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9. ABSTRACT

From 1966 to 1972, India more than doubled its annual wheat production, from 11.4 million tons in 1966-67 to 26.4 million tons in 1971-72. This has enabled India to increase its share of world wheat production from less than 4% in 1965-66 to nearly 8% in 1971-72. While the annual rate of wheat production increased during that period by 14.27%, the production of other major cereals in India did not increase as rapidly. Rice production increased at an annual rate of only 3.63%, and total cereals by only 5.46%. The phenomenal increases in wheat production resulted in less dependence on imported cereals. Imported cereals decreased from 10.4 million tons in 1966 to 2.1 million tons in 1971. This report discusses in some detail the genesis and progress of high-yielding varieties of wheat in India, the development strategies employed, the planning and coordination of the program, the benefits of the program, and guidelines for future action. One of the principal conclusions presented is that large and small farmers rapidly adopted use of the high-yielding varieties of wheat because of the higher net income its higher yields could provide them. While this might seem over-obvious, the implication is that government pricing and marketing policies affecting farmers and middlemen are an important factor in providing a real economic incentive for farmers to adopt high-yielding varieties of wheat or other cereals.

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FOREWORD:ON LAUNCHING THE STUDIES AND MOTIVATING HYPOTHESES

Launching the Studies

The study described in the following chapters is one of a series aimed at enlarging understanding of the factors impinging on the adoption of new maize and wheat technology. Better understanding of the elements shaping the diffusion of new cereals technology can help governments and development assistance agencies to increase farmer income, hence the interest in the topic. Interest increased as controversy about effects of introducing new technologies attracted widespread attention to the theme.

CIMMYT, with its mandate defining its role in the development and diffusion of maize and wheat technology, quickly assumed a participant's role in the discussions. The concern and the interest emanating from the critical importance of the theme stimulated CIMMYT to look for a modus operandi through which patterns of adoption and the forces shaping those patterns could be identified. Better understanding of these relationships would influence CIMMYT efforts to develop new technology, the orientation of its training program, and the approach taken in counseling governments about national programs.

In order to better comprehend what influences farmer response to new technology, CIMMYT set out to facilitate the research on which this and the other studies of the series are based. We decided to examine eight cases in which maize or wheat technology had been introduced to farmers. In identifying programs for study, we limited consideration to those in which the technology had been available to farmers for no less than five years and in which no less than 100,000 hectares of land might have been affected. Eight programs were selected for study. For maize the focus was on Colombia, El Salvador, Kenya west of Rift Valley, and Mexico's Plan Puebla. For wheat, programs in India, Iran, Tunisia and Turkey were considered. CIMMYT's maize and wheat staff participated in the selection of these programs. With their knowledge of programs around the world it was possible to choose a varied set of experiences—e.g. programs with and without irrigation, with and without effective price guarantees, with massive extension effort and with virtually none.

To the extent possible, each of the adoption studies was under the supervision of an indigenous economist. In only one case was it necessary to turn to an expatriate and there we had the good fortune to collaborate with a researcher with several years experience in the area. Each of the collaborators shared CIMMYT's concern for farmer response to new technology.

Beyond sharing this concern, each collaborator had an interest in farm level research done in close cooperation with agricultural scientists. The importance of this interest emerges from our conviction that agricultural scientists who are knowledgeable about a particular maize or wheat area can contribute substantively to research on the cereals economy of that area. Their special knowledge about the interaction between plants and their environments is important in identifying agro-climatic zones, critical periods for the crop, and activities which are essential to effective cultivation. Many agricultural scientists played a prominent role in these studies; each warrants our gratitude for his contribution.

As the studies were completed it became apparent that much could be said for publishing them in a standard format. With several serving as Ph.D. dissertations and others as less formal research pieces, a common format could only be achieved through reworking the original monographs. In every case but one, then, CIMMYT's publication is an abridgement of a longer piece. The Indian study, itself a review of the findings of several other research efforts, is being published in its entirety with no effort to recast it in the form of the others.

In making the abridgement we have followed certain norms. Mathematical proofs have been eliminated, literature reviews have been included only where they relate to points which are unique to a given study, and the discussion of the hypotheses motivating the studies have been dropped. This last decision arises from recognition of the substantial commonality of these hypotheses among the studies. This suggested that, rather than presenting essentially the same discussion in the text of each abridgement, the hypotheses could be treated once in an abbreviated form for all studies. That treatment follows below.

The Hypotheses

While each of the studies examines a somewhat different set of circumstances all depart from the same general assumption about farmer behavior. The assumption is that farmers are income-seeking risk averters who are sensitive to the nuances of the environment in which they farm and that they are generally effective in their decision making. For the six studies based on original survey data and to a more limited extent for the study of Plan Puebla, this common point of departure leads to a great deal of similarity in the motivating hypotheses.

Given a farmer oriented by the assumptions described above, we might expect to see relationship between the adoption of elements of the new technology and: 1) characteristics of the farmer—his age, education, family size, farming experience, off-farm work, percentage of land owned; 2) characteristics of the farm—its agro-climatic region, competition of industrial crops, relative importance of cereals, nearness to markets, farm size; 3) characteristics of government programs—access to credit, access to information (through extension agent visits or visits to demonstration plots).

Some of the relationships between these variables and the adoption of elements of the new technologh are more arguable, some less. Least arguable are hypotheses relating adoption to education, farming experiences, percentage of land owned, more favored climatic regions, relative importance of cereals, nearness to markets, farm size, access to credit, and access to information. With other things equal and accepting our assumptions that farmers are income-seeking, risk-averting, sensitive, and effective maximizers, actually no one would argue that any one of these relationships should be negative.

Somewhat more arguable is the relation of age and family size to adoption. Even here it is likely that only a few would argue that these relationships might be positive.

Most arguable are the relationships linking adoption to off-farm work and competition of industrial crops. With respect to the former, some hold that the relationship is positive as more off-farm work implies more income, therefore a greater capacity to bear risk, hence a greater willingness to adopt new technologies. Others hold the converse, arguing that more off farm work implies less interest in the farm, hence less willingness to put in the time and energy associated with taking on new technologies. So too for industrial commodities, where those who see the relationship as positive allude to greater experience with improved inputs and larger incomes while the contrary view rests on capital restrictions and the high opportunity cost of labor.

With knowledge of the relationships among these variables, researchers and policy makers can better develop and diffuse new technologies. Some of the variables considered, e.g. age and family size, are beyond the control of these decision makers. Nonetheless, by incorporating them in the analysis the effects of variables subject to their control are more clearly discerned. Knowledge of how these variables, e.g. agro-climatic zones and extension programs, relate to adoption can be of critical importance in affecting the development and diffusion of new technology.

With this rough sketch of the general argument, readers wanting more detail about the derivation of the hypothesized relationships can turn to the relevant original piece from which this series of abridgements was drawn. In all cases the studies feature the effects of agro-climatic region and farm size on adoption of elements of new technology. This emphasis is related to the earlier controversy about the effects of new technology where these two factors played prominent roles.

Before moving into the abridgement, some attention to the phrase "elements of the new technology" is warranted. Much has been made of the concept of a package of practices in the introduction of new technology. We've chosen to look at this a bit differently, taking the view that the differences in risk, expected income, and cost of each element of the technology are large enough to outweigh the effects of the interaction among these elements. That is to say, perceptive and prudent decision makers might well choose to take up only a part of the package rather than the entire package. For the programs studies, the two dominant elements in the package are improved seed and fertilizer. These two were analyzed as dependent variables for each of the studies. Of lesser importance are such elements as seed treatment, date of planting, method of planting, use of herbicides, use of pesticides, planting density, and seed bed preparation. Nevertheless, where one of these was recommended and where data are adequate, these are also treated as dependent variables.

What follows

The following is a review and summary of data and literature related to the adoption of new wheat technology in India. Initiated in 1973 the study was finished in 1974. Unlike the remaining publications in this series, it appears unabridged, as it was written.

Donald Winkelmann
El Batan

PREFACE

A vast literature, most of which is of high analytical quality, has come into existence on the "second generation" problems of the High Yielding Varieties (HYV) Programme. The problems of employment and income distribution, in particular, have received careful attention. In comparison the problems connected with the introduction of the new programme and prospect of its further spread have received scant attention, particularly by the economists. These are no less important aspects. Therefore, when Dr. Winkelmann of the CIMMYT wrote to me asking whether I would undertake a survey of the discussion on these aspects of the HYV programme in India, I readily agreed. This document is the outcome. At this stage I have done nothing more than piecing together the findings of various researchers on the pace and prospects of expansion of the HYV programme in wheat in the first quinquannium or so of its introduction.

