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IMPROVED SEEDS OF CHANGE IN DRYLAND AGRICULTURE: PROMISE AND IMPLICATIONS FOR ECONOMICS RESEARCH*

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Abstract

One of the main sources of productivity growth in dryland agriculture in India in the 1980s and 1990s will be varietal change. We take stock of some promising types of varietal change in four ICRISAT mandate crops–sorghum, pearl millet, pigeonpea, and groundnut. We discuss the role of economists in integrating information systematically from several sources to assess researchable problems and alternative solutions in crop improvement research in the third section. We conclude with an evaluation of the ability of the economist to respond to the challenge of interdisciplinary research.

Introduction

In the 1982 annual meeting of the Indian Society of Agricultural Economics at Pantnagar, Professor Dantwala remarked that agricultural economists made little, if any, contribution to the green

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revolution. When basic biological research markedly shifts yield distributions, it is hard to see how economists can usefully add much to *ex ante* analysis on resource allocation for agricultural research. For instance, we have little basis for saying that ICRISAT has invested too much or too little in nitrogen fixation research in pearl millet. If successful, such research can radically alter the production environment in which the crop is grown. But as research becomes more applied, information on farmer circumstances and the production environment becomes more relevant to agricultural research decision-making, and economists can play a more productive role.

Because of the harsher production environment in dryland agriculture, there is generally less scope for abrupt technical change. If researchers ignore information on the production environment, it is unlikely that incremental but sustained technical change will be forthcoming.

One of the main sources of productivity growth in dryland agriculture in India in the 1980s and 1990s will be varietal change. In the next section, we state why we believe that improved varieties are perhaps the most important source of increased crop productivity and yield stability in dryland agriculture. We then take stock of some promising types of varietal change in four ICRISAT mandate crops-sorghum, pearl millet, pigeonpea, and groundnut. We discuss the role of economists in integrating information systematically from several sources to assess researchable problems and alternative solutions in crop improvement research in the third section. We conclude with an evaluation of the ability of the economist to respond to the challenge of interdisciplinary research.

Improved Seeds and Dryland Agriculture

When we visualise dryland agriculture, we picture low productivity per unit of land as characteristic of stagnant technical change. While the scope for rapid, discontinuous productivity increases–characteristic of the green revolution– is probably limited to a few rainfall-assured, higher-production regions, agricultural change in dryland agriculture is more dynamic than what popular thinking suggests. But such change is so piecemeal, and the weather so variable, that it often goes unnoticed.

Relative Contribution of Seeds

Most of us have heard about government officials having to post guards around godowns to prevent theft of the semidwarf wheat varieties that were the foundation of the green revolution in the irrigated Punjab. Or about farmers travelling hundreds of miles by bus to Ludhiana to take back a handful of wheat seed to eastern Uttar Pradesh.

The demand for improved seed is also strong in dryland agriculture. Seeds are usually the cutting edge of technical change in agriculture, because they are much easier for farmers to adopt than other improved components and recommendations. Seeds are divisible; farmers can plant them on as much or as little land as they want. They are cheap; the cost of seeds, even for hybrids, represents only a small percentage of out-of-pocket expenses per hectare. Hence their diffusion imposes few demands on the credit system that may be fragmented, with many farmers delinquent (Sanghi, 1982; Bhende, 1983). They imply little additional effort for the farmer and can be more easily evaluated than other improved practices.

Examples of Varietal Change in Dryland Agriculture

High-yielding varieties (HYVs) are not strangers to dryland farmers' fields in India. There are several success stories. By 1978-79 about 70% of the finger millet (ragi) area in Karnataka, the principal producing state in India, was planted to improved varieties released in the late 1960s (Directorate of Agriculture, Karnataka). Yields average more than 1 t/ha and irrigation accounts for only about 15% of planted area.

Adoption of hybrid sorghum has been impressive in the main producing regions in Maharashtra; similar is the case with pearl millet in Gujarat. By 1980-81 about 50% of rainy season sorghum in Maharashtra and 85% of total pearl millet sown in Gujarat was planted to hybrids[1]. Only about 12% of rainy season (kharif) sorghum area in Maharashtra and 19% of total pearl millet area in Gujarat is irrigated (Directorates of Agriculture, Maharashtra and Gujarat).

Adoption of improved castor cultivars in Aurepalle, one of the sites of the ICRISAT Village-Level Studies, illustrates the impact a small absolute increase in varietal productivity can have on farmers' income in marginal production regions. Farmers switched from their local castor varieties to the improved Aruna variety and the Gauch-1 hybrid from Gujarat in the late 1970s and early 1980s[2]. By 1981-82, these two improved cultivars were planted on 80% of castor area in the village and production increased by about 200 kg/ha over traditional varieties.

Such a small increase in productivity is not enough to spark the imagination of researchers or policy-makers, but it can significantly enhance the welfare of many poor farm households. From 1975-76 to 1979-80, net household income averaged Rs 4600 per cropping year. Across the 20 castor-cultivating households in the sample and valued at net harvest prices, average net crop income increased by 32% and net household income rose by 15%. Initially, lower income households benefited relatively more because they had proportionally more of their land planted to castor. These gains do not have large multiplier effects, but they are potentially important to poor dryland families who receive them.

The demand for pearl millet hybrids and improved pigeonpea varieties is also strong in Aurepalle. In 1980-81 we experimentally marketed seeds to farmers in the village at market prices. Demand was selective; there was excess demand for some improved varieties and no demand for others.

The Aurepalle experience is similar to the other study villages. ICRISAT resident investigators in the study villages are annually inundated with requests from respondent farmers to facilitate timely delivery of improved seeds of dryland crops, reflecting the demand for modern cultivars in SAT India.

Taking Stock of the Promise in Four ICRISAT Mandate Crops

In this section, we briefly inventory some types of expected varietal change that promises to increase productivity and improve yield stability in dryland agriculture. We focus on research being carried out by ICRISAT, usually in collaboration with the all-India crop improvement projects, in four of its mandate crops: sorghum, pearl millet, pigeonpea, and groundnut. Any assessment of the prospects for technological change is fraught with uncertainty and errors of commission and omission. In particular, we have not attempted to collect information on what national crop improvement scientists perceive as promising.

