of satisfaction can be allowed all around. India, as the Prime Minister has been quoted as having said recently at the North-South Summit at Cancun, is again poised for take-off for rapid development and rapid reduction in poverty.

Agricultural progress must continue but at a greater rate than ever before. Plans to ensure that this will be done are in hand and are embodied in the chapters of India's Sixth 5-year Plan. A compound growth rate of 5.2 per cent per annum is projected for agriculture for the Sixth Plan period, the same figure that is projected for growth in the economy as a whole. The Plan reads very well, all the interlocking calculations have no doubt been done, the targets and projections seem to make sense, and the general tone is optimistic and confident. And yet it may not be enough.

FAO, in a recent document prepared for the Seventh Ministerial Session of the World Food Council (WFC/1981/5), estimates that world cereal production needs to increase at 4 per cent per annum to meet consumption requirements, or at a greater rate if stocks are to be replenished. The National Planning Commission Projection of 3.65 per cent growth in Indian cereal production over the Sixth Plan period is below the consumption requirement projected by FAO. The difference of 0.35 per cent is significant because India is such an important nation in the world grain scene. Nonetheless, the Indian projection itself must be considered somewhat optimistic. At no time in the last 30 years has the growth rate in cereal production for any 5-year period reached 3.65 per cent. Mostly it has ben below 3 per cent. Can India then do more? Can it reach its own projected targets? Can it exceed them? Can it reach a growth rate of 4.65 per cent instead of 3.65 per cent and thus supply grain to other nations and contribute to the replenishment of world food stocks?

If this is possible at all, it is most likely to be in those areas where Plan projections equal or are below recent performance trends. Table 1, modified from a table in the Sixth Plan, gives the figures for cereal production for the 1979-80 base, the production target for 1984-85—the end of the Plan period—the production growth rate necessary to achieve the target production, and the best growth rates in yields per ha achieved in any recent 5-year period for the major cereal crops of the nation. The figures in the last column of the table will vary, of course, depending upon which years are chosen and how average yields are computed, but an examination of the actual yields over the last 10 years for which published figures are available (1968-69 to 1978-79) show that the trends in yield are accurately enough portrayed by the figures shown, except perhaps for pearl millet for which the year-to-year fluctuations are rather large.

The trends in yield suggest that opportunities do exist to increase cereal production above the projections of the Sixth Plan with sorghum and other coarse grains: cereals grown mainly under rainfed conditions. Is this now the time, then, for rainfed agriculture to contribute more than its allotted share to the growth of agricultural and food production in this country?

If increases above the Sixth Plan projections are desirable, should they be sought in wheat and rice rather than in coarse grains? Recent growth in yields per hectare for these two crops are below the substantial growth in their production already required by the Sixth Plan. Thus further increases in their production could be achieved only by increasing the area of land upon which they are grown. For wheat and rice this means increasing the area of irrigated land above the 4.7 per cent annual average growth rate projected in the Sixth Plan which would be difficult and costly to achieve.

Table 1—Production 1979-80 to 1984-85[a] and growth rates for production and yield of cereals in India

Cereal	Production (million tonnes)		Growth rates (per cent)	
	Base 1979/80	Target 1984/85	Production 1979-80 to 1984-85	Yields/ha recent 5-year period
Rice	51.24	63.00	4.2	3.4
Wheat	35.64	44.00	4.3	4.1
Sorghum	10.88	12.00	2.0	6.7
Pearl millet	5.28	5.80	1.9	5.7
Maize	6.23	6.80	1.8	1.5
Other cereals	6.98	7.50	1.5	2.6
Total cereals	116.25	139.10	3.65	—

[a]Data for production and production growth rates taken from Sixth 5-Year Plan, Table 9.6.

In contrast, the growth rates in yields per ha for sorghum and pearl millet are well above their production growth rates projected in the Sixth Plan. Even if land area used for these crops decreased, it still would be relatively easy to achieve higher than projected rates of production.

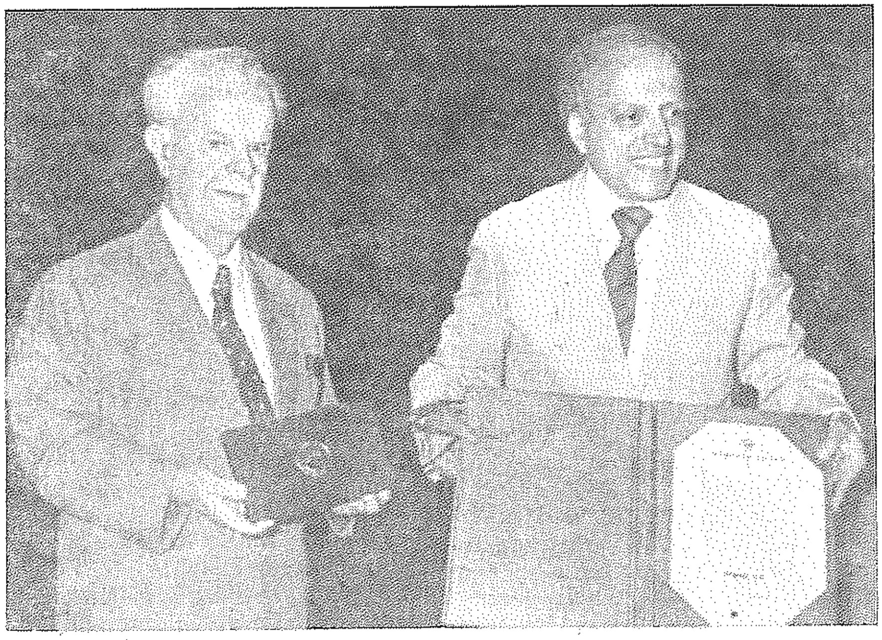
Rainfed Area of Land

Approximately 142 million hectares of land are cultivated in India every year. Of this area, about 108 million hectares is used in rainfed agriculture. Because the possibility of bringing more land into cultivation is small, major attention must be given to increasing the use of existing land.