This study was undertaken when I was working as Member, Agricultural Prices Commission. I am thankful to Dr. Dharm Narayan, Chairman, Agricultural Prices Commission for giving me permission to undertake this work, and more so for the discussions I had with him on this and related topics. I have benefited from his insights in India's agricultural problems. I have also received valuable comments from several friends. I wish to record in particular my thanks to Dr. D.S. Tyagi of the Agricultural Prices Commission and Shri M.D. Desai and Shri S.L. Bapna of the Agro-Economic Research Centre, Vallabh Vidyanagar, Mr. R.R. Umesh acted as my research assistant for this project. Shri S. Banahopadhaya and Shri G.A. Pillai assisted me at the stage of revision of my draft. All these were of considerable help. I have received very useful comments from Dr. Winkelmann and through him from Dr. Glenn Anderson of CIMMYT.

The first six years of the HYV programme for wheat (1966-67 to 1971-72) were unique in several respects. For the first time, a concerted effort was made to raise the production of an important cereal in a measurable way. The lessons drawn from this experience has relevance for this country as well as other developing countries which are seeking to raise the level of agricultural production with the large scale introduction of the High Yielding Varieties programme.

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I. GENESIS AND PROGRESS OF THE HIGH-YIELDING VARIETIES PROGRAMME IN WHEAT

Introduction

The remarkable increase in wheat production in India since mid-sixties merits a close look. An explanation of the phenomenon of major breakthrough in wheat production, which sharply contrasts with relative stagnation in production of other cereals, is likely to provide valuable lessons for future agricultural development. In this report an attempt has been made to underline the factors which have made this breakthrough possible and highlight the problems and issues which are yet to be tackled.

The report is divided in three parts. Part one briefly traces the history of efforts to increase agricultural production in India during the first three plan periods (1951-65), suggests reasons for the acceptance (in mid-sixties) of the strategy of agricultural development revolving round high-yielding varieties of seeds and describes the administrative and other measures to facilitate geographical spread of the new varieties. Part two, which is the core of the report, discusses the factors responsible for the rapid spread of the new varieties as well as their actual performance with the help of a set of micro level studies. Part three highlights some of the unresolved problems and the prospects for the future growth. The implication of this "wheat revolution" in terms of income distribution and employment generation have not been discussed in this review. This is mainly because the latter issues, often described as "second generation problems", have been widely commented upon.[1] On the other hand, the first generation problems, i.e., problems connected with the extension of new varieties and measures to exploit their potentialities to the maximum, have not been subjected to detailed scrutiny and examination.

Wheat Revolution in India

Judged by any standard, India's performance in wheat production during recent years, particularly since 1966-67,[2] when high-yielding varieties (HYV) were introduced for the first time for commercial production, has been remarkable.[3] In the course of six years (from 1966-67 to 1971-72) wheat production has increased from 11.4 million tonnes to 26.4 million tonnes, or has more than doubled. No other major wheat producing country in the world has surpassed this rate of increase in the production of the cereals.[4] (See Table 1.1). This has enabled India to increase its share in the world's wheat production from less than 4 percent in 1965-66 to nearly 8 per cent in 1971-72.

Increase in wheat production provides a sharp contrast to the performance of other major cereals during this period. Thus, as against the annual growth rate of 14.27 percent per annum in wheat production, from 1964-65 to 1971-72[5], the rate of growth in rice production, during the same period, was 3.63 per cent and that in the total cereals was 5.46 per cent (see table 1.2). This has resulted in growing dependence of the nation on wheat for its food supplies. Wheat consituted about 16 per cent of cereals produced in 1964-65; its share increased to 28.3 per cent in 1971-72. In terms of marketable surplus[6] and in terms of its share in the total procurement for public distribution[7] its significance is all the more greater. The phenomenal increase in wheat production has also meant progressively less dependence on the imports of cereals for managing the country's food economy. The imports of cereals which has reached an all time high figure of 10.4 million tonnes in 1966, came down to 2.1 million tonnes in 1971. Therefore, an understanding of the factors which have influenced the rate of growth in wheat output are of vital importance to this country's food economy.

The lessons that one would be able to draw from India's performance in the initial phasing of the HYV programme in wheat will be more than of local importance. With stagnation in the supplies of rice and millet in recent years, the dependence of the world economics, particularly of the food-deficit countries, on wheat is progressively increasing. In the short run, at least, there is no escape from increasing the supplies of wheat, whenever it is possible. This makes India's experience in this regard all the more relevant.

Development Strategies in the First Three Plans

Year 1966-67 marks a water-shed in the agricultural planning in India. This was the year when a large scale release of new varieties of wheat ushered in an era of New Technology in Indian agriculture.[8] However, the planners in this country were not writing on a clean slate. From the beginning of the planning era (in 1951), and in fact even earlier than that, one can identify certain common elements in the strategy of agricultural development. Principal among these are (a) extension of irrigation, (b) popularisation of plant nutrients, particularly inorganic fertilisers, (c) research on different varieties and crops, (d) introduction of land reforms, and (e) provision of institutional support to agriculture, especially in the fields of credit and marketing. Over the period of time and in different areas these programmes have worked with varying degree of success.

Experience has shown that even with the traditional varieties, irrigation provides a sizeable increase in yields. Indian planners attribute 20 to 30 per cent increase in yield in different cereals in response to irrigation [32] The emphasis on irrigation in India's planning is evident from

Table 1.1. **Compound growth rate of wheat production in selected countries of the world.**

Countries	Compound growth rate (percentage) For 1961-62 to 1971-72	For 1964-65 to 1971-72
India	8.78	14.27
Pakistan	6.56	8.62
Argentina	-1.69	-0.61
Canada	0.39	-6.18
Australia	0.31	-3.24
U.S.A.	4.44	2.14
France	3.53	3.19
U.S.S.R.	4.10	3.28
Mexico	3.49	2.26
China	4.90	3.33
World	3.74	3.05

Source: Data used from Production Yearbook 1964 and 1969, FAO, Rome, for the years between 1961 and 1968. For later years Fertilizer Statistics 1972-73 and 1973-74, Fertilizer Association of India, New Delhi.

Table 1.2. **Compound growth rates of area, production and yield of the cereals.**

Crop	Period	Percentages Area	Production	Yield
Rice	1949-50 to 1971-72	1.15	2.88	1.71
	1964-65 to 1971-72	1.00	3.53	2.91
Wheat	1949-50 to 1971-72	2.65	5.40	2.72
	1964-65 to 1971-72	6.36	14.27	7.32
Jowar	1949-50 to 1971-72	0.54	1.48	0.93
	1964-65 to 1971-72	-0.59	-1.32	-0.75
Bajra	1949-50 to 1971-72	1.04	3.14	2.03
	1964-65 to 1971-72	0.42	6.34	5.88
Maize	1949-50 to 1971-72	2.81	3.74	0.91
	1964-65 to 1971-72	3.50	3.85	0.35
Total	1949-50 to 1971-72	1.15	3.08	1.81
Cereals	1964-65 to 1971-72	1.43	5.46	4.62

Source 1. For the period from 1949-50 to 1971-72 growth rates are taken from draft fifth five year plan Vol. II, Government of India, Planning Commission. 2. For the period from 1964-65 to 1971-72, growth rates are calculated by fitting the equation $\hat{y} = e^{a+bt}$ when y denotes production and t_b time. Thus the growth rates "r" are calculated by $r = e^b - 1$. Data used from Estimates of Area and production of principal crops in India 1972-73, Directorate of Economics and Statistics, Ministry of Agriculture, Govt. of India, 1974.

Table 1.3. **Import as percentage of foodgrains production in successive plan periods.**

('000 tonnes)

	Production of Foodgrains (Average for five years)	Imports (Average for Five years)	Imports as % of Production
First Plan (1951-56)	63,181	2,464	3.90
Second Plan (1956-61)	73,999	3,464	4.68
Third Plan (1961-66)	81,040	5,084	6.27

Source. Various issues of *Food Statistics,* published by the Directorate of Economics & Statistics, Ministry of Food and Agriculture, Government of India.

the amount allocated for the development of water resources in different plans; the expenditure on irrigation (including flood control) was Rs 4340 million during the first plan, Rs 4300 million during the second plan and Rs 6640 million during the third plan. It accounted for 22.0, 9.0 and 8.0 per cent of the total plan outlay in the first, second and third Five-Year Plans respectively. Over and above the extension of irrigation through public investment, private efforst in this direction have also been considerable. All these efforts are reflected in the expansion of area under irrigation over the period 1951 to 1965. The net irrigated area increased from approximately 21 million hectares to nearly 27 million hectares during this period.