Sorghum

An assessment of emerging sorghum varietal technologies has to take into consideration the fundamental role that cropping season plays in sorghum production in India. Sorghum is grown in two markedly different cropping seasons. Rainy season (or kharif) sorghum is produced in regions with relatively assured monsoon rainfall in black soils, or in red soils with reduced moisture-holding capacity that makes post-rainy season cropping infeasible. Post-rainy season (or rabi) sorghum is grown in unassured rainfall regions, and the cropping is carried out under receding soil moisture, usually in deep black soils. In 1980-81, the kharif crop accounted for about 60% of area and about 70% of production (Directorate of Economics and Statistics, 1982). Although the area under sorghum is declining in some states–most notably Karnataka, Andhra Pradesh, and Madhya Pradesh–the proportional area planted in each cropping season has been relatively constant over the last 15 years.

Hybrid Adoption

Hybrids first released by the All-India Coordinated Sorghum Improvement Project (AICSIP) in the mid-1960s are widely diffused in some kharif growing areas, particularly in the two principal sorghum-producing states of Maharashtra and Karnataka. They are sparsely adopted in other states. Kharif hybrids include CSH 1, CSH 5, CSH 6, and most recently CSH 9. Fewer releases have been targetted for and found a home in the rabi growing tracts.

The disparity in adoption performance between the two cropping seasons is vividly portrayed in Figure 1 for the major sorghum-producing districts in Maharashtra, Karnataka, Andhra Pradesh, Madhya Pradesh, Tamil Nadu, and Gujarat. Moderate to high acceptance of sorghum hybrids in the kharif growing regions in

Maharashtra and Karnataka is "interrupted" by negligible adoption in Ahmednagar, Poona, Sholapur, Gulbarga, and Bijapur districts which produce a rabi crop. The data in Figure 2 graphically illustrate the variation in adoption performance between kharif and rabi growing regions in Maharashtra and Karnataka. A quadratic specification with cropping-season independent variables explains 88% of the interdistrict variation in adoption.

For most innovations, adoption and diffusion follow an S-shaped path over time. Data from most sorghum-producing districts in Karnataka suggest that adoption and diffusion of sorghum hybrids follow a similar pattern (Bhat, 1983). Because first-generation sorghum hybrids are mature innovations–most are more than 10 years old–the level of adoption in recent years has reached a plateau, significantly less than 100% in most cases (Figure 3). Except for Belgaum, we would not expect further extension efforts to result in wider adoption of first-generation hybrids–like CSH 1, CSH 5, and CSH 6– in most districts of Karnataka. To break these "ceiling" levels of adoption, qualitatively different second- and third-generation hybrids and varieties will have to be released. An intriguing question, underlying the graphs in Figure 3, is why kharif producing regions are characterised by markedly different plateau levels. For example, the estimated value for the ceiling parameter in Chitradurga is 70% of kharif area, while it is 35% in Mysore.

Kharif Prospects

The high yield potential of the short-statured, early maturing, photoperiod insensitive kharif hybrids is frequently not realised in farmers' fields because of many biological and environmental yield reducers[3].

Insect pests include shoot fly, head bugs, midge, and stem borer; grain mold is probably the most damaging disease and some hybrids are particularly susceptible to the parasitic weed Striga. ICRISAT is working with AICSIP to develop cultivars with broad-based multiple resistance to these pest problems. Such varieties and hybrids should offer more stable yields to the farmers, who have already adopted the first-generation hybrids. They should penetrate into some kharif cropping areas that have been bypassed by varietal change.