Massive development of irrigation will be the main approach. The Sixth Plan projects irrigation to increase at an average compound growth rate of 4.7 per cent per year, similar to the projected rates of growth for rice and wheat production. By the mid 1990's, some 70 million hectares of cultivated land will be irrigated. The remaining 72 million hectares, or nearly 50 per cent of the cultivated land, will remain in rainfed agriculture.

The rainfed agricultural areas lie mostly in the center and west of the country between latitudes 12 degrees and 28 degrees north bounded longitudinally by a line running through Dehra Dun and Hyderabad on the east, and the national boundaries or the Western Ghats on the west. Nearly all the districts in this region have less than 25 per cent irrigated land and most have less than 10 per cent. Twenty of the 24 stations of the All India Coordinated Research Project on Dryland Farming, lie west of the line between Dehra Dun and Hyderabad. The remaining 4 stations lie in the rainfed rice growing areas of the eastern States.

The mean annual rainfall in the rainfed area varies from about 350 to 1400 mm. It is seasonal and received mostly during the southwest monsoon except in the southeast where additional rain is received in the northeast monsoon in the last few months of the year. Most of the region is semi-arid, but a substantial area in Rajasthan, Gujarat, and between Sholapur and Ananthapur is arid, with rainfall of 500 mm or less falling in just one or two months.



Sir John Crawford (left) and Dr. M. S. Swaminathan who received the Borlaug Award on behalf of Dr. R. S. Murthy. The Borlaug Award consists of a Gold Medal, a Citation & Cash Prize of Rs. 10,000.

The soils are mostly black—Vertisols and associated shallower soils. But many other soils also occur in this vast area. Red soils—Alfisols—predominate in the southern rainfed regions below Hyderabad, red and yellow soils—Ultisols—in eastern India, and alluvial soils in the rainfed agricultural areas of the river basins. The technology used in rainfed farming must be tailored to the soils to which it is applied.

Currently, the rainfed region provides only 42 per cent of foodgrain production, but almost all the coarse grains, pulses, a substantial amount of rainfed rice and wheat, and most of the cotton are produced there. Average yields are low, generally below 800 kg/ha. It is not difficult to believe that these low yields can be increased by 50 to 100 per cent with the technologies that now exist.

Developing Rainfed Areas

The lead combination—improved seeds and fertilisers

To the surprise of many an academic, the subsistence farmer on close acquaintance proves to be a rational human being experienced in making economic choices and decisions. He is a subsistence farmer more by circumstance than by choice. Offer him proven opportunities to significantly increase his income and improve the quality of his life and he will gladly accept them. But do not expect him to accept technological changes that are not adequately tested or understood, or which cannot fit his circumstances. The more complicated the technology, the less willing he will be to try it. The possibility of adopting a package of practices piecemeal is likely to have considerable appeal.

The combination of improved, input-responsive seeds and fertilisers is composed of elements with which most farmers now have some acquaintance, is scale neutral and simple enough to try. An overwhelming body of evidence suggests that the combination succeeds in nearly all years in most rainfed regions. Its adoption provides substantial financial benefits to the farmer changing his attitude towards intensive agriculture and giving him the confidence to accept other improved practices.

Improved seeds

The combination of genes for reduced plant height and reduced susceptibility to lodging with genes for responsiveness to applied nutrients resulted in quantum jumps in the yields of wheat and rice in irrigated agriculture. Similar approaches are proving successful with maize, sorghum and millets grown in rainfed conditions. Improved varieties and hybrids significantly outyield local varieties in most years in most rainfed areas. The cost of purchasing improved seeds is small for these crops and the benefits substantial. The ratio of benefit to additional cost is often in excess of 10—by all standards sufficient to ensure widespread adoption. Satisfactory grain quality, earliness and suitable levels of disease and pest resistance are necessary in combination with the high yields to make the improved cultivars attractive to farmers. Although year-to-year variability in yield is higher for improved cultivars than for local varieties, the yield gains and other characteristics of good cultivars are sufficient to persuade farmers to take the higher risks involved. In Maharashtra State hybrids now make up 35 per cent of all sorghum planted in in the rainy season, and improved varieties make up more than 70 per cent in the post-rainy season. Average yields in the State are 50 per cent higher than they were ten years ago.

In spite of the apparent benefits, rates of adoption of improved seeds of the dryland crops lag far behind the rate of adoption of high yielding varieties of irrigated wheat, although they are not so far behind the rates for high yielding varieties of irrigated rice (Table 2). Sometimes improved cultivars are susceptible to pest attack when grown near local varieties, or their grain quality is judged inferior or they do not provide enough straw for forage. These are generally transient problems that diminish in importance as the improved seeds spread. Transient, too, is the farmer's perception that the new varieties are more risky in rainfed conditions. New varieties and hybrids now go through many years of tests before they are released for farmers' use. They perform better under stress than local varieties, and better under both low and high fertility conditions also.

Perhaps the major reason for the slow rate of adoption is that the introduction of new seeds alone does not represent a large enough change in the pattern of traditional agriculture to arouse the farmer's interest. Small faults or problems either real or imagined associated with the new seeds dissuade him from trying them. They are simply not worth the trouble.

Fertilisers

Although most of the soils in the rainfed area of the country are low in fertility, particularly in nitrogen, phosphorus and zinc, fertilisers are not commonly used in rainfed agriculture. Districts with less than 25 per cent irrigated land use an average of 18 kg/ha of fertilisers ($N+P_2O_5+K_2O$) per hectare of cropped area compared to 57 kg/ha in irrigated districts. Most of the fertilisers used in these unirrigated areas are concentrated on the small areas of irrigated crops such as rice and sugarcane, but some are used on dryland cash crops such as cotton, tobacco and groundnut, or on high yielding cultivars of sorghum or millet.

There is much evidence to show that fertiliser use is economic on the staple, rainfed cereals. Several hundred experiments on cultivators' fields with sorghum, maize and pearl millet in rainfed areas of India have given average gains of 14 kg of grain per kg of N and 7 kg of grain per kg of P_2O_5. Benefit to cost ratios are 2.5 or better. Responses to fertilisers by available varieties of rainy season sorghum and pearl millet are generally better than responses by rainy season maize or post-rainy season sorghum.