The expansion in the fertilizer use in India has been even more remarkable. The per hectare use of N and P which was respectively 0.42 kg. and 0.03 kg. in 1952-53 increased to 3.53 kg. of N and 0.85 kg of P. The use of K which was virtually non-existent in the earlier years, amounted to 0.50 kg. per hectare in 1965-66. In other words, application of N rose by more than eight times and that of P by twenty-eight times. It must be noted, though, that even while the consumption of N and P increased dramatically it was still well below the recommended levels.

Apart from strengthening the input base of agriculture, a series of land reform legislation have been enacted in the country since Independence with the objective of ensuring social justice and providing incentives to the actual tillers of the soil. While the focus of these reforms in the first few years was on the abolition of functionless intermediaries, e.g. *Zamindars* and *Jagirdars*, the later period legislations were aimed at regularising, and subsequently eliminating tenancy in land. During the 1960's, a number of laws were enacted to impose and ceiling on land which a cultivator could own or operate. These laws were implemented with varying degrees of effectiveness. Their total outcome probably falls short of the expectations, yet in several parts of the country they helped in achieving the convergence of ownership and operation of land and probably eradicated some of the more exploitative arrangements in the cultivation of land [48].

The most important institutional support provided to the agriculturists since 1952-53 was a net-work of the National Extension Service (NES) and the Community Development (DC) Blocks. These agencies covered practically the whole country by 1960-61. The major objective of the NES and CD schemes was to raise the level of rural life through community efforts. On the production side the movement strove to make farmers aware of new opportunities in the field of scientific agriculture and also to arrange for supply of modern inputs and supporting services. The NES established a creditable record in the extension of fertilizer use and improved seeds in the country-side. [34]

Among the other notable institutional support, mention may be made of the extension of institutionalised credit, regulated marketing and the expansion of the cooperative

sector in the processing of agriculture produce.

While these are the continuing aspects of production policy, a marked change was introduced in the early sixties (in 1961) by the initiation of Intensive Agricultural District Programme (IADP). Under this programme intensive efforts were made under the direction of the Union Ministry of Food and Agriculture to introduce a package of improved practices in areas of assured rainfall and irrigation. [26] Some of these areas were in the vanguard of the high-yielding varieties programme, when it was introduced in 1966-67.

The Overall Impact

In spite of a generally favourable impact of these measures, the desired results could not be obtained mainly due to their faulty implementation as well as certain gaps in the policies. The major gaps in the field of policy till mid-sixties were an absence of a coherent price policy as well as a research and development policy. The price policy was based mostly on the immediate considerations and was expressed in terms of ad-hoc measures for regulation and fixation of prices. The research policy lacked a focus and failed to create an integrated research system which is to necessary for a country of the size and diversities of India. Other not-so-desirable features on the policy plane were lack of clarity in defining actual goals, in waivering between the extensive or the intensive approach to the developmental tasks and, pre-occupation with some less important issues, e.g., the controversy on the unit of the cooperative organization for supply of inputs and credit. Thus, the efforts though massive, and mostly in right directions, lacked sharp focus and in the absence of a set of consistent policy instruments devised to achieve the given objectives, were not as effective as they could have been. [14]

Progress in the Pre-HYV Period

In spite of several handicaps, impact of these measures on raising the level of agricultural production was not inconsiderable. In fact, from 1952-53 to 1964-65, the annual compound rate of growth in agricultural production was 3.01 per cent, that in the cereals was 2.74 per cent and among the major cereals the growth in rice production was 3.18 per cent, in wheat 3.30 per cent and in jowar 1.96 per cent. It was mainly because of the rapid increase in the demand for foodgrains that the increased production was found inadequate and imports of foodgrains started mounting up, setting at naught one of the principal goals of agricultural policy, i.e., meeting country's requirement of foodgrains from domestic production.

Attainment of self-sufficiency in foodgrains has been one of the major goals of India's agricultural policy since independence.[9] This was because given a normal crop the deficit to be covered by the country even in the earlier period was marginal. [47] With the low foodgrains yields then obtaining it was always thought possible to cover the gap between availability and requirement by raising the yield levels. The foreign exchange constraint on the economy ruled out the possibility of making available adequate quantities of foodgrains by imports. In successive plans—in fact, even before the planning started, in 1949, when "Grow-More-Food" campaign was launched the goal of self-sufficiency in food was mentioned as one of the important goals of India's developmental efforts. However, with a rapidly increasing population, growing at the rate of 2.2 to 2.4 per cent per annum and a high income elasticity of demand for food (0.5 to 0.6), attempts to bridge the gap between the requirement and availability of foodgrains were not successful. If the imports of foodgrains is taken as an indicator of the short-fall in the availability from the domestic sources, the performance till the end of the Third-Five-Year Plan (65-66) was in no way reassuring (see Table 1.3).

Along with the need for raising the levels of agricultural production the other essential requirement was to minimize year to year fluctuations in agricultural production. Due to the continental size and climate of the country, and dependence of large parts on the natural rainfall for supply of water for cultivation purposes, production of crops fluctuates year to year, mainly due to the vagaries of the monsoon. Provision of irrigation had dampened such fluctuations to an extent. However, the year to year variations in output of different crops, as reflected by the coefficient of variation, showed that the problem was quite serious (See Table 1.4).

The weakness of the agricultural production base became glaring during the drought years of 1965-66 and 1966-67. Production of major cereals in one single year, 1965-66, dropped by 18.9 per cent, i.e., from 76,939 thousand tonnes (in 1964-65) to 62,403 thousand tonnes. In its coverage and intensity this drought was one of the most serious ones in the recent history. But it also created a sense of urgency in improving the production performance of Indian agriculture.

Table 1.4. **Co-efficient of variation (in percentage) in the output of major crops, from 1951-52 to 1964-65.**

Year	Co-efficient of variation Before eliminating the trend	After eliminating the trend
Rice	15.75	6.07
Jowar	12.99	9.67
Bajra	15.54	13.02
Wheat	17.70	8.93
Pulses	10.35	9.73
Cotton	10.97	9.86
Sugarcane	22.43	10.17

Based on *Indices of Production-Revised Series*, published by the Directorate of Economics and Statistics, Ministry of Food and Agriculture, Government of India, New Delhi.

High-Yielding Varieties Programme

The new strategy of agricultural development adopted since 1966-67 revolves round the high-yielding varieties of seeds. The Indian plant breeders were working for more than a decade to evolve suitable wheat varieties which would be both high-yielding and rust resistent. In 1962 while cooperating with International Spring Wheat Nursery, Dr. M.S. Swaminathan and Dr. M.V. Rao observed the high yielding potential of certain mexican wheat varieties entered in the International Spring Wheat Rust Nursery at New Delhi. Further consultations with Dr. Norman Borlaug confirmed that these lines can be the "possible tools for breaking the yield barrier."

With the assistance of the Rockefeller Foundation, a large number of semi-finished lines and four recently released Mexican varieties (Lerma Rojo 64, Sonora 64, Sonora 63, and Mayo 54) were introduced into India. These dwarf Mexican varieties in addition to their high yield potential were photoinsensitive, had synchronized tillering, early maturity (as compared with *deshi* varieties) and made better use of solar radiation (greater gain per day) than the existing *desi* types. Fortunately the wide adaptation of these varieties made their large scale introduction possible without a substantial timelag for adapting them to Indian conditions.

On the research side, coordination of research involving the "organized cooperation" of all centres dealing in wheat research had begun in 1961. In 1964 at the annual meeting of the All India Coordinated Wheat Improvement Programme, the testing programme was reorganized and preliminary agronomic trials in addition to widespread yield trials were placed throughout the five wheat regions of India. The results of these trials, encouraged the government of India to import 250 tons of Sonora 64 and Lerma Rojo 64 in 1965. In the following season widespread agronomic trials were conducted which led to the development of a sound package of practices for growing the new varieties. It was found that among the four Mexican varieties, Lerma Rojo 64 showed the widest adaptability and a further import of approximately 18,000 tons of seed was made in the summer of 1966. This together with the increase made from the previously imported material provided seed for some 292,000 hectares in the very first year of launching of the programme.

There are some distictive features of these varieties which made their acceptance at a rapid rate possible. The foremost aming these being high profitability due to high yields which, in turn, were due to remarkable response to the modern inputs, like fertilizers. First in the experimental trials and later in the farmers' fields, it was shown that per hectare yield from the new varieties was substantially higher than that in the case of old varieties. The improved tall varieties such as C-306, produced maximum yields of about 3500 kgs. per hectare, but beyond that point they showed no further increase in yield with higher rates of fertilization, mainly because of lodging. Sonora-64 and Lerma Rojo-64, on the other hand, showed progressively higher yields with increasing rates of fertilizer application upto 160 kgs. of nitrogen per hectare with the compliment of other production factors such as adequate irrigation and improved cultural practices. [4]

Under favourable conditions the new varieties made it possible to increase yields by two and a half times that obtained with the best local varieties. The dwarfness of the size made this possible as they could absorb more nutrients without lodging. This characteristic also made them more resistant to some of the natural calamities, such as strong winds.