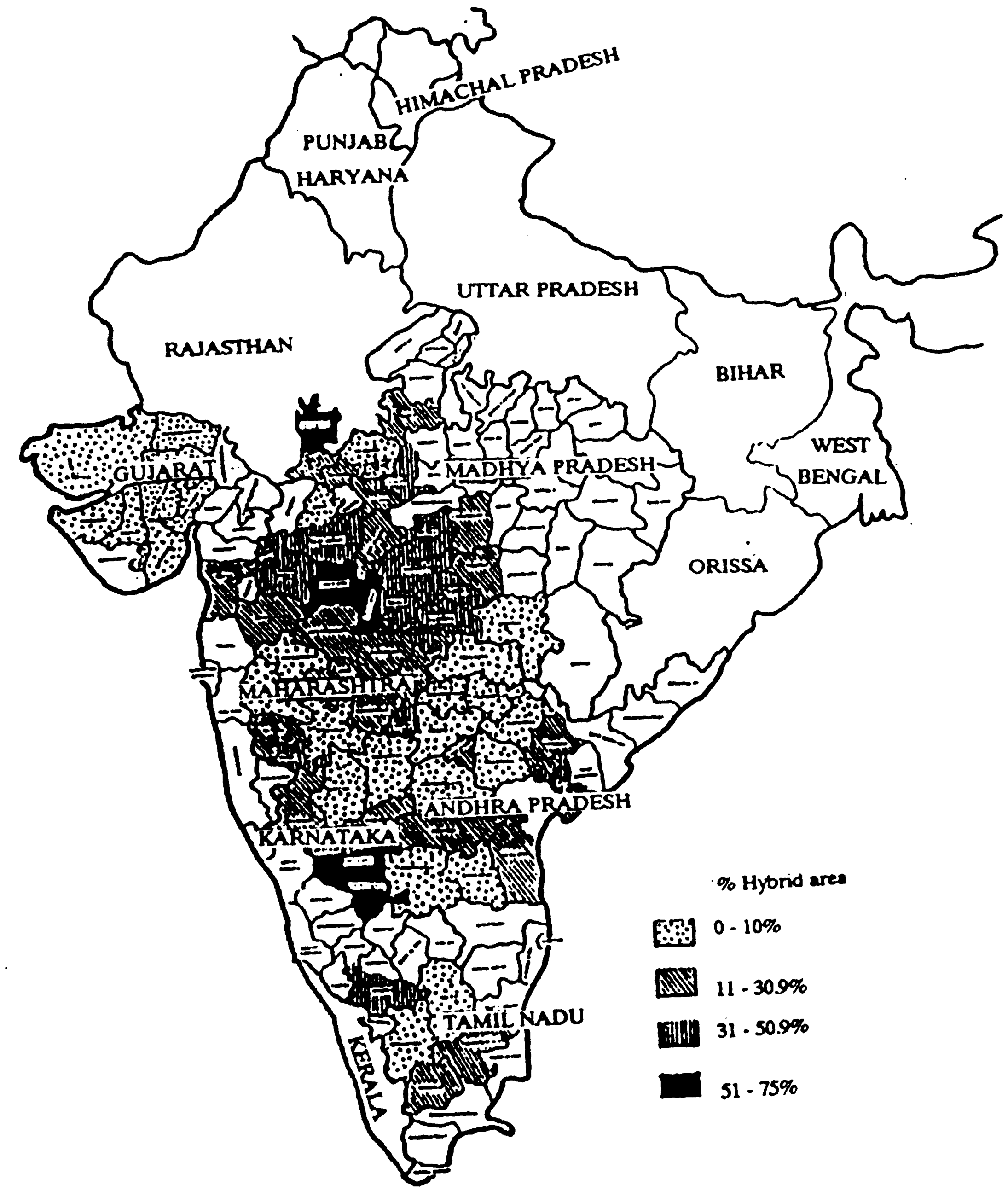

FIG. 1. Per cent adoption of hybrid sorghum to total sorghum area in major producing districts (> 50,000 ha) in Maharashtra, Karnataka, Andhra Pradesh, Madhya Pradesh, Tamil Nadu, and Gujarat in 1978-79.

(Source: Season and crop reports of the Directorates of Agriculture of respective states for the various years.)

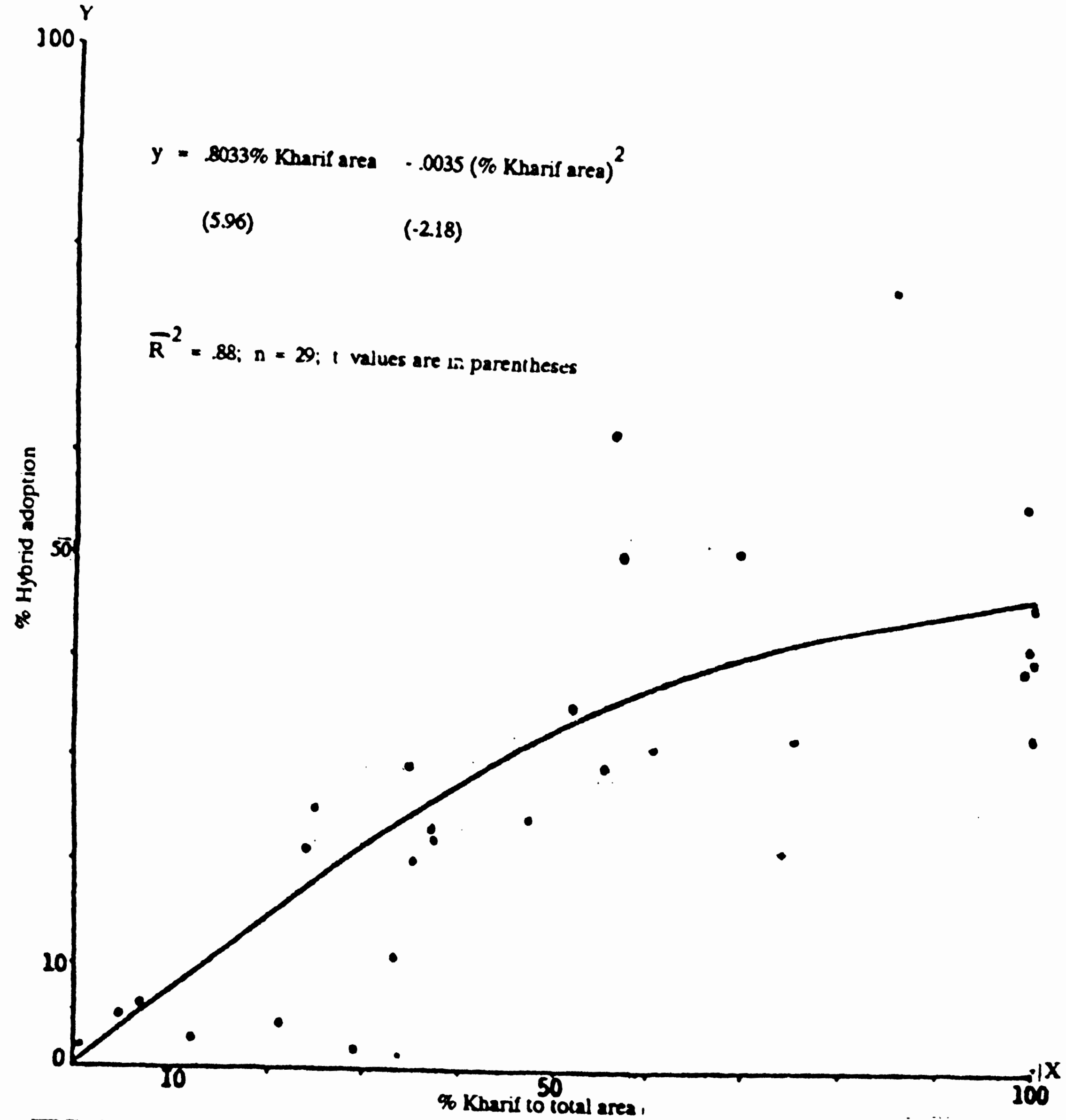

FIG. 2. **Hybrid adoption by cropping season in the major sorghum-producing districts in Maharashtra and Karnataka.**

Improved varieties should also help mitigate seed-type and seed-production problems of hybrids (House, 1982; Chopra, 1982).

Rabi Prospects

Increasing productivity of sorghum grown in the rabi season represents the stiffest challenge facing sorghum researchers in the 1980s. The most common genotype planted by rabi sorghum growers is Maldandi, an improved selection released in 1934 from the Sholapur research station.