Soil type and particularly water-holding capacity of the soil have significant effects on the efficiency of fertiliser use. Crops grown on the same soil in the rainy season will usually have higher fertiliser-use efficiencies than crops grown in the post-rainy season on receding stored moisture.

Table 2—Adoption of HYVs for important food crops of India (1966-67 to 1977-78)[a]

Cropping year	Paddy: Total cropped area ('000 has.)	Paddy: HYV adoption (per cent)	Wheat: Total cropped area ('000 has.)	Wheat: HYV adoption (per cent)	Maize: Total cropped area ('000 has.)	Maize: HYV adoption (per cent)	Pearl millet: Total cropped area ('000 has.)	Pearl millet: HYV adoption (per cent)	Sorghum: Total cropped area ('000 has.)	Sorghum: HYV adoption (per cent)
1966-67	35,251	2.5	12,838	4.2	5,074	4.1	12,239	0.5	18,054	1.1
1967-68	36,437	4.9	14,998	19.7	5,583	5.1	12,808	3.3	18,423	3.3
1968-69	36,967	7.1	15,958	30.0	5,716	6.8	12,052	6.2	18,731	3.7
1969-70	37,680	12.0	16,626	36.7	5,862	6.7	12,493	10.2	18,605	3.1
1970-71	37,592	14.9	18,241	35.5	5,852	7.9	12,913	15.9	17,374	4.6
1971-72	37,758	19.6	19,139	41.1	5,668	8.7	11,773	15.9	16,777	4.1
1972-73	36,688	22.3	19,463	52.7	5,838	8.7	11,817	21.2	15,513	5.6
1973-74	38,286	25.4	18,583	58.7	6,015	13.0	13,934	23.6	16,716	6.9
1974-75	37,889	28.4	18,010	62.3	5,863	11.2	11,285	22.4	16,189	8.1
1975-76	39,475	31.5	20,454	65.8	6,031	18.8	11,571	25.0	16,092	12.2
1976-77	38,511	34.6	20,922	69.4	6,000	17.7	10,751	21.1	15,772	15.5
1977-78[b]	40,002	39.0	21,203	73.3	5,700	20.5	11,035	23.8	16,273	18.7

[a]Table kindly supplied by T. S. Walker.
[b]Anticipated.

Correct timing and placement of fertilisers are important for beneficial results. Nitrogen is most effectively used in split applications. Compound fertilisers, containing nitrogen, phosphorus, and sometimes other nutrients, when used should be properly tailored to the needs of crop and soil. Farmyard manure, green manures or legumes in rotation are all valuable contributors of nutrients that can reduce to some extent the amounts of commercial fertilisers that must be otherwise used.

Although the results would suggest that fertiliser use alone is a satisfactory lead practice, there are too many examples where fertilisers added to local varieties did not provide significant improvements or did not cover the additional cost involved. Although far too few experiments have been carried out long enough to obtain useful probabilities over time, the negative results are sufficient to feed farmers' fears and deter Government agencies from recommending the application of fertilisers to local cultivars, particularly in dryland agriculture. Because of this lack of interest or enthusiasm, the distribution system for supplying fertilisers in a timely manner to the villages is seldom adequate and further hinders their adoption. Inappropriate recommendations of balanced fertilisers do not help.

Combining seeds and fertilisers

Although use of improved seeds or the addition of fertilisers to local varieties provide added benefits in most years, the additional yield of 300 to 400 kg/ha is not sufficient to lead to change. A combination of improved seeds and fertiliser, however, yields an additional 1,000 to 1,500 kg/ha or more, gives positive and beneficial yields consistently and provides the spark that is needed. The added benefits, often exceeding Rs. 2,000/ha, can significantly improve the farmer's income. The greater yields can significantly increase the production of foodgrains in the country.

Farmers are already aware of the value of combining improved seeds and fertilisers in the rainfed areas. Where adapted fertiliser-responsive varieties or hybrids are grown, they are usually fertilised (1). There are 20 rainfed districts in the country in which sorghum is an important rainy season crop. In 16 districts, farmers fertilise more than 75 per cent of the improved rainfed sorghum cultivars they grow, in 7 they fertilise it all. There are 7 districts in which pearl millet is an important rainfed and rainy season crop. Farmers fertilise more than 75 per cent of their improved, rainfed pearl millet cultivars in all but one of the districts.

If these farmers have already adopted the combined use of improved seeds and fertilisers to their benefit, then many more could and should. But there are some deterrents. Although the added benefits are substantial, the added cost ranging from about Rs. 400—1,000 per hectare can be a problem for the small or marginal farmer who lacks access to institutional credit. The lack of well adapted fertiliser-responsive cultivars, for example, for post-rainy season, sorghum obviously prevents the use of the combination. Inadequate fertiliser distribution, inadequate extension and inadequate infrastructure in general are deterrents to the adoption of improved seeds plus fertilisers as they are to other improvements in agriculture.

The lead combination of improved seeds and fertilisers is a satisfactory and relatively inexpensive beginning strategy throughout the rainfed areas, but it will give only limited and erratic results if it is not combined with other improved practices. The rest of the package is necessary to take account of the basic climatological and soil characteristics in different areas and districts to assure stability of yields, ameliorate some of the effects of drought and increase food production per unit of land and capital.

Improved management of soil

Effective soil management practices in the rainfed areas produce a suitable seedbed, ensure the proper placement of seed and fertilisers, control weeds, conserve soil moisture and minimize runoff and erosion.

Dry season primary tillage is now a common practice in many rainfed areas. The soils are ploughed or harrowed in March or early April, after any post-rainy season crop is harvested. Because there is still some moisture in the soil, the power required for tillage is less than it would be later in the season and draft animals are well-fed and strong. Some weeds will grow but these can be removed in the final preparation of the seedbed, which is done nearer to the onset of the rains. Pre-monsoon showers, which are nearly certain climatic events in most rainfed districts, will soften the soil for final land preparation.