Secondly, the plants were also found to be more rust and other pest resistent compared to the traditional varieties. The new varieties had greater resistance to all the three common forms of rusts, i.e., stem rust, leaf rust and stripe or yellow rust. Thirdly, the maturity period of these varieties being shorter, they enabled a more flexible cropping pattern than was the case with the original varieties. Double or multiple cropping with early maturing spring wheat was now within the realm of possibility. Finally, as the new strategy was a seed based strategy it was assumed to be size-neutral and, therefore, in a country where small farms dominate it was considered eminently suitable for large scale application.

It was also to the advantage of the country that a major breakthrough in agricultural production was heralded by wheat. The wheat belt is more or less a continuous area with a large degree of ecological and agro-climatic uniformity, unlike rice or millet zones which are interspersed all over the country. This made the adaptive research in wheat relatively simpler. The wheat growing areas are also comparatively more developed in terms of infra-structure, particularly irrigation, and are economically more advanced than the rice or the millet growing tracts. In most of the areas wheat, even though it is a principal crop, is preceded by a *Kharif* (autumn) crop, which makes it possible for the growers to depend on funds obtained from sale of the first crop. This enhances their capacity to innovate and to take risk.

On other considerations also, such as assured market, favourable prices, absence of serious pests and possibility of decentralised water management, wheat can be considered a "low-risk" crop. This is in contrast to rice and milled which are all "high-risk" crops since they are exposed to many serious pest problems, marketing difficulties due to marked consumer preferences, and to either shortage or excess of water, depending on the behaviour of monsoon.[10] [18]

The research efforts in adapting new varieties to Indian conditions were well planned and proved every effective. Following Borlaug's strategy in Mexico, the seed was multiplied simultaneously in different locations, in large number of plots and in conditions approximating to actual farm conditions. In 1965-66, a National Demonstration Programme was launched. Under this programme research personnel at various stations were asked to go out to the

farmers' fields and arrange demonstrations of the new varieties with the recommended practices. Thus, scientists came in close contact with the farmers and gained better understanding of their problems. They (the scientists) proved to the extension personnel, as much as to the cultivators, the value of the new technology. The programme was continued in the following year. In the subsequent year the extension services took over the programme.

The substantial import of seeds, in the initial years, once their suitability to Indian Environment was proved, saved the time which would have been otherwise spent in seed multiplication for commercial application. This strategy enabled sowing of the new varieties on more than 292,000 hectares in the very first year of their release.

Research scientists in India constantly worked to adapt the new varieties by exploiting their high yield characteristics, their rust resistant qualities and their suitability for diverse ecological environments. These varieties were subjected to exhaustive physiological, pathological, chemical and agronomic tests. The new agronomic practices to achieve maximum results were standardized. The scientists were also alive to the problem of evolving varieties suitable to Indian conditions. In addition to *Lerma Rojo* and *Sonora-64* two purely Mexican varieties, four selections from these varieties, viz., *Kalyansona, Sonalika, Safed Lerma* and *Chhoti Lerma* were approved by the Central Variety Release Comittee in 1965-66.

The specific problems which these varieties were likely to face in India were promptly looked into. The most important among these being the consumer resistance to small grain and red colour of the "Mexican" wheat as shown by the price differential between Mexican and *deshi* varieties. To meet consumer preference Indian breeders at the Indian Agricultural Research Institute (I.A.R.I.) developed "Sharbati Sonora" by irradiating the original Mexican "Sonora-64" with Gamma rays. The resultant mutant was bold and amber in colour, and was acceptable to the consumers. [18] Currently, experiments are being carried out to evolve protein-rich varieties to meet the severe protein deficiency in the country. A high tradition of research in wheat breeding and a far-sighted scientific leadership provided the necessary technical base for exploiting inherent qualities of new varieties to the nation's advantage.

It was not only the inherent superiority of the dwarf Mexican varieties and far-sighted research and development policy pursued by the scientists in charge of wheat programmes, but also the ancillary measures taken by the Government which made it possible to extend these varieties over large areas in a relatively short-time. For the first time, there was a complete rapport between the policy makers, the scientists and the extension staff as for as the propagation of these varieties is concerned. The Government also created a complex of institutions to popularise the high-yielding varieties of wheat. Such institutional support included (a) provision of seeds through the National Seeds Corporation, (b) strengthening of credit base by activising country's extensive cooperative structure, (c) development of orderly marketing through the Food Corporation in India, (d) improvement of technical base by organising nearly thirty-five Coordinated Research Programme in different commodities, and (e) establishment and strengthening of agricultural universities in different States.

A favourable climate for adoption of the new technology was provided by declaring minimum support as well as procurement prices on the recommendations of the newly established Agricultural Prices Commission. In order to make the price policy effective the Food Corporation of India was set up in the public sector with the objective of attaining "commanding heights" in foodgrains trade. Concurrent evaluation and feed-back was attempted by involving the Programme Evaluation Organization of the Planning Commission and the Agro-Economic Research Centres of the Ministry of Food and Agriculture in the task of economic appraisal of the programme. The HYV programme, thus, received unparalleled institutional support from its very start.

Spread of High-Yielding Varieties

Because of all the favourable features narrated above, by 1971-72, i.e., within six years of the launching of the high-yielding varieties programme, nearly 7.5 million hectares were brought under these varieties. This accounted for 39 per cent of the total area under wheat in that year.[1] The contribution of the HYV programme during this period can be gauged by the fact that if the earlier (pre-HYV period) trend in wheat production would have continued, the total production of wheat in 1971-72 would have amounted to nearly 16.1 million tonnes. The actual production in that year was 26.4 million tonnes. This difference of nearly 10.3 million tonnes suggests a rough measure of the success of the programme during the first six years of its operation.

Among the major wheat growing States in the country, Bihar, the Punjab and Haryana had already brought more than 60 per cent of the wheat area under new varieties by 1971-72, while Rajasthan, with 34.1 per cent of the wheat area under HYV, and Uttar Pradesh with 36.4 per cent, were near the national average during that year. The only major wheat growing State trailing behind was Madhya Pradesh, which had hardly 8 percent of the wheat area under HYV. In another, rather minor, wheat growing State, Gujarat, the HYV area was around 12 per cent of the total wheat area. In both these areas a large proportion of wheat was grown on drylands. On the other hand, in the principally rice and millet growing States which among themselves accounted for nearly 13.7 per cent of the total area under wheat), the performance of HYV wheat was quite satisfactory—with over 40 per cent of their wheat area under high-yielding varieties. (See Tables 1.5, 1.6, and 1.7). Any year to year analysis of these figures cannot be very exact because in the earlier period, i.e., till 1968-69, improved local varieties were also included in the high-

Table 1.5. **Area under high yielding varieties of wheat.**

State	1966-67 Total Area ('000 hectares)	1966-67 Area under HYV ('000 hectares)	1966-67 Percentage	1967-68 Total Area ('000 hectares)	1967-68 Area under HYV ('000 hectares)	1967-68 Percentage	1968-69 Total Area ('000 hectares)	1968-69 Area under HYV ('000 hectares)	1968-69 Percentage	1969-70 Total Area ('000 hectares)	1969-70 Area under HYV ('000 hectares)	1969-70 Percentage	1970-71 Total Area ('000 hectares)	1970-71 Area under HYV ('000 hectares)	1970-71 Percentage	1971-72 Total Area ('000 hectares)	1971-72 Area under HYV ('000 hectares)	1971-72 Percentage
Bihar	809	25	3.1	1,054	182	17.3	1,095	301	2.5	1,145	437	38.2	1,316	886	67.3	1,397	1,000	71.6
Gujarat	461	1	0.2	553	161	29.1	503	167	33.2	433	17*	3.9	577	101*	17.5	575	68	11.8
Haryana	738	13	0.9	846	101	11.9	895	259	23.9	1,017	440	43.3	1,129	630	55.8	1,172	740	63.*
Himachal Pradesh	269	1	0.4	311	11	3.5	313	23	7.3	330	61	18.5	302	109	36.1	410	125	30.5
Jammu & Kashmir	161	1	0.6	187	28	15.0	200	36	18.0	210	40	19.0	184	57	31.0	225	81	36.0
Madhya Pradesh	2,130	16	0.8	2,661	15	1.7	3,056	81	2.7	3,176	150	4.7	3,403	201	5.9	3,509	280	8.0
Maharashtra	876	43	4.9	891	14	1.6	873	63	7.2	865	152	17.6	882	211	23.9	1,009	263	26.1
Mysore	298	1	0.3	305	11	0.4	310	26	0.8	327	36	1.1	305	47	1.5	347	52	15.0
Punjab	1,615	59	3.7	1,804	639	35.4	2,066	1,012	48.5	2,162	1,418	65.6	2,299	1,499	65.2	2,320	1,620	69.8
Rajasthan	961	9	0.9	1,265	126	10.0	1,162	190	16.4	1,254	288	23.0	1,478	368	24.9	1,524	520	34.1
Uttar Pradesh	4,394	363	8.3	4,970	1,587	31.9	5,239	2,515	48.0	5,378	1,640*	30.5	5,907	1,938*	20.2	6,046	2,200	36.4
		(200)	(4.6)		(888)	(17.9)		(1,357)	(25.9)									
West Bengal	55	8	14.5	79	28	35.4	150	62	54.7	240	174	72.5	360	-	—	500	400	80.0
All India	12,838	541	4.2	14,998	2,942	19.6	15,958	4,793	30.0	16,626	4,910	29.5	18,240	6,123	33.6	19,163	7,439	39.1