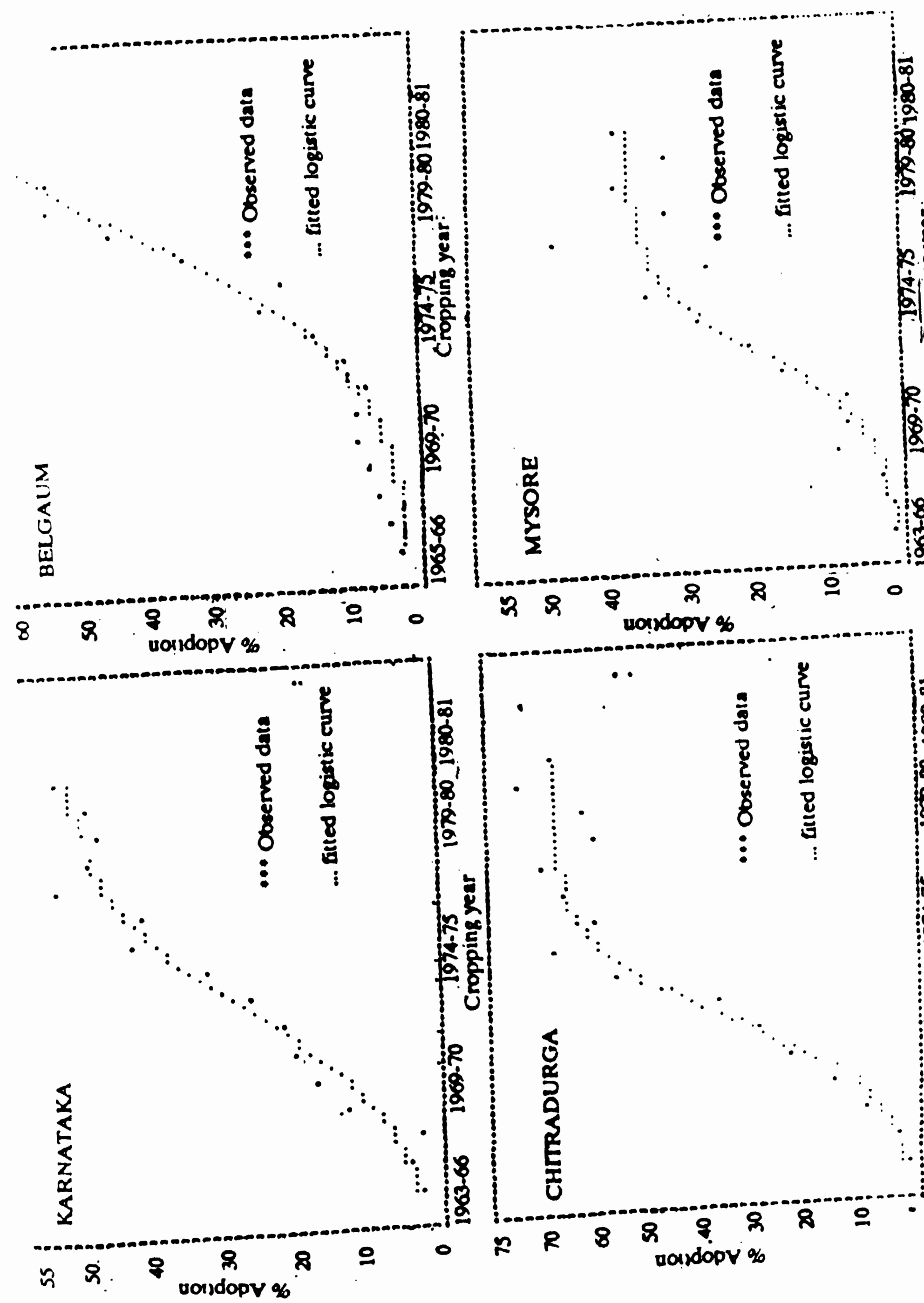

FIG. 3. Per cent of total kharif area planted to hybrid sorghum in Karnataka State and the districts of Belgaum, Chitradurga and Mysore from 1965-66 to 1980-81.

Pest problems are not as severe in the rabi season as in the kharif season. But the problems of growing sorghum under receding soil moisture are illustrated with the data in Table 1 (Walker and Subba Rao, 1982a). Soil depth largely determines moisture-holding capacity and available moisture to the plant. Numerous studies (Singh, 1983) have shown that early planting can significantly increase yield, but for several reasons it is not always possible for farmers to advance the planting date.

Pearl Millet

Pearl millet hybrids first released in 1966 have been more widely adopted by farmers than sorghum hybrids (Figure 4). (This observation is somewhat obscured by the use of different legends in Figures 1 and 4.) We also expect that more recent data will show that hybrids are penetrating into some of the harsher environments of Rajasthan, the principal state in area producing pearl millet.

TABLE 1: Yields and net returns of post-rainy season sorghum cultivated in farmers' fields in Shirapur and Kalman villages in Sholapur district from 1975-76 to 1979-80.

Soil depth	Yield (kg/ha)		Net returns	Number of
	Grain	Fodder	(Rs/ha)	observations
Deep black	375	988	544	95
Medium black	258	793	383	261
Shallow black	171	746	283	438
Gravelly and others	133	535	198	98

Source: Walker and Subba Rao (1982a).

Compared to sorghum, pearl millet faces fewer yield-reducers. At present, insect pests do not pose major problems. The main sources of yield loss are disease and environmental stress. The first-generation hybrids (HB 1, HB 3, and HB 4) suffered from severe attacks of downy mildew in the early 1970s, which caused high economic losses (Kanwar, 1975).

Maintenance research on downy mildew resistance and screening and breeding for ergot and smut resistance should result in varieties and hybrids with higher levels of disease resistance. Physiological research on environmental stresses may also lead to more drought tolerant and better emerging cultivars; however, the gestation period

for this research is likely to be longer. The release of more improved varieties will also provide the farmer with more options, particularly in areas where hybrids have not made much headway.

Pigeonpea

The prospects are bright for increasing pigeonpea productivity in India in the 1980s and 1990s. There are several potential means of increasing productivity. First, extra early and early-maturing pigeonpea lines under intensive management and high plant population have much higher yield potential than medium- and late-duration types. In Australia, the best early-maturing pigeonpea lines have consistently yielded over 6 t in trials (ICRISAT, 1982). The availability of early-maturing types has opened up possibilities of pigeonpea-wheat cropping system in northwestern India (ICRISAT, 1982). Results from trials at ICRISAT Centre in 1982-83 show that under intensive management it may also be possible to obtain high yields with early-maturing types in central and peninsular India (R.Sheldrake, personal communication). Early-maturing pigeonpea lines represent a significant breakthrough in yield per day of crop duration and are indicative of the technical change that heralded the green revolution and which may markedly alter the production environment of pigeonpea in India. A high priority should be attached to agronomic research on early-maturing pigeonpea varieties to fully exploit this abrupt change in yield potential. Early-maturing varieties may find a home in some of the better resource-endowed dryland environments, but it is unlikely that they will improve yields in unassured rainfall and unprotected conditions.