Crust formation on the surface is a problem with many sandy-textured soils. The power required to break the crust is low but the crust reforms after rains, impedes seedling emergence and increases runoff and erosion. Incorporating organic matter into the soil helps to decrease the strength of the crust—probably by increasing soil moisture near the surface—but no satisfactory technology yet exists for dealing permanently with this problem.

Time of planting is important for both rainy and post-rainy season crops. Planting as early as the rains will permit is now firmly recommended. It makes the best use of available water, avoids certain pest and disease problems and ensures good yields in most years. For soils that have low capacities to store moisture, very early planting may not be the wisest course because of the erratic early season rains. Planting two weeks after the onset of the rains gives generally better and safer yields for these soils. Probabilities based on climatological evidence can now be used to predict optimum planting dates for various crops on different soils.

Accurate placement of seed and fertilisers ensures high seedling densities, vigorously early growth and resistance to drought, but is seldom attained in traditional agriculture. Practicable and economic new technologies to ensure accurate placement in rainfed conditions with bullock-drawn equipment have yet to be developed. Great gains can be made here from increased research.

Timely weed control measures are important to conserve moisture under fallow and to avoid competition to the standing crop. Poor weed control can reduce yields by 50 per cent or more. The use of herbicides is uneconomic or uncommon except on some cash crops, and weeding is done manually or by using animal-drawn implements. Weeding is a major source of employment for landless labour.

Improved management of rainfall

In the rainfed areas of India, there is no normal rainfall year. Erratic rainfall falling on soils with poor infiltration characteristics causes many difficulties and problems. The use of straw mulches or deep ploughing are proven techniques for improving infiltration and available soil water, but are not practicable in present-day Indian conditions where nearly all crop residues are removed from the land and bullock power is generally inadequate to allow deep tillage. The solution is to use the small watershed as the basic farming unit, making use of its natural topography and drainage patterns.

Contour farming or the use of ridges or broadbeds and furrows within the watershed greatly improved rainfall management and water availability to crops where the land has gentle slopes. Bench terracing is needed where slopes are greater.

Land treatment can be carried out by the farmer himself in gently sloping land at very little cost. Land smoothing can be accomplished with traditional equipment, and bullock-drawn equipment and implements are now available to make the graded ridges or beds and furrows. Contour bunding appears to be no longer recommended. Bench terracing and the construction of conservation structures and community drains will all require active Government cooperation. Many of the benefits from these measures accrue to the community as a whole, and those that are captured by the farmer himself are usually of a long-term nature. It is appropriate in these circumstances for Government to provide substantial financial support and incentives for these measures.

Dry seeding before the onset of the rains is a means to increase water-use efficiency on soils with good water-holding capacities. It is not a difficult practice for farmers to understand and adopt, but it has not been proved successful with all crops. The utilization of deep rooted plants that harvest the water in the lower horizons of the soil increase the efficiency of water use.

Proper choice of cropping systems

The best crops and cultivars to use in any particular district depend upon climate, soils and agricultural and socio-economic traditions. Considerable efforts by the All India Coordinated Research Project for Dryland Agriculture have now determined the most appropriate crops for most of the rainfed regions of India.

Intercropping and sequential cropping are common enough practices now in rainfed agriculture. They increase the efficiency in use of natural and capital resources, and return two incomes a year from the farm instead of one.

Intercropping has traditionally been the small farmers' means of reducing risk and extending the cropping season. Research has confirmed the wisdom of the farmer's practice—even though not all farmers' combinations are scientifically sound—and intercropping combined with improved seeds, fertilisers and improved soil management is a highly profitable and stable means of increasing crop yields and cropping intensity in rainfed agriculture. Many of the rainfed black soils traditionally cropped only in the post-rainy season can produce two crops a year without difficulty. Intercropping is one way to bring about this major increase in production.

Double cropping, that is, the growing of two sole crops in sequence, is an alternative to intercropping favoured by the largest farmer or by farmers with some access to irrigation. Input-responsive cultivars are generally earlier maturing than local varieties and increase the possibilities for double cropping.

On Alfisols and sandy alluvial soils, which do not store enough moisture to allow production of two crops a year, multiple cropping can at least allow the season to be extended. Relay cropping may be possible where very short season crops such as early millets, mung bean or cowpea are grown. Intercropping with long season hardy crops such as castor or pigeonpea ensures the use of residual soil moisture and provides some additional yield.

Supplemental life-saving irrigation

Dry periods within the normal rainy season are typical of many monsoonal climates even when normal or above normal seasonal rainfall occurs. The result is usually a reduction in crop yield especially on soils which have relatively low water-holding capacities. Having water available for supplemental irrigation is an important means of reducing risk and improving production in rainfed agriculture.

Many of the farmers in rainfed areas have access to water from wells, streams and tanks. One survey has estimated that 50 per cent of the farmers have some source of minor irrigation and that with the water available they can irrigate about 4 per cent of their land. The amount seems small, but it probably can be used more efficiently for life-saving irrigation on fertilised, high-yielding upland crops than on small areas of rice. In a much-quoted example from ICRISAT one 5 cm irrigation strategically applied during a dry spell on a red Alfisol nearly doubled the yield of sorghum and maize. At product prices prevailing at the time of harvest, gross values were increased by Rs. 3,120 per hectare for maize and Rs. 2,780 for sorghum. Our chairman, Sir John Crawford, in the fourth Coromandel Lecture estimated that water will add about 500 kg/ha to the yield of grain crops.

During the post-rainy season, supplemental irrigation can substantially boost crop yields because residual soil moisture is seldom sufficient to prevent drought stress at important physiological stages of growth. The appropriate time for this irrigation must be chosen with care to make the best use of the water applied. For chickpea, a typical post-rainy season crop, irrigation before sowing is highly beneficial in ensuring good stand density and a profitable crop. For grain sorghum, the most important times for supplemental water are panicle emergence and flowering.

Significant opportunities exist for water harvesting in the rainfed areas. Runoff from heavy rains occur in all but the driest years providing opportunities for water harvesting. So far, successful, profitable examples are few and specific to location. A more concerted research effort is required before water harvesting in rainfed areas can be considered more than a promise.