*Excluding local improved varieties. (a) Anticipated coverage. Figures in the ( ) are based on estimates of area under HYV only i.e. excluding the area under local improved varieties.
Source: Directorate of Economics & Statistics, Ministry of Agriculture, Directorate of Extension, Ministry of Agriculture.

Table 1.6. **Percentage share of total area, area under HYV, and production of wheat by different states.**

State	1965-66 Area	1965-66 Area of HYV	1965-66 Production	1966-67 Area	1966-67 Area of HYV	1966-67 Production	1967-68 Area	1967-68 Area of HYV	1967-68 Production	1968-69 Area	1968-69 Area of HYV	1968-69 Production	1969-70 Area	1969-70 Area of HYV	1969-70 Production	1970-71 Area	1970-71 Area of HYV	1970-71 Production	1971-72 Area	1971-72 Area of HYV	1971-72 Production
Bihar	5.4	–	4.6	6.3	4.6	3.2	7.0	6.2	5.5	6.9	6.3	6.8	6.9	8.9	6.0	7.2	14.5	5.3	7.3	13.4	9.4
Gujarat	4.1	–	5.6	3.6	0.2	4.0	3.7	5.6	4.2	3.2	3.5	3.3	2.6	0.3	2.9	3.2	1.6	3.9	3.0	0.9	3.4
Haryana	5.4	–	8.7	5.7	2.4	9.3	5.6	3.4	8.9	5.6	5.4	8.2	6.1	9.0	10.6	6.2	10.3	9.8	6.1	9.9	9.0
Madhya Pradesh	19.1	–	12.8	16.6	2.9	9.0	17.7	1.5	11.4	19.2	1.7	10.8	19.1	3.0	11.0	18.6	3.3	10.9	18.3	3.7	11.6
Punjab	12.3	–	18.4	12.6	10.9	21.9	12.1	21.7	20.3	13.1	21.1	24.2	13.0	28.9	24.0	12.6	24.5	21.6	21.1	21.6	21.1
Rajasthan	7.7	–	7.6	7.5	1.7	7.7	8.4	4.3	8.0	7.3	3.9	6.3	7.5	5.9	6.3	6.1	6.0	8.2	8.0	6.9	7.2
Uttar Pradesh	32.7	–	36.0	34.2	67.1	37.1	33.2	53.9	35.3	32.7	52.5	32.6	32.4	33.4	31.4	32.4	31.6	32.3	31.5	29.4	28.5
Others	13.3	–	6.3	13.5	10.2	7.8	12.3	3.4	6.4	12.0	5.6	7.8	12.4	10.6	7.8	11.7	8.2	8.0	13.7	14.2	9.8
Total (All-India)	100.0	–	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Directorate of Economics & Statistics, Ministry of Agriculture.

Table 1.7. **Compound growth rates of wheat, 1964-65 to 1971-72.**

State	Area 1964-65 ('000 hectares)	Area 1971-72 ('000 hectares)	Production 1964-65 ('000 tonnes)	Production 1971-72 ('000 tonnes)	Yield 1964-65 (kg/hectare)	Yield 1971-72 (kg/hectare)	Compound growth rate Area	Compound growth rate Production	Compound growth rate Yield
Bihar	636.3	1,397.4	417.8	2,493.7	636	1,785	12.63	28.88	14.45
Gujarat	444.1	574.5	415.9	897.4	937	1,562	2.27	10.50	8.13
Haryana	722.4	1,172.0	920.0	2,394.0	1,274	2,043	8.57	17.57	8.29
Madhya Pradesh	3,157.9	3,509.0	1,980.9	3,045.4	627	863	4.66	10.94	6.80
Punjab	1,563.0	2,320.0	2,360.0	5,598.0	1,510	2,413	7.11	17.09	9.32
Rajasthan	1,183.4	1,524.4	1,103.1	1,904.4	932	1,249	5.04	11.84	5.14
Uttar Pradesh	3,965.4	6,045.8	4,117.9	7,545.0	1,038	1,249	6.66	12.46	4.45
All India	13,422.1	19,162.5	12,257.0	26,477.4	913	1,382	6.38	14.27	7.63

Source: Directorate of Economics & Statistics, Ministry of Agriculture.

yielding varieties group. From 1969-70 onwards the definition is more strict. This has particularly affected the reported figures of two wheat growing States, Uttar Pradesh and Gujarat. Similarly, there is some doubt on the accuracy of the figures of Bihar.[12]

Mainly because of inclusion of the indigenous improved varieties. Uttar Pradesh and Gujarat were in forefront of the HYV movement till 1969-70 in the sense that the proportion of wheat area under the HYV in these States was higher than the national average. The Punjab took the lead in the second year of the programme, in 1967-68, and had retained its leading position till 1971-72, although in the last two years Bihar had reported slightly higher proportion of area under the HYV than the Punjab. Haryana, the other major wheat producing State, came in the forefront in 1969-70, as it ranked third, after Bihar and the Punjab, in terms of proportion of the area under the HYV to total wheat area. It has retained the position since then. An interesting feature observed in 1971-72 was the highly satisfactory performance of principally non-wheat producing states, e.g. West Bengal.

The limited experience of six years has shown that the principal wheat growing States of the Punjab, Haryana and Uttar Pradesh contributed the most to the expansion of the HYV areas in the first three years. The early pioneers had two common characteristics, viz., there were major wheat producing States, in terms of area under wheat; the yield levels in these States were also already high, (See Table 1.7). In the later part of the period under review the eastern States like Bihar and West Bengal also joined the rank of the HYV leaders. So far the Central and Western parts—the latter after a short-lived spurt in HYV areas in Gujarat, which could as well be due to a generous definition of the HYV—have not shown much dynamism in this regard. This fact underlines the contribution of limited areas in raising total wheat production at a significantly higher level.

A district-wise analysis of area under high-yielding varieties of wheat further confirms the conclusions arrived at on the basis of State-wise information. Thus, ranked on the basis of area under high-yielding varieties of wheat in 1970-71, the latest year for which district-wise information is available, the first 20 districts accounted for 44 per cent of total area under the HYV in the country. These districts accounted for 22.1 per cent of area under wheat in the country in 1964-65; in 1970-71 their share was 24.8 per cent. Yield-wise, per hectare output in these districts in 1964-65 was nearly one and a half times (144.5 per cent) of the national average. In 1970-71 they slightly improved their position in this regard. The fact that a small but a dynamic core has supported the wheat revolution in this country is borne out by these indicators. However, a substantial number of these districts (nine) had already reached, by 1970-71, the saturation level of, say 60 per cent or more of wheat area under the HYV; six of them had 50 to 60 per cent of wheat area under the HYV. Only one of these 20 districts had less than 35 per cent of wheat area under the new varieties.

Of these 20 districts, as many as nine were from the Punjab. Of the remaining, seven were from Uttar Pradesh, three from Haryana and one was from Bihar. Concentration of large number of districts in progressive and better endowed areas was a result of deliberate policy. The rapid expansion of area under HYV wheat in these districts was equally an outcome of detailed and coordinated planning in which all agencies, the Central, the State and the District were assigned clear roles. It was also a part of the new strategy to take adequate steps for improvement of input supplies, extension and marketing. This can be well illustrated by the way in which the HYVs were propagated in the Punjab.