Secondly, some pigeonpea varieties released in the 1980s will carry multiple disease resistance, particularly to wilt and sterility mosaic. An international survey estimates that these diseases inflict losses of U.S. $ 113 m/yr (about 915 million Indian rupees) on the pigeonpea crop (Kannaiyan et al., 1981). Multiple resistance also brightens the prospects for improved cropping systems, such as rabi-kharif-rabi perennial pigeonpea.

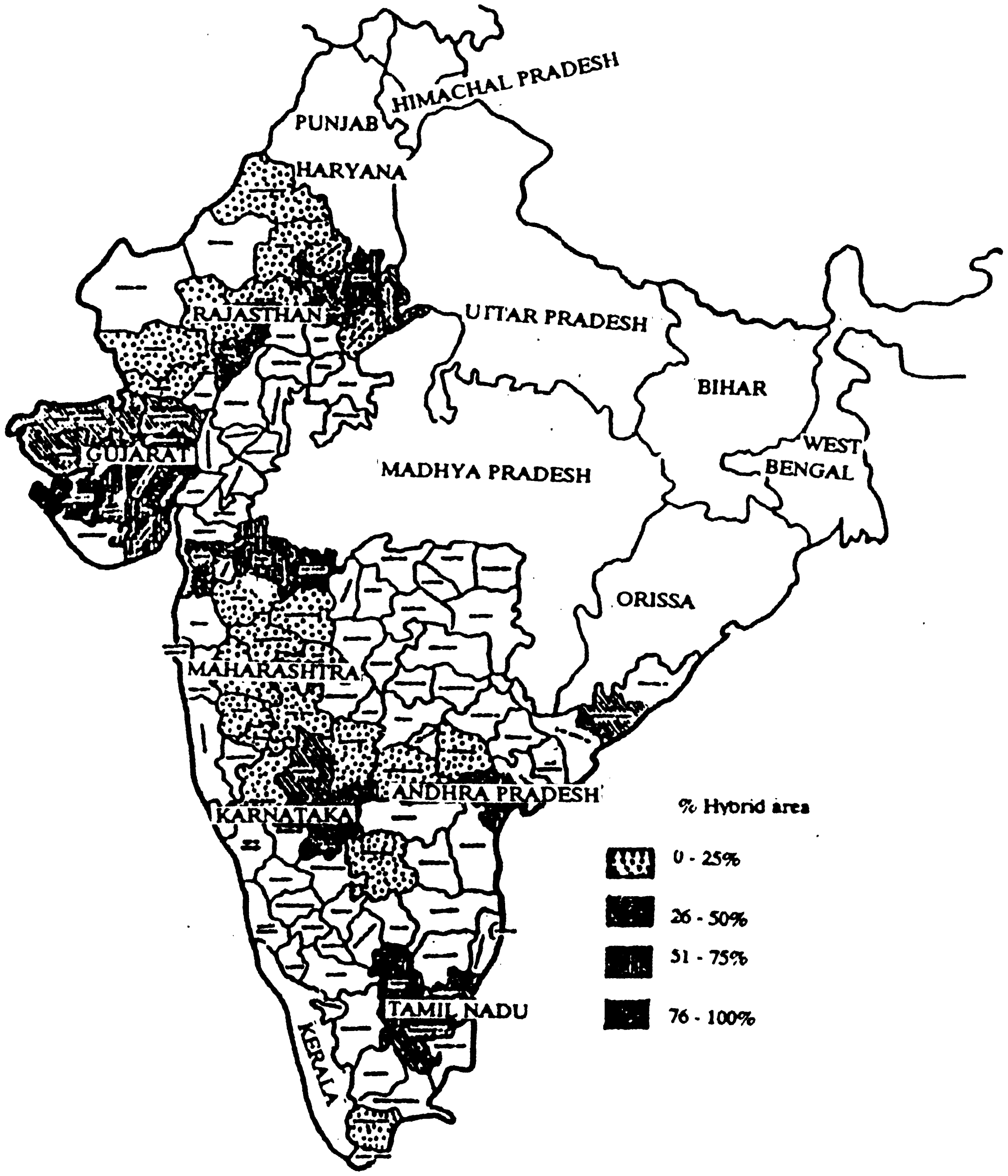

FIG. 4. Per cent adoption of hybrid pearl millet to total pearl millet area in major producing districts (> 50,000 ha) in Maharashtra, Karnataka, Andhra Pradesh, Rajasthan, and Tamil Nadu in 1978-79 and in Gujarat in 1977-78. (Source: Seasons and crop reports of the Directorates of Agriculture of respective states for the various years.)

Thirdly, it may be possible to incorporate moderate levels of resistance to **Heliothis** pod borer into some varieties (Bhatnagar et al.,1982). Extensive field surveys suggest that **Heliothis** populations destroy at least 40% of the crop in central and southern India in most years (ICRISAT, 1982). Reed and Pawar (1982) have conservatively estimated that the value of pigeonpea grain loss from **Heliothis** pod borer damage exceeds U.S. $ 300 million (about 2580 million Indian rupees) annually.

In dryland agriculture, farmers intercrop pigeonpea with cereals. Data from the ICRISAT Economics Programme study villages suggest devastating losses to pigeonpea in farmers' traditional cropping systems. The losses are consistently so large that we often wonder why farmers continue to plant pigeonpea. In Aurepalle, where one row of pigeonpea is usually intercropped with four rows of sorghum mixed with millet, farmers harvested on average 27 kg of pigeonpea per intercropped ha in 169 fields from 1975-76 to 1980-81 (Walker and Subba Rao, 1982a). In Kanzara,where one row of pigeonpea is usually intercropped with 12 rows of cotton and two rows of sorghum, pigeonpea yields averaged 36 kg per intercropped hectare in 190 fields from 1975-76 to 1980-81. In most cases, pod borer attack was the cause of negligible yields. Screening and breeding for pod borer resistance, if successful, has the potential to unambiguously benefit poor farm households in dryland areas.