Benefits and costs in step-wise adoption of technologies

At ICRISAT over the last 5 years data have been obtained on the benefits and costs of step-wise adoption of improved technology on a deep Vertisol, typical of soils that occur in the center of the rainfed region, and an Alfisol, typical of soils that occur in the south. The rainfall at ICRISAT—about 800 mm annually—is in the middle of the range for the

Table 3—Average gross returns, inputs and gross profits from improved technology for the period 1976-79 on a deep black soil (Vertisol) at ICRISAT

Treatment no.	Description of treatment				Average		
	Seed	Fertiliser	Management	Irrigation	Gross returns (Rs/ha)	Inputs (Rs/ha)	Gross profit (Rs/ha)
1.	Local	Local	Local	No	1,716	1,230	486
2.	Local	Local	Improved	No	2,147	1,116	1,031
3.	Local	Improved	Local	No	2,385	1,576	809
4.	Local	Improved	Improved	No	3,003	1,491	1,512
5.	Local	Improved	Improved	Yes	3,374	1,745	1,629
6.	Improved	Local	Local	No	2,610	1,273	1,337
7.	Improved	Local	Improved	No	3,069	1,225	1,844
8.	Improved	Improved	Local	No	3,891	1,672	2,219
9.	Improved	Improved	Improved	No	4,802	1,557	3,245
10.	Improved	Improved	Improved	Yes	5,623	1,811	3,812

rainfed areas. The examples, therefore, may have relevance in a fairly wide area, but evidence suggests that they will not apply to those black soil areas where, because of paucity of total rainfall or shallowness of soil, no more than one crop per year is feasible.

The data are given in Tables 3 and 4, expressed in rupees per hectare instead of yields, because various crop combinations were tried over the period of the experiments. The results are averages for five separate experiments over a 4-year period.

On the Vertisol, additional gross returns of Rs. 894 were obtained from the use of improved seeds alone (Table 3). The average additional cost of the seeds was only Rs. 43 per hectare giving a benefit to additional cost ratio of 20.8. Fertilisers alone, without improved seeds, gave an added value of Rs. 669 for an extra cost of Rs. 346. The benefit to cost ratio of 1.9 would not be sufficient by itself to induce farmers to accept fertilisers. Furthermore, in some years the returns to fertilisers alone were not sufficient to cover the costs involved.

The combination of improved seeds and fertilisers resulted in a very substantial increase in gross returns of Rs. 2,175 per hectare more than double the gross profit obtained using traditional practices. The cost of fertiliser and seed was Rs. 440 giving a benefit to cost ratio of 4.9. The profit from the combination of improved seed and fertilisers was more than the cost in all five experiments.

Combing improved seeds and fertilisers with improved management, in this case the use of raised beds and furrows, more careful placement of seed and fertiliser and more intensive weeding, that is, a full package of improved practices, increased gross returns by Rs. 3,086. Average added costs were Rs. 327 for a benefit cost ratio of 9.4. The use of supplementary water increased profits by an additional Rs. 570 equivalent to about 5 quintals per hectare of increased yield, confirming the figure given earlier by Sir John.

In the similar set of experiments conducted on the Alfisols, average gross returns rose from Rs. 1,403 per hectare under simulated traditional practices to Rs. 3,823 using improved seed, fertiliser and management (Table 4). Average gross profits rose from Rs. 424 to Rs. 2,625. Improved seeds alone gave a benefit to cost ratio of 10.7, improved fertiliser gave 2.38 and improved seeds plus fertiliser 3.9. For the package of practices without supplementary irrigation, the benefit to cost ratio was 11.0. For

Table 4—Average gross returns, inputs and gross profits from improved technology for the period 1976-79 on a red soil (Alfisol) at ICRISAT

Treatment no.	Description of treatment				Average		
	Seed	Fertiliser	Management	Irrigation	Gross returns (Rs/ha)	Inputs (Rs/ha)	Gross profit (Rs/ha)
1.	Local	Local	Local	No	1,403	97[illegible]	424
2.	Local	Local	Improved	No	1,919	968	951
3.	Local	Improved	Local	No	1,872	1,176	696
4.	Local	Improved	improved	No	2,853	1,149	1,704
5.	Local	Improved	Improved	Yes	2,977	1,371	1,606
6.	Improved	Local	Local	No	1,887	1,024	863
7.	Improved	Local	Improved	No	2,277	1,011	1,266
8.	Improved	Improved	Local	No	2,295	1,206	1,089
9.	Improved	Improved	Improved	No	3,823	1,198	2,625
10.	Improved	Improved	Improved	Yes	3,676	1,395	2,281

this soil irrigation did not increase the profits obtained.

Adopting full package of practices

The stepwise or piecemeal adoption of a package of practices commencing with a combination of improved seeds and fertilisers will enable the spread of modern agriculture and higher production throughout the rainfed areas. Where the lead practices are already in use, or in well-favoured locations, it is possible to consider adopting a full package of proven practices. Although the total effort required to convince the farmer to use such a package is greater, the benefits are correspondingly larger.

One technology that appears to be ready for adoption on a wider scale is the rainy season use of millions of hectares of deep Vertisols that currently are farmed only in the post-rainy season (2). A technology developed at ICRISAT and tested on the research station at an operational scale over the last seven years has been moved this year into pilot-scale testing in farmers' fields. The technology is bullock-powered and based upon the concept of the small watershed as the basic resource management unit. It appears well-suited to the deep Vertisols with annual average rainfall between 750 and 1200 mm, that is, to vast areas of soils in the States of Madhya Pradesh, Maharashtra, Andhra Pradesh and Karnataka. Cooperative and independent research by ICAR and University scientists give results that agree in many respects with those achieved at ICRISAT. The possibility of utilizing this technology in whole or in part appears to be recognized in the Sixth 5-Year Plan which refers (paragraph 9.30, page 103) to increasing agricultural production in rainfed lands on a watershed basis in areas with annual average rainfall between 750 and 1125 mm.