Planning and Coordination of HYV Programme in Punjab[13]

In late 1965, a conference on Intensive Agricultural programme, called by the Union Government, recommended the following norms for the selection of HYV areas: (1) The selected areas should, as far as possible, be under the IADP or IDA district blocks where necessary organisation and facilities have already been built up. (2) The selected blocks must have about 80 per cent of cultivable area under irrigation, of which substantial portion should be under minor irrigation,—as the latter permits better control over water supply. (3) Other than IADP/IAA, districts may be selected provided they have substantial area under irrigation and are important wheat growing tracts.

Soon thereafter chief ministers of the States met, in April 1966, and took the following major decisions, (1) Selection of districts, blocks and village where the HYV programme will be launched during 1966-67 should be immediately finalised. Within the villages the selection of participants in the programme should also be completed early. (2) A calendar of operations indicating a break-up of important programmes into specific tasks and assignments of specific responsibilities and a time table for the programme of these tasks should be prepated for a state as a whole and for individual districts under HYV programme. (3) Every state government should work out credit requirements for implementing the HYV programme, village-wise and cultivator-wise. (4) Proper arrangements should be made for the distribution of major inputs like fertilizers, pesticides etc. upto the village level. (5) The field extension agency at district as well as block levels should be strengthened on a high priority basis. (6) Respective state governments should take immediate steps for producing the bulk of foundation and certified seeds of HYVs of wheat and paddy required by them. (7) The States should ensure full coordination among the agriculture, community development and cooperative departments for implementing the HYV programme. (8) The participants in the HYV programme be invited to join demonstration-cumtraining camps.

The Chief Ministers also decided upon a target of nearly 250,000 hectares to be brought under HYV wheat programme in 1966-67. However, a review of the arrangements made to popularise high yielding varieties in different States by officials of the Government of India made them bold to increase the target to nearly 500,000 hectares. In order to fulfil this target, the estimated requirements of inputs, particularly improved seeds, fertilisers and credit were worked out and arrangements for their procurement and distribution were finalised.

As regards HYV seeds, the National Seeds Corporation of India made arrangements to procure seeds from two principal sources. About 17,750 tonnes were to be imported from Mexico, the rest were to be purchased from the Registered Seed Growers among whom foundation seeds were distributed in the previous year. Similarly, credit requirements were calculated on the basis of a credit limit of Rs. 150 per acre, as an indicative norm, and arrangements were made through the cooperative structure to provide credit to the HYV growers. The state governments were left free to revise these norms in the light of their own needs.

A significant role was assigned to the cooperatives in supply of inputs as well as credit. In order to streamline the cooperative structure in the HYV areas, a meeting of the Registrars of Cooperatives was called in April 1966 and all the necessary details were worked out.

Finally, when these decisions, taken at the Central level, were transmitted to the Punjab Government, the Punjab officials started translating these various requirements for their own State. They, however, made a departure in the sense that the target for the Punjab was fixed at nearly 104,000 hectares instead of 83,000 hectares suggested by the Central Government. Input requirements were worked out on the basis of the revised target. The input requirements were finalised after breaking up the targets among different districts and then among different blocks in the districts. Accordingly, agricultural department and the cooperative department of the state government worked out their requirement of seeds, fertilisers and credit. In the case of credit, however, the requirements were calculated at the rate of Rs. 500 per acre.

As the availability of inputs in the country was restricted, two principal bottlenecks being the availability of seeds and fertilisers, the state government was asked to lower their sights. It was found that with the supplies allocated for the Punjab by the Government of India, only 58 thousand hectares could be covered under HYV wheat.

Once the position regarding input availability became clear and the targets were suitably revised, the Director of Agriculture of the State issued detailed instructions to all District Agricultural Officers emphasising the following points: (1) it was necessary to identify areas and cultivators who would take up the programme; (b) lists of such farmers be prepared and submitted to Assistant Registrars of Cooperative by September 1966; (c) the following criteria be used for the selection of farmers; (i) availability of assured irrigation, (ii) membership of cooperative credit societies, (iii) capacity to invest in modern inputs and undertake modern cultivation.

The Director also decided the districtwise acreage to be brought under HYV wheat and these were indicated to the respective District Officers by August 1966. By about the same time, the Registrar of Cooperatives asked his district level officers to take appropriate steps to ensure adequate availability of inputs in the areas which were already selected for introduction of the HYV programme.

At the field level, detailed arrangements were made to supply seed, fertilisers and credit to the participant growers. Quantities of required seeds were procured through the National Seeds Corporation of India during September-October 1966. It was distributed through the Department of Agriculture. The Department appointed Agricultural Inspectors at the Block level to transact the whole business. The farmers were required to purchase the seeds from Block level depots. For the fertilizers, the cooperatives were the main supplying agencies. It was expected that the village level cooperative societies will indent the requirements of their members by the middle of October. These indents were to be consolidated by the District Cooperative Warehousing Societies which were the agents of the State Cooperative Marketing Federation. The State Cooperative Marketing Federation then intimated the Secretary, Agricultural Department requirements received from its various constituents. The Secretary asked the concerned fertilizer factory to send the supplies to the respective indentors, or to the District Warehousing Societies, which then distributed the fertilisers among the village cooperative societies on the basis of the quantities originally indented.

The credit supplies were arranged through the District Cooperative Banks. These were asked to ascertain from the village cooperatives the number of participating farmers in the HYV programme and to assess their credit requirements. After consolidating their requirements, the District Cooperative Banks applied to the Reserve Bank of India, through the State Cooperative Bank, for an appropriate credit limit. The Reserve Bank of India sanctioned a sum of Rs. 12.5 million for advances for wheat in Punjab in October 1966. The credit was distributed part in cash and part in kind, e.g., in form of fertilisers, according to an agreed formula.

The foregoing account indicates the type of planning and coordination which preceded launching of the HYV programme in one of the more successful States. Although there were several snags in the actual implementation of this programme, by and large, the work was conducted as planned. A sound research base and the meticulously planned ground work in the areas which were well endowed, and among the farmers who had the necessary wherewithals, gave spectacular results in the very beginning of the programme and ensured its subsequent momentum.

Notes

1. For an excellent summary of the discussions, see Tom Byres, Dialectics of Green Revolution, *South Asia Review*, Vol. 5, No. 2 January 1972.

2. The year referred to hereafter is the agricultural year, July-June.

3. A small quantity of seeds, some 250 tonnes, were brought into India and distributed to selected growers in 1965. However, the commercial production of new varieties started in 1966-67.

4. This also compares favourably with the rate of growth in wheat production in Mexico, during the hey-days of wheat revolution in that country, see Borlaug, Wheat Breeding and Its Impact on World Food Supply. *Proceedings of 3rd International Wheat Genetics Symposium*, Camberra, 1968.

5. The rate of growth in production is calculated with 1964-65 as the base, rather than 1966-67 when the HYV programme in wheat was launched, because 1965-66 and 1966-67 were two drought years and any comparison with 1965-66 or 1966-67 as the base would exaggerate the rate of growth in production in the subsequent years.

6. Principally due to the concentration of this increase in already surplus areas, e.g. the Punjab, Haryana and Western parts of Uttar Pradesh, the marketable surplus as a proportion of increased production is high, and progressively rising figure.

7. The government of India is pursuing policy of providing cheap foodgrains to the weaker sections of society, through a net work of "fair-price shops". The issue prices charged at these shops are lower than the prevailing market prices. These shops are supplied foodgrains from the Central Stocks which are built partly by imports, but in recent years progressively more by procurement of foodgrains in domestic markets. The share of wheat in the total domestic procurement was 57 per cent in 1971, its share in the issues from the fair-price shops was also 57 percent in the same year. (See, Directorate of Economics & Statistics, Ministry of Food and Agriculture, *Food Statistics*, New Delhi, 1972)

8. The main elements of the new strategy of agricultural development were to (i) bridge the gap between the available scientific knowledge and the extent of agricultural practices at the field level, (ii) select areas of assured rainfall and irrigation for concentrated application of a package of practices suitable for the high yielding varieties; (iii) achieve higher production of subsidiary foods; and (iv) prepare detailed "schedules of operations" specifying the responsibilities and roles of different agencies, see Ministry of Agriculture, Agriculture Production in Fourth Fifth year Plan, New Delhi, 1965.

9. Implicit in the idea of self sufficiency is a normative price level at which the market will clear. This price level is never defined. But generally a physical norm of availability of foodgrains i.e. the availability of 2,000 to 2,200 calories per day per capita, is suggested as the target. This view of the self sufficiency is also not unambiguous, as the same number of calories can be obtained from varying proportions of cereals and non foodgrain eatables e.g., eggs, milk, etc. In practice, a per capita per day availability of 16 to 18 ozs. of cereals is the standard by which the foodgrains requirement for self-sufficiency is estimated.