Groundnut

In low rainfall years, drought stress reduces yield in kharif dryland, groundnut-growing regions; in high rainfall years, dryland groundnut farmers often cannot reap the benefits of adequate moisture because of foliar-diseases. ICRISAT has invested considerable resources in a broad-based programme to screen and breed for foliar-disease resistant groundnut genotypes. The two principal diseases are rust and leaf spots, which are persistent yield-reducers in kharif drylnd groundnut. Severe rust attacks can result in a loss in pod yield of over 50% and an even greater loss in haulm yield (Subrahmanyam and McDonald, 1983). Genotypes with good resistance to rust and leaf spots have been identified (Subrahmanyam et al., 1980). Presently, the most resistant genotypes do not have high yield potential and further work is required to improve the agronomic background of resistant types (Subrahmanyam et al., 1983). But genotypes with intermediate yield potential may be acceptable to groundnut farmers in marginal dryland, and in drought-prone regions where spraying the crop with fungicide may not be economical.

How Economists Can Help

With the wider diffusion of farming systems research methodologies in the 1970s, there is a clearer perception of the value of including social scientists, particularly economists, in interdisciplinary agricultural research teams. Placing economists in farming systems research programmes is fairly widely accepted by most scientists and research administrators, but fewer biological scientists and research administrators see a productive role for economists in crop improvement programmes. Perhaps the question we are most often asked by visitors to the ICRISAT Economics Programme is: "Why are the economists not located in the Farming Systems Research Programme?". There are several reasons, but an important one is that we believe that economists can contribute as much to crop improvement research as they can to farming systems research.

Aside from more traditional economics research on commodity demand and supply, economists can help integrate information from several sources to assess more systematically researchable problems and alternative solutions in crop improvement research (Perrin, 1976). Incorporating multiple insect and disease resistances and environmental stress tolerances in improved varieties and hybrids increases the demand for supportive economics research in several areas. The following list, by no means exhaustive, is indicative of how economists can contribute to crop improvement research.

Describing the Production Environment

Perhaps the most important service that economists can render to sharpen within-commodity research priorities is to provide a more thorough understanding of the production environment and, more importantly, how that environment is changing over time. This task is made easier for the major cereal crops by a wealth of secondary data in India. For dryland pulses and oilseeds, data are not as abundant and hence special-purpose surveys are needed.

Several examples from the ICRISAT mandate crops illustrate the importance of attaining a sounder understanding of the production environment. In sorghum, insect pests, disease, and environmental stresses are markedly different between the kharif and rabi cropping seasons. In kharif sorghum, the nature and incidence of environmental stresses leading to production problems, such as poor stand establishment, vary considerably across red, black, and sandy soils. Poor emergence and stand establishment may be caused by high soil temperature, low soil moisture, or soil crusting. Knowing which of these factors is most constraining in different soil and rainfall environments would be useful for developing and assigning priorities to different screening techniques. Similarly, the incidence of drought stress is more likely at some physiological growth stages than others, depending on soil type and rainfall patterns. Information on its relative occurrence in different environments would be valuable for drought-tolerance screening. Monitoring changes in relative area between cropping seasons and shifts in area among soil types and rainfall environments within cropping seasons is as important as following trends in the demand for sorghum as a food grain, as animal feed, and as fodder.

The area planted to irrigated summer pearl millet is increasing in some states where hybrids are highly competitive, particularly in Gujarat. Research allocation decisions on investment in hybrids vis-a-vis varieties are partially conditioned by information on whether the agronomic potential of the production environment is improving or deteriorating. Payoffs from maintenance research on downy mildew resistance and screening for ergot resistance also hinges to some extent on whether the production environment is becoming wetter or dryer.

For sorghum and pearl millet, adoption research on why the mature hybrids released in the 1960s have reached ceiling levels of diffusion across different regions could generate some information relevant for crop improvement resource-allocation decisions. Because adoption plateaus are frequently determined by soil, agroclimatic, and biological variables, results from such base data adoption analyses often contain implications for technological policy. For example, adoption of hybrid sorghum may be markedly less in regions where planting season rainfall is late and unreliable, resulting in greater potential shoot fly damage. Adoption could also be dampened in districts where rainfall during the early-October harvesting period is high, resulting in grain mold damage and large price reductions.

For groundnut, distinguishing the relative importance of the kharif dryland and rabi-irrigated production environments is necessary for focusing on investment decisions with regard to foliar-disease resistance and drought-tolerance research. A two-pronged research strategy is probably needed to address problems of the more marginal kharif drylands and the higher production potential irrigated-rabi tracts, where foliar disease is not a significant yield reducer. The relative weights assigned to the prongs depends on farmers' area-response decisions.

The economics of management practices can also have implications for crop improvement. A specific example is the decision on whether to apply calcium in the form of gypsum in screening varietal material for drought tolerance. For some varieties, the response differs substantially and differentially with and without application of gypsum. Information on the economics of gypsum application in drought-prone groundnut-growing areas should be valuable in deciding how much gypsum to use in drought-tolerance screening.

Protective spraying is usually carried out when pigeonpea is planted in pure stands; most farmers intercrop pigeonpea with cereals and do not spray. Therefore, intercropping is an indicator of the unprotected environment. Trends in sole cropping vis-a-vis intercropping will partially determine the profitability of pure plant-resistance based strategies, pure chemical-control strategies, and combinations of the two.

Quantifying Economic Losses from Yield Reducers

Breeding for resistances and tolerances places a premium on fairly reliable crop loss assessments. Approaches range from intensive field monitoring and measurement with scoring techniques (Pinstrup-Andersen et al., 1976) to more extensive surveys over a

larger area (Kannaiyan et al., 1981). Because pest damage is highly specific to locations and cropping years, crop loss estimates are subject to a wide confidence band (Davies, 1982). Loss estimates can easily be inflated, and experimental measurement can be severely biased (Reed, 1982). Interdisciplinary research between entomologists and economists should result in more reliable assessments than either discipline working separately in this difficult research area.