For on-farm verification of the technology, we have been working with farmers in the village of Taddanpalle, 40 km north of ICRISAT in Medak District. It has the right soils, slopes, and rainfall. The farmers after some initial hesitation agreed to cooperate with us even though it meant substantial changes in their manner of farming and some changes in other aspects of their lives. The farmers are very poor in this village, but they agreed to pay virtually all the costs and do virtually all the work that was needed to test the technology. Where they needed financial help, the State Department of Agriculture assisted them in finding it, either through the banks or through existing Government channels. The research agencies—ICRISAT, ICAR, and APAU—agreed only to provide advice and some services, and ICRISAT agreed to compensate the farmers up to the normal level of their traditional yields if the experiment proved to be a failure.

In February of this year, after the traditional crop had been harvested, ICRISAT and State engineers surveyed the land and planned the watershed, leaving in place the property boundaries. The farmers did the land smoothing work with their own animals and equipment, but used the ICRISAT tool carrier behind their bullocks for most operations. The animals were rather weak, and because the traditional crop was harvested late, the soils were already quite hard. It did not take long for the farmers to get used to the equipment, but the beds and furrows were not well made—but no worse than the first ones we put in at ICRISAT in 1973.

Although the farmers were willing to install drainage ways on their own land they were not willing to work collectively to install the necessary community drains to connect the watershed to the existing main drain system. In consequence, in the very heavy rains in the early part of the year, the watershed did not work properly and the lower parts of some fields were flooded. When the farmers saw this and saw how this did not happen at ICRISAT, we were able to persuade them to undertake the construction of the community drains. The State Department of Agriculture, through its existing soil conservation programme, paid for their labour to put the drains in place. Since then, in a year where the rainfall has been 70 per cent above normal, there have been no further problems of waterlogging or drainage.

ICRISAT and the other research agencies recommended what crops would be best, but the farmers made their own choices. In consequence, on this 15 hectare watershed with 14 farmers we have eight different crop combinations. With one exception, the crops have done well and far exceed anything else for miles around. Not surprisingly, there have been some problems. The farmers are not used to obtaining such high yields. Threshing and storage are new problems for them, accentuated in this very wet year because it has not been possible to dry the grain on the head in the field.

Average yields on the 23 separate fields—some farmers divided their fields to try different crop combinations—have been 2,000 kg/ha for sorghum grain, 7,576 kg/ha for sorghum dry fodder, 1,737 kg/ha for maize grain, 3,561 kg/ha for maize dry fodder and 490 kg/ha for mung bean. Much of the crop will be sold this year but some will be consumed within the village. Based on market prices, farmers have already covered their direct costs including the cost of land smoothing and shapping and have made a profit. And they still have the post-rainy season crop to come. Most of the adjoining farmers, having fallowed their land in accordance with traditional practice, have as yet reaped neither food nor income.

The stability question

The erratic nature of rainfall always makes rainfed farming a risky business. The farmer is well aware of this, indeed he seems preoccupied by it. He tends to plan for the bad year.

There is ample evidence to show that the increased yields that come with the use of improved seeds are accompanied by increased fluctuations around the mean. Although the absolute variability is thus increased, the relative variability is reduced because of the higher average yields obtained. This increased variability —of instability—certainly worries the economist. Does it worry the farmer, and if so, what should he do about it?

No doubt the farmer is concerned about risk. His is a very risky life, but we know that he does not shun risk. We find that he is moderately but not strongly averse to risk; he is willing to accept the risk involved with improved seeds if their yield potential is high and they otherwise meet his needs. Increased variability or instability will not concern him too much if he continues to make a profit. A concern for complete crop failure will restrain him from investing in modern agriculture.

Multiple cropping and particularly intercropping increases stability as shown in one recent study by ICRISAT. It was found that crop failure with pigeonpea may occur 1 year in 5, in sorghum 1 year in 8, but with the intercrop of sorghum and pigeonpea only 1 year in 36. It is true, from a mathematical point of view, that the combination of the intercrop is less stable than it should be, but this should not worry the farmer. His productive agricultural life is unlikely to extend to the 40 years needed to test the stability of intercropping.

Instability is also reduced by using cultivars that are resistant to pests and diseases and by using more uniform planting dates district by district. As has already been mentioned, the farmer often may have access to a small supply of supplemental irrigation which if used judiciously can prevent significant reductions in yield.

From years of experience, the farmer understands how to cope with drought in all but the worst years. His ability to handle the situation depends upon the nature and size of his farm, the production systems he uses and the alternatives available. Small farmers adjust more rapidly than large ones. A mechanized farm can install drought-adapting practices more rapidly than a non-mechanized one, a sole commodity farm is less adaptable than one with mixed commodities. In the infrequent years of very severe drought, Government intervention is essential. Left to himself at those times, the farmer may need to dispose of his productive assets, to migrate in search of work, even to sell his land. He and his family may never recover from such drastic steps. A minimum programme of crop insurance in rainfed farming will serve not only to take care of these problems but act as a substantial incentive to raise production in general. There is no doubt that the farmer in rainfed agriculture in India under-invests because of uncertainty and risk. Guarantee him a certain minimum and his conservative economic stance will change.

Inputs and institutions

The technology needed to develop the rainfed regions must be supported by adequate and timely supply of improved seeds, appropriate fertilisers and agricultural chemicals and the provision of technical and institutional services.

To establish the lead combination of improved seeds and fertilisers throughout the rainfed area, there must be a supply of improved input-responsive seeds of an array of crops. Almost all the annual crops of India are grown in this vast area, and farmers often need to change the crops they grow for a variety of reasons. Opportunities to choose must be available. The strong agricultural research network that India has built can service this need.

New market facilities and strategies will be needed to cope with increased local supplies of crops. Storage facilities will be needed both on-farm and in local market towns to prevent storage losses and to help ensure that what is supplied through the market network is in reasonable balance with demand.

With the necessary institutional services in place—as indeed they are in most of the rainfed districts—and seed and fertiliser supplies assured, the lead combination can be spread by an expanded and well-organized programme of extension demonstrations. Achieving the adoption of a full pockage of practices is more difficult. It requires the organization of village-level operational research and pilot projects.