10. According to some other scientists, from the standpoint of diseases wheat is more vulnerable than many other crops.

11. The wheat area during this period increased from 12.8 million hectares (in 1966-67) to 19.2 million hectares (in 1971-72). If related to the base period (1966-67) area, the proportion of area under high yielding varieties would amount to nearly 50 per cent.

12. For example, information on the market arrivals in this state is not consistent with the reported increase in production.

13. Discussion in this section heavily draws upon the work of V.K. Gupta and K.B. Kothari, *"Planning and Implementation in Agriculture—Studies in HYV Programme, Vol. II. Mexican Wheat in Punjab;* Indian Institute of Management, Ahmedabad, 1967 (mimeo). For a similar account, but pertaining to HYV Programme in hybrid *bajra* (pearl millet) in Gujarat, see, B.M. Desai and M.D. Desai, *The New Strategy of Agricultural Development in Operation*, Thacker, Bombay, 1969.

II ECONOMIC PERFORMANCE OF HIGH-YIELDING VARIETIES IN WHEAT

Economic Superiority of High-Yielding Varieties

Various forms of institutional support and detailed planning and coordination at all levels had created a suitable climate for rapid expansion of area under HYV wheats. However, the most important factor in their ready acceptance was the expectation of higher incomes by the adopters. This awareness of comparative advantages of the HYV of wheats in the Punjab in the very first year of the programme ensured its large scale adoption [11]. Even in relatively backward areas, such as Kosi region of Bihar, a keen observer of the Indian rural scene, Ladejinsky found that given assured water supply, effective varieties and remunerative prices, villagers in that area reacted as favourably to new varieties as cultivators in the progressive areas [20].

A number of studies in India have examined the factors affecting adoption of HYV wheats and have also given useful information on the expenditure on and net returns from these varieties compared to the local varieties. The objectives, scope and methodology of these studies considerably vary; so do the concepts of farm size, incomes, expenditure etc. which they have followed. It will be neither possible nor useful to enumerate results of all the studies of the HYV programme. A fairly exhaustive bibliography at the end of this review lists most of the studies which were conducted till 1972.

In drawing lessons from the experience of the past six years or so, major reliance has been placed on five groups of studies. The Programme Evaluation Organisation of the Planning Commission made country-wide studies of the HYV programme and evaluated its results (these are referred to as PEO studies). The results pertaining to the rabi season (i.e. wheat season, October-April) of 1967-68 and 1968-69 have been looked into. Similarly, Intensive Agricultural District Programme (IADP) is periodically evaluated by a committee of experts in the Ministry of Food and Agriculture. The IADP evaluation reports pertaining to four principal wheat growing districts, viz., Aligarh (in Uttar Pradesh), Shahabad (in Bihar), Ludhiana (in the Punjab) and Pali (in Rajasthan) were examined for the present study. These reports cover three wheat growing seasons of 1966-67, 1967-68 and 1968-69, excepting the report of Pali which pertains to only 1967-68.

The Ministry of Agriculture had also organised a series of Farm Management Surveys (FMS) in various parts of the country. Two of these schemes were located in major wheat growing districts of Muzaffarnagar (in Uttar Pradesh) and Ferozepur (in the Punjab) and were conducted in the post-HYV period. The reports for years 1966-67 to 1968-69 in the case of Muzaffarnagar and 1967-68 to 1969-70 in the case of Ferozepur were found relevant for the present study. Since 1970, the Government of India have organised a comprehensive scheme for studying the cost of cultivation of principal crops (hereafter referred to as Cost of Cultivation Scheme) for finding out the cost of production of important crops grown in the country. The results from these studies conducted in two wheat growing States of the Punjab and Haryana for the year 1970-71 and in Uttar Pradesh for the year 1971-72 were available for scrutiny and examination.

The fifth important source utilised for the main discussion is a set of studies on the High-Yielding Varieties Programme (referred to as AERC studies) conducted by the Agro-Economic Research Centre sponsored by the Government of India and Functioning at various universities and institutes of national eminence. The studies conducted by the Centres are more in the nature of case studies, though they cover practically all the principal wheat growing regions, i.e., Karnal (in Haryana), Amritsar (in the Punjab), Saharanpur (in Uttar Pradesh), Kota (in Rajasthan), Tikamgarh (in Madhya Pradesh) and Faisabad (in Uttar Pradesh). These studies variously cover the years 1967-68 to 1971-72. Besides these references is also made to two studies, both sponsored by U.N.D.P. and both having 1971-72 as the reference year. One of these was located in the Kota district of Rajasthan and the other in the Karnal district of Haryana.

The note in the appendix gives relevant details about the scope, coverage and the sampling technique adopted in these various studies. Apart from the studies listed above, a number of useful researchers have been conducted by individual research workers. Although such studies do not have extensive coverage of uniform set of definitions and concepts, they do provide significant insights into the performance of the HYV programme at the farm level. At appropriate places, references will be made to some of these studies.

The results pertaining to returns from HYV wheat as revealed in various studies are summarized in Table 2.1. A perusal of the table will show that using comparable definitions of incomes, HYV wheats yield easily one and half to two times the income which the local varieties yield. There is, however, no marked difference in these proportions between the areas where spread of HYV was more rapid compared to the areas where the spread was rather slow. Although the results from various studies are not strictly comparable, they do suggest that in the areas where HYV spread more rapidly cultivation standards of local

varieties were also fairly advanced.

The conclusions arrived at on the basis of these major studies have been supported by a number of other studies. The Pantnagar study of HYV wheats for 1966-67 has shown that even while allowing for higher costs and lower prices, the farmers adopting HYV wheats increased their income by 70 per cent [45]. AERC study of four Karnal villages in Haryana State for 1967-68 rabi shows that the net returns over expenditure from Mexican wheat was around Rs. 600 while that for the local wheat was Rs. 400 [2]. Chaurasia and Singh, in their study of a Madhya Pradesh village (Panagar village of Jabalpur District), found that for 1968-69, net returns from the HYV turned out to be about 75 per cent higher than that from the local varieties [8]. Lavania and Dixit, in their study of Aligarh district (in Uttar Pradesh), found that adoption of HYV resulted in a net income of about Rs. 900 per hectare while income from local varieties was Rs. 460 [24]. Acharya's study of Udaipur villages (in Rajasthan) showed that HYV gave almost 75 per cent more returns compared to that

Table 2.1. **Income per hectare from HYV and Deshi wheat (Rupees per hectare).**

Name of Study/ Centre	Year	Average Income from HYV	Average Income from Deshi Variety
Farm Management Studies:			
Muzaffarnagar*	1966-67	1945	757
	1967-68	1760	819
	1968-69	1988	1217
Ferozepur*	1967-68	1577	475
	1968-69	256	130
	1969-70	324	160
A.E.R.C. Studies:			
Kota**	1968-69	403	346
	1971-72	344	100
Tikamgarh**	1968-69	961	643
Karnal**	1967-68	1499	988
	1971-72	1195	699
Saharappur**	1967-68	1317	837
	1968-69	1084	777
Faizabad**	1968-69	559	340
Amritsar**	1968-69	1340	538
Bijapur**	1967-68	1148	911

*Net Income = Gross Income *minus* Cost C. Coverage of different costs in Indian Farm Management Studies are as follows.

Cost A_1: Hired human labour, bullock labour, machine labour, seed manures, fertilisers, pesticides, farm buildings, interest on crop loans and other working capital, land revenue and other taxes, and miscellaneous itemas such as payment to artisans etc.

Cost A_2: Cost A_1 plus rent paid on leased in land.

Cost B: Cost A_2 plus rental value of owned land plus interest on owned fixed capital (excluding land)

Cost C: Cost B plus imputed value of family labour.

**Net returns i.e. difference between output and Current farm expenditure (C.F.E. includes, cash and kind expenditure).

Reference: See appendix.

from the local varieties [1]. Shyamal Roy, after looking into the data from various studies, came to the conclusion that in four important wheat growing areas, viz., Uttar Pradesh, the Punjab, Haryana and Rajasthan, the additional net profit (per acre) from HYV wheats was around Rs. 317 [41]. All this evidence clearly shows that net increase in income from the adoption of HYV was sufficiently large to enthuse wheat growers to change-over to new varieties.