Assessing Varietal Resistance and Alternative Control Options

Besides providing information to assess crop losses and to establish economic threshold-decision rules, economists can help identify more broadly-based pest control strategies, of which varietal resistance is only a component (Reichelderfer et. al., 1983). Strategies featuring multiple options for different environments are important because resistances are often negatively correlated with yield potential (Subrahmanyam et al., 1983). It may take many years to incorporate multiple resistances into suitable agronomic backgrounds. For example, in groundnut improved varieties with high yield potential are usually susceptible to foliar diseases, while more resistant varieties generally have lower yield potential. The expected diffusion and impact of varieties resistant to rust and leaf spots hinges on the economics of chemical control in regions with varying production potentials.

It is not easy to assess the economics of chemical control because, frequently, effective fungicides and insecticides are not sold to farmers on a timely basis. Nor are price data freely shared by pesticide manufacturers. Moreover, experimental data under farmers' field conditions are usually lacking. Despite these difficulties, economists will find it worth their effort to evaluate alternative control options for persistent yield-reducers, such as foliar diseases in groundnut and **Heliothis** pod borer in pigeonpea.

Monitoring Varietal Testing and Release Policies

Recently, economists have taken a more active interest in multi-locational varietal testing (Evenson et al., 1979; Binswanger and

Barah, 1980). They have focused attention on statistically identifying whether genotypes that are broadly adaptable across many locations are also more stable yielders over time. Other important issues in multi-location testing include:

a. the degree to which variability across test sites reflects environmental variability across farmers' fields;
b. the balance between public and private-sector participation in varietal testing and release;
c. the flexibility of the release policy across space and over time; and
d. the relative importance between yield and other criteria in deciding on cultivar advancement and release.

Decisions taken on these issues can markedly affect the pace and nature of varietal change in farmers' fields and should not be ignored by economists. The need for flexible testing and release policies is brought out in the following example:

> "Recent surveys show that the early maturing IR747 and IR1561, are popular in Central Luzon in the dry season. Those lines were never released because they lacked resistance to tungro virus and there was concern that farmers would plant them in the wet season. There was underestimation of how quickly farmers would discover that the varieties were suited to dry-season but not to wet-season conditions. Perhaps, there is too much worry about protecting farmers, who all too frequently know best what is good for them or what works in their environment." (Herdt and Baker, 1977, p.6.)

Overly protective release policies can also have harmful side effects that are not readily foreseen. For example, farmers who are innovators and early adopters reap the benefits of successful technical change and they also bear the cost of research mistakes (Binswanger and Ryan, 1977). If researchers and extensionists were infallible, the income gains from early adoption and diffusion would be much more skewed than if they behaved like the rest of us who occasionally err.

Striking a balance between yield and other criteria, such as resis-

tance traits in testing and release policies, is not easily achieved. Relying strictly on yield potential ignores in varietal testing the reality that it may take years or may even be technically infeasible to incorporate multiple resistances into highly productive agronomic backgrounds. For example, the modern groundnut cultivar Robut M 33-1, with a yield potential of more than 5 t/ha, can yield as little as 200 to 300 kgs/ha under a severe foliar disease attack (D. McDonald, personal communication). Resistant genotypes with a potential of 2.5 t/ha can yield as much as 2 t/ha under similar conditions. It would be interesting to study the fate of released varieties with intermediate yield potential which have higher levels of disease and insect resistances and/or stress tolerances, compared to higher but less-resistant yielders. The advocates of high yield potential may well be right, but the empirical evidence on adoption and diffusion should be assessed.

Evaluating Stability

Yield stability usually ranks high on the list of objectives of most crop breeders, particularly those working on crops that are primarily grown in dryland agriculture. But improved yield stability on the farm does not automatically mean increased production stability for the region or the nation. Economists can contribute towards a more comprehensive appraisal of several dimensions of yield stability from the perspective of the farmer at the microlevel, and the policy-maker at the national level. The following two examples illustrate this point.

Experimental evidence under protected and moderate-to-high fertility convincingly indicates that first-generation high-yielding sorghum hybrids have greater yield stability than unimproved local varieties (Barah et al., 1981). These results suggest that more disease and insect-resistant and stress-tolerant improved hybrids and varieties may not significantly reduce yield stability, when compared to their first-generation counterparts.

It is an open question whether this conclusion applies to less protected and lower fertility environments, typical of many farmers' fields in the semi-arid tropics of India. But a more fundamental issue relates to the basis for comparisons on yield stability. Clearly, for rabi sorghum that is largely solecropped on residual soil moisture, stability comparisons between improved and traditional cultivars are valid and thoroughly informative. But for sorghum hybrids planted in the kharif season, stability evaluations that use local varieties as a yardstick do not tell the whole story. In the rainy season, local varieties are commonly planted in intercropping systems. They often are relatively minor components in those systems, particularly in the black soil, cotton-growing regions of Maharashtra, where sorghum hybrids are more widely diffused. Most hybrid sorghum is solecropped and managed more intensively than in competing intercropping systems.

When improved hybrids and local varieties are used in such differing cropping systems, risk analysis between cropping systems may offer a more informative perspective on relative stability than comparisons between types of cultivars in sole cropping. Sorghum hybrids may be notably more stable than local varieties, but returns in solecropped hybrid sorghum may be markedly more variable than what is obtained in competing intercropping systems. In such systems, local sorghum occupies a proportionately small area, and consequently plays a minor role in conditioning revenue variability. In Kanzara, one of the study villages, we found that switching from the more traditional cotton-sorghum intercropping systems to solecropped hybrid sorghum implies accepting more risk for higher profits (Walker and Subba Rao, 1982b)[4].

To evaluate this tradeoff, we parametrically reduced the coefficient of variation (CV) of hybrid sorghum yield from 10 to 90% in a portfolio analysis. We calculate that a 30% reduction in the CV of hybrid sorghum yield (holding mean yielding constraint) would initially lead to 46% increase in hybrid sorghum area. This analysis, based on nonexperimental cropping systems data, indicates that improving yield stability in first-generation sorghum hybrids may initially lead to greater sorghum production via enhanced area supply response even though yield levels will not have appreciably changed.