The key to the success of such projects is the human factor: the interest and involvement of the farmers and the constant and dedicated attention of trained, motivated and resourceful field extension staff backed up by production and management specialists who are available when called. The Union Minister of Agriculture and Rural Reconstruction in his inaugural address at the 75th Anniversary Celebrations of IARI suggested creating a management infrastructure in which the State would become a partner with the millions of small and marginal farmers in the management of a modern agriculture wholly owned by the farmers themselves. Public servants oriented towards joint management with farmers could ensure success not only of the pilot projects but also of the subsequent operational projects throughout the land. Without such support, a programme of development of rainfed agriculture could become a "shell without substance", the term used by Sudhir Sen (3) to describe the Community Development Programme in its latter days.

Achieving 4 per cent Growth in Cereal Production

The Sixth 5-Year Plan projects an average annual growth in cereal grain production of 3.65 per cent over the Plan period. FAO has called for 4 per cent. I have tried to show that increased production of grain can be obtained by developing rainfed agriculture. It is interesting to consider whether and how the additional production could be achieved from the rainfed areas, that is, to raise the Sixth Plan cereal grain production target by 2.3 million tonnes over the 5-year period.

The easiest way would be to enable—or simply to allow—sorghum production to continue to increase at or near the average rate, 6.3 per cent, that it has increased over the most recent 8-year period for which data is available—1969-70 to 1977-78. This would more than fulfil the requirement. An annual average growth rate for sorghum production of only 5.6 per cent would provide the added 2.3 million tonnes required. There seems no reason to think that this could not be achieved, particularly because the Sixth Plan emphasizes increased production from rainfed agriculture.

Other crops besides sorghum are, of course, necessary: the emphasis on sorghum is to some extent symbolic. Pearl millet production could certainly be increased now that new downy-mildew resistant hybrids are available. More pulses, oilseeds and fibre crops could also be produced.

For maize and rainfed rice the situation is different. Suitable technologies acceptable to the farmer do not yet seem to have been evolved for these crops in the areas where they are mostly grown. A substantial effort in agricultural research and extension, and improvements in infrastructure are still required to raise growth rates of production for these crops. Efforts are needed in eastern India and the hilly and tribal areas. Efforts would be rewarding, therefore, for important social reasons.

The additional requirements for inputs to obtain the increased production appear quite modest. Using as a basis for calculation the results of the national agronomic demonstrations in recent years, I have calculated that an increase in sorghum of 2.3 million tonnes by the end of the Plan period would add only about 1.5 per cent to the Plan targets for certified seed and for nitrogen, phosphorus and potassium fertilisers. No doubt the Plan proposals for increases in these inputs are already considered highly optimistic or ambitious in some quarters, but the totals I am talking about, that is, adding about 8,000 tonnes of certified seed and 130,000 tonnes of additional plant nutrients, do not seem to me to place an insuperable extra burden upon the industries concerned. Surely Coromandel Fertilizers Ltd. would appreciate a chance to help meet the challenge.

The Government has recently acknowledged shortfalls in the supply of certified seeds. But the seed rates for sorghum, the millets and maize are so low—about one-tenth the seed rates for irrigated wheat and rice—that problems of seed supply could surely be minimized.

Supply of course is not enough. Distribution and technical services are both essential components of such a programme. The Government has already given a lead by insisting that fertiliser distribution to at least every block headquarters in the country should be accomplished by the end of this Plan period. The Fertiliser Industry although raising some caveats has agreed to try. I hope it will be possible to go further; to bring inputs to every village, at least in that rainfed region with rainfall between 750 and 1200 mm where the greatest potential for increased production exists.

Improvements in technical services are already in hand. The country has embarked upon a determined effort to increase the efficiency and availability of agricultural extension services throughout the country. My impression is that it is succeeding but that it has a long way to go. ICRISAT has been undertaking socio-economic studies in 11 villages, 7 of them within the most suitable area for increases in rainfed farming. None of those villages appear to be receiving regular attention from the extension services. The farmers have been only vaguely aware of the real potential of improved technology. We have since introduced improved technology into 4 of those villages, and the farmers have been most interested and responsive.

Private industry too must do its share. The rewards appear substantial. In a recent publication, one fertiliser company described its own experiences in participating in a production campaign in rainfed areas in Maharashtra. Over a 3-year period fertiliser consumption was increased at a compound annual growth rate of 34 per cent and the company increased its own sales at a compound annual growth rate of 60 per cent. I am sure that supply rather than demand will limit the continuance of growth rates of this magnitude.

The research and demonstration efforts that have been made in recent years in the rainfed areas have identified a few items that are needed in addition to the normal technical and institutional services for agriculture. Improved land management increases the demand for bullock power compared with present utilization patterns. Small farmers in particular find the lack of bullocks to be a major constraint. If the banks presently do not provide loans for the purchase or custom-hiring of animals, policies may be required to enable this to be done.

To effect the improved drainage that is needed during periods of heavy rainfall requires the provision of community drains, that is, drains that serve several farmers or several villages. The farmers themselves quite naturally are unwilling to bear the cost of these community works, although they may be willing to provide the necessary labour. State Soil Conservation programmes are able presently to provide only part of the funds and services required. Other major rural development programmes, such as the Food for Work and National Rural Employment Programmes presumably could be utilized. At the present, these appear to be mostly oriented towards the drought prone areas, but greater coverage throughout the rainfed region of the country would seem necessary and beneficial.

Improved technology, at least as we see it from ICRISAT, requires some improvement in farm implements. Wheeled tool carriers, if heavy enough, improve seed and fertiliser placement and by reducing the bullock-power and manpower needed for each operation, increase the number and timeliness of the operations that can be performed. The tool carriers and implements that perform best are costly—at about one-tenth of the price of a tractor—and are out of the reach of individual small farmers. Entrepreneurs who would custom-hire the tool carrier may need to be encouraged by appropriate policies. One possibility would be the extension of the educated unemployment scheme to include the financing of wheeled tool carriers.