Social benefits from multiple-resistance breeding partially depend on the extent to which gains in improved yield stability from more pest-resistant and stress-tolerant varieties can be translated into increased regional and national production stability. Stability issues are complex and it is important to first focus on simple em-

irical question. Has the adoption and diffusion of HYVs increased roduction instability? Results from several studies suggest that intability in Indian food grain production is increasing (Mehra, 1981; Hazell, 1982). Between 1954-55/1964-65 and 1967-68/1977-78 the coefficient of variation of total cereal production in India increased 4.0 to 5.9. Hazell (1982) has used a covariance analysis to partition the change in variance in total cereal production into four sources: 1. production variances of individual crops within the same state; 2. covariance of production among crops in the same state; 3. covariances of production among states in the same crop; 4. covariances of production among different crops in different states.

Hazell hypothesises that if HYVs are a significant source of production instability, then increased production variances within states should be large contributors to explaining increases in the variance of cereal production. But his results show that only about 18% of the increase in variance of total cereal production can be accounted for by changes in crop production variances. The remaining 82% is explained by changes in the covariance components, particularly interstate covariances within crops which contribute 41% to the change in variance in total cereal production. Changes in yield covariances are much more important than changes in yield variances. Hazell concludes that the increase in instability in India's cereal production between the two periods cannot be attributed to HYVs but rather to other causes. He additionally draws the implication that there is less scope for yield-stabilising varietal technologies to decrease production instability in Indian agriculture.

Reddy (1983) recently applied Hazell's covariance analysis to district data in Karnataka. He found that HYV adoption was significantly ($P<.05$) and positively correlated to increases in yield covariances between districts for the same crop. Differences in HYV adoption between districts were negatively associated with positive changes in yield covariances, which played a major role in contributing to increased production variance between the two periods.

Therefore, the introduction and diffusion of HYVs could have significantly contributed to the substantial changes in interstate yield covariances documented by Hazell. More statistical analysis of underlying causes is needed to understand regional and national implications of breeding for yield stability[5].

Filtering and Conditioning Information to Improve Linkages Between Farming Systems and Crop Improvement Research

Although it does not fall within the domain of economics, economists can help improve quality and flow of information between research scientists in crop improvement and those working on dryland farming systems. The main objective of farming systems research is to integrate and organise information in a coherent fashion so that improved technological components are more speedily generated and delivered to farmers. Many of those improved components will have to come from crop improvement programmes. There are always numerous demands from various sources to breed for different characteristics based on felt needs. Such demands can be highly location and year-specific. Some demands have economic and technical potential; some have only economic potential, and many will be technically infeasible and economically unsound. Assigning of breeding priorities should be based on revised information each year, and the economist should ensure that such information reflects representative conditions in the production environment.

Crop improvement scientists also place demands on farming systems researchers to develop agronomic recommendations for improved varieties and hybrids. The payoff to such agronomic research is especially high following a breakthrough in knowledge that has led to an abrupt shift in yield potential. For example, improving management of high-yielding extra-early pigeonpea lines should rank high on the research agenda for cropping systems.

The Capacity of Economists to Respond

In his book on agricultural research policy, Ruttan (1982, pp.8-9) makes a personal statement about his transition from the Head of the Economics Programme at the International Rice Research Institute (IRRI) to the Head of the Department of Agricultural Economics at a land grant university in the U.S. Ruttan was hopeful that he could apply the interdisciplinary mission-oriented research

approach followed at IRRI to find solutions to production problems in the agriculture of the state. Ruttan expressed disappointment with departmental research, and felt it was too compartmentalised to make much progress and offered few incentives for interdisciplinary research.

With a few notable exceptions–such as Punjab Agricultural University–Ruttan's comments could probably apply to the prospects for interdisciplinary research in agricultural economics in the Indian state agricultural universities, which are patterned after the U.S. land-grant model. Moreover, a heavy teaching load, unfilled staff positions, collection of routine data on cultivation costs, and burdening administrative responsibilities militate against well-focused, problem-oriented interdisciplinary research between farm scientists and economists.

If economists are to play a more active role in interdisciplinary research in crop improvement programmes, we believe they will have to be posted directly in the coordinating units of such programmes. Placing an economist in the important All-India Coordinated Crop Improvement Projects such as those concerning pulses, oilseeds, and major cereals is required. Because scientists usually develop a certain affection for and tunnel vision about their crop, it would also be advisable to have a few economists stationed outside the crop improvement projects, to address resource-allocation decisions among crops and other macropolicy issues.

These suggestions are not new. Several schemes have been proposed to give shape to these suggestions, but none has been implemented. Unless action is taken soon, Professor Dantwala's words will also apply to the contribution that economists can make to varietal change in dryland agriculture. Along with other social scientists they will be observers of, and not participants in, the development and diffusion of improved varieties and hybrids.

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Footnotes

1. Because of the planting of second-and third-generation hybrids, these data may overestimate the rate of adoption of pearl millet hybrids.

2. For a similar experience in other red-soil villages, see Sanghi (1982).

3. Farmers prefer the grain and fodder quality of the local varieties which, according to the village-level study data from 1975-76 to 1982-83, fetch about 20% higher grain price and 100% higher fodder price than the hybrids. Hybrid grain quality has improved with the recent release of CSH 9.

4. The coefficient of variation in net returns for the two competing cotton-sorghum intercropping systems is 74% and 99% while the CV for sole-cropped hybrid sorghum is 115% from farmers' fields for the period 1975-76 to 1980-81. The data were "detrended" for yield differences caused by variation in management practices among farmers.

5. For example, the contribution of HYVs needs to be tested in a regression analysis where differences in HYV adoption rates, changes in interstate rainfall covariances, changes in interstate irrigated area covariances, and other factors are hypothesised to explain changes in interstate yield covariance.

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ELEVEN

FERTILISER USE ON INDIA'S NONIRRIGATED AREAS: A PERSPECTIVE*

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Abstract

This paper elaborates three propositions: 1. There is need for sustained rapid growth of fertiliser use in India; 2. this depends on accelerated growth of fertiliser use on nonirrigated areas; and 3. there is scope to step up fertiliser use on nonirrigated areas, especially because their unexploited potential will continue to increase with technological improvements. The paper suggests that successful exploitation of this potential would require its conversion into farmers' demand for fertilisers and this demand being met by the fertiliser supply and distribution systems.

Specific measures the paper suggests are: a. emphasis on location-specific research, strengthening of extension services, and an effective interface between the two; b. adequate and timely flow of credit and fertilisers to non-irrigated areas; and c. ensuring that

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