I have not tried to calculate the additional outlays of public funds that would be needed to promote increased production in the rainfed areas. My impression is that the amounts would be modest, probably of a similar order of magnitude to what I have shown for increased inputs. Perhaps these are already in train in accordance with the Sixth Plan's emphasis upon rainfed agriculture. Actually the planned growth rates for rainfed cereals that are shown in the Sixth Plan and Table 1 do not seem to agree with the stated emphasis. The higher figures that I have proposed would, I suggest, bring anticipated achievements more in line with the statement and with the major Plan objectives of increasing growth through more efficient use of resources and improved productivity, in reducing poverty and unemployment, in reducing regional inequalities in the rate of development and in protecting and improving the nation's ecological and environmental assets.

Concluding Statements

The rainfed area is the home of millions of people. Their per capita income is low. Most of them are disadvantaged and backward by every measure and criterion. Their basic needs are inadequately met.

An increase in rainfed farming of the magnitude that is suggested here will add many crores of rupees to total income but the increase in per capita income would be small. For the rural areas in which the income increases would actually occur, however, they would mean a lot. For example in the Akola district of Maharashtra, our research over the last 6 years shows that use of the lead practices of improved seeds and fertilisers throughout the district would double gross returns and, after allowing for normal costs including more labour or increased returns to labour, *would provide a net increase in per* capita income to small and medium farmers and their families *of about* 25 per cent.

What would the rural people do with such an increase? Strangely enough, there is little research information available to answer this question. There are numerous studies on the inverse of this question. "What do they do in times of drought?" but next to nothing on what they will do in good times.

What evidence is available from expenditure and price elasticities (4) suggests that they would consume *more food*: more calories and more protein, more sugar and less starch, more protective foods such as milk, vegetables and fruits. If they could obtain more fuel they would have more cooked meals and fewer intestinal parasites. No doubt they would put more into important social obligations. If their incomes increased sufficiently they would buy more radios—thereby increasing their access to technological information—and bicycles—thereby increasing their access to the market. They might elect to keep their children in school for one more year or improve their homes and household sanitation. Surely rural people can hope for—even expect—such modest improvements in the quality of their lives.

I have left to last a consideration of the *utilization of the increased* crop production that would come from a push to develop rainfed agriculture. There is no need to dwell on what would happen to the increased production of pulses and oilseeds, nor do I think that any case needs to be made for the increased production of industrial crops. This leaves us then with only the cereals to worry about. Is there a problem? I think not. While the whole emphasis of this lecture and indeed of Government's plans in agriculture relate to the all important concern to ensure food supplies for the people, it is obvious that the feed grain industry in this country is growing at a faster rate than the food grain industry. There is potential there to absorb additional production.

India's involvement in the international grain trade over the last two decades has mostly been on the receiving end. This, *too, is changing.* Over the last two years or so, there have been exports of grain. The Minister of Agriculture and Rural Reconstruction in the speech referred to earlier has suggested that this country could export 5 *million tons of* foodgrains in the next few years on a continuing basis. The Sixth Plan refers only to the export of rice, but there is no reason not to include other food—and feed—grains.

Finally, if the farmer cannot find anything else to do with the grain he produces, he and his family can always eat it. The rural people of this country have nutritional deficiencies, the most important in calories. They simply do not get enough to eat. Our studies on the disaggregation of risk in rainfed agriculture show that the farmer faces greater instabilities in yield than in price. The subsistence farmer and his family must still worry most about their ability to subsist. They must *somehow* get beyond this stage if they are *to* contribute to development.

The successful *agricultural* experience of recent years has taught us that agriculture is a potent instrument for rapid economic growth (5). What now needs to be realized is that the rainfed areas are not just problem areas requiring famine relief and protection, but can be major contributors to growth, and to increasing employment and *to the rapid* reduction of rural poverty.

References

1. D. Jha, S. K. Raheja, R. Sarin and P. C. Mehotra. Fertilizer use in semi-arid tropical India: The case of high-yielding varieties of sorghum and pearl millet. ICRISAT Economics Program Progress Report, 22 June 1981.
2. Improving the Management of India's Deep Black Soils. Proceedings of the seminar on management of deep black soils for increased production of cereals, pulses and oilseeds, New Delhi, 21 May 1981. Sponsored jointly by ICAR and ICRISAT.
3. Sudhir Sen. A Richer Harvest. New Horizons for Developing Countries. Published by Tata-McGraw Hill Publishing Co., New Delhi, 1974.
4. R. Radhakrishna and K. N. Murthy. Models of complete expenditure systems for India. International Institute for Applied Systems Analysis Working Paper WP-80-78, May 1980.
5. The point is well-made by M. S. Swaminathan in his Presidential Address "Indian Agriculture at the Crossroads" to the Indian Society of Agricultural Economics, December 1977.

6. My ICRISAT Colleagues, J. S. Kanwar, J. G. Ryan, S. M. Virmani, R. W. Willey, T. W. Walker and H. L. Thompson read and commented on the manuscript and supplied data for the tables. Their assistance is gratefully acknowledged.

CORRECTIONS

In November 1981 issue of Fertiliser News in the article "Vibration Measurement — Case Histories" by Shri R. K. Dixit and Shri R. D. Goyal on page 29 in second column lines 7 to 10 please read :

$$\text{(Displacement) peak} = A_0 \qquad (2)$$

$$\text{Velocity peak} = \left(\frac{dy}{dt}\right)\text{peak} = A_0 \times 2\pi f \qquad (3)$$

instead of

$$\text{(Displacement) peak} = y$$

$$\text{peak} = A_0 \qquad (2)$$

$$\text{Peak} = \left(\frac{dy}{dt}\right)\text{Peak} = 2A_0 = \pi f \quad (3)$$

* * *

In December 1981 issue of *Fertiliser News* in article "Fate of Fertiliser Nitrogen in Soil-Plant System—Quantitative Approach Using ^{15}N as Tracer" by Dr. B. V. Subbiah and Dr. M. S. Sachdev on page 31 in third column please read F.N.D.F.F.

$$= \frac{\%\ ^{15}N \text{ excess in plant}}{\%\ ^{15}N \text{ excess in applied labelled fertiliser}}$$

instead of F.N.D.F.F

$$= \frac{\%\ ^{15}N \text{ abundance in plant}}{\%\ ^{15}N \text{ abundance in applied labelled}}$$

The errors are regretted.

—*Editor*