However, most of the studies reviewed above refer to the first three years of the HYV programme. There are only two studies relating to the more recent years viz., Kota and Karnal studies for 1971-72. This limited information clearly shows the economic superiority of the HYV wheat during recent years also. On the other hand, these two studies also suggest that the level of returns from the HYV wheats as well as deshi wheat, has gone down considerably [32,21]. Three factors may explain the lower returns in recent years: (1) increase in the prices of inputs particularly fertiliser and labour, (2) decline in the relative price of wheat over the years and (3) the decline in yield per hectare. The decline in the yield was caused by the low level of fertiliser use and the use of poor quality of seed obtained from the natural selection "on the farmers" fields. Another reason sometimes advanced for the lower yields in the subsequent years is that the early adopters were farmers with greater managerial skills and better resources the subsequent adopters lacked in both. However, nothing conclusive can be inferred from the result of the available studies. As regards the accelerated expansion of area a reasonable hypothesis could be that on the farms of early adopters initial difference in net income remained the same or might have declines due to increase in input cost which might have neutralised some gains from increase in productivity but the demonstrable gains reaped by the successive waves of adopters kept on the accelerated pace of expansion of area under the HYV wheats.

Economic Use of Inputs

The higher incomes from the HYV wheats could be due to larger yields or lower per unit cost or both. The available evidence suggests that the larger incomes are due to better response to modern inputs particularly fertilisers at higher levels of input utilisation, which accounts for larger per hectare production and profitability.

Wherever comparable data are available, it can be seen that yields from high-yielding varieties at the field level is easily one and half to two times the yields from the local varieties. This is apparent both in the developed as well as relatively underdeveloped regions. However, in developed regions, like Ludhiana (in the Punjab), the difference in the yields from the local and Mexican varieties is larger in absolute terms than, say, in the underdeveloped areas like Shahabad (in Bihar) or Pali (in Rajasthan) (See Table 2.2).

There are few reliable studies to look into per unit cost of the HYV and the traditional varieties. The cost

Table 2.2. **Yield Levels of HYV & Deshi (local) Variety of Wheat.**

Name of Study/ Centre	Year	Variety	Yield (kg/ha) HYV	Desi
A.E.R.C. Studies				
1. Kota	1968-69	S-64	806	839
		S 227 (Kalyansona)	821	
		Kalyan Sona	2572	
	1971-72	All HYV varieties	1541	862
2. Tikamgarh	1968-69	S-64	1883	
		LR	1562	
		S-308 (Sonalika)	2023	
		Other HYV	1189	
		Total of HYV	1906	
3. Karnal	1967-68	LR	2704	1676
		S-64	2291	
		S-307 (Safed Lerma)	3659	
		S 308 (Sonalika)	3388	
		Kalyan	3663	
		PV-18	3675	
	1971-72	All HYV varieties	2430	1341
4. Amritsar	1967-68	PV-18	3679	1684
		LR	2956	
		S-64	2944	
		Kalyansona	3845	
		Other HYV	3453	
	1968-69	All HYV varieties	2996	1284
5 Shaharanpur	1967-68	Mexican	2382	
	1968-69	Mexican	2116	1383
6 Faizabad	1968-69	LR	1483	
		S 64	1510	
		S-227 (Kalyansona)	463	
		S-308 (Sonalika)	2318	

mprehensive and detailed enquiry among these, viz., mprehensive Scheme to study Cost of Cultivation onsored by the Ministry of Agriculture, has shown that 1970-71, per quintal cost of production of wheat m the HYV was lower, to the tune of Rs. 3, both in Punjab and Haryana. Lavania and Dixit's study in igarh district (in Uttar Pradesh) also suggest somewhat ver per unit cost for HYV compared to the local eats [22].

The main source of higher incomes is larger yields due better response of the HYV to the use of improved uts. A number of studies have been made to assess the nomic returns from the use of inputs in the production HYV wheat. Most of these studies have concentrated on response of fertiliser which is the crucial factor in termining yields from the HYV. There are, however, a v studies which have looked into this problem in a more nprehensive way. As an illustration, one can cite the dy by P.V.G.K. Rao [38] for the year 1968-69 which vered Amristsar district of the Punjab State.

In this study, an attempt was made to examine the hnical conditions of production of four different varieties of wheat, three Mexican varieties and one local variety, by estimating production functions of the Cobb-Doughlas type. For each variety, the following functions were fitted:

(i) $Y = a x^b$ where Y = *output*
x = *production expenses in rupees*
b = *elasticity of output with respect to production expenses.*

(ii) $Y = a x_1^{b1} x_2^{b2}$

where Y = *output*
x_1 = *production expenses in rupees*
x_2 = *farm size in acres*
b_1 and b_2 = *elasticity of output with respect to the factors of production.*

In this exercise all the multiple correlation coefficients were found to be statistically significant at 1 per cent level and value of R^2 indicated that with a solitary exception i.e. in three out of the four varieties examined, more than 90 per cent of the variations in output were explained by the

Table 2.2 (continued)

Name of Study/ Centre	Year	Variety	Yield (kg/ha) HYV	Desi
	1967-68	HYV	2246	
7. Bijapur	1967-68	All HYV varieties	1862	1393
Farm Management Studies				
1. Muzaffarnagar	1966-67	2414	1336	
	1967-68	3254	1962	
	1968 69	3482	2324	
2. Ferozepur	1967-68	2708	1873	
	1968 69	2950	1363	
	1969-70	2829	1562	
I.A D.P. Studies				
1. Aligarh	1966-67	HYV	2960	1940
	1967-68	HYV	2120	1560
	1968-69	HYV	1960	1510
2. Shahabad	1966-67	Mexican	1570	680
	1967-68	Mexican	1710	990
	1968-69	Mexican	1810	1110
3. Ludhiana	1966-67	Mexican	4750	2360
	1967-68	LR	3660	2320
		S-64	3050	
		PV-18	4800	
	1968-69	PV 18	3250	1880
		K-227	3750	
		S-308	3510	
4. Pali	1967-68	S-64	1730	1170
Cost of Cultivation Study				
1. Haryana	1970-71		2390	1981
2. Punjab	1970-71		2452	2004
Ad-hoc Studies				
U.P. Small Farmers' Study				
1. Badaun	1969-70		1940	960
2. Nainital	1969 70		2260	780

Reference. See Appendix.

factors included in the analysis. From the test carried out for finding the deviation of the sum of elasticities from unity, it was concluded that constant returns to scale existed in the case of PV-18, Sonalika (S-308) and local wheat and increasing returns prevailed in the production of Kalyan. Marginal value productivities were estimated at geometric mean level of inputs for all the four varieties. It was found that Kalyan tops the list followed by PV-18 and Sonalika in that order. Further, it was estimated that an average increase in production expenses—which approximate to the variable costs—by one rupee, other inputs being held constant, would generate additional output worth Rs. 2.39 in the case of Kalyan, Rs. 2.70 for PV-18, Rs. 2.48 for Sonalika and Rs. 2.42 for local varieties.

The second type of function revealed that an additional rupee spent on total expenses added output worth Rs. 2.19 in case of Sonalika. The returns per rupee of expenditure in the case of other varieties i.e., Kalyan, PV-18 and local were calculated at Rs. 1.27, Rs. 1.36 and Rs. 0.90 respectively. It was further estimated that keeping the same input-output ratios, an addition of one acre under Kalyan brings returns of Rs. 524.80, while return from an acre under PV-18 will be Rs. 393.80, Rs. 395.42 from Sonalika and Rs. 304.60 from the local variety.

In another study of HYV wheat in Udaipur district of Rajasthan, Acharya came to the conclusion that taking all the inputs into account, HYV wheats yield almost 75 per cent higher returns compared to that from the local varieties [1]. The productivity of almost all inputs was found to be higher in the case of the former. Judged by the production elasticities and marginal value products, the resources employed in the HYV were found to be used more efficiently.

Further, the PEO study for rabi 1968-69 concluded that yield levels within a State suggest that among the HYV growers, the higher the use of improved inputs, particularly fertilisers and the larger the adoption of improved practices, the better are the results [34]. Similar conclusions were arrived at by some of the AERC studies [10].

Analysing the farm level data from three wheat growing IADP districts, Malone concluded that in two of these districts, correlation between the lower use of fertiliser and lower yields could be discerned, although the relationship was not close. He found that in all the situations

examined a rupee invested in fertilisers yielded more than its value in terms of extra yields [25].

The differing responses from the use of fertilisers with the HYV and the local wheats were brought out more sharply by the data from the controlled experiments. One such study of the economics of input use in HYV and local wheats in the Punjab State was made by Kahlon and Kaul [15]. This study which was based on experimental results used a non-linear regression function with output as the dependent variables and cost of fertiliser (including cost of application) as the only input cost. The economics of fertiliser use on semi-dwarf high-yielding wheat, Kalyan-227 and two tall indigenous improved wheat varieties, i.e., C-273 and C 306, cultivated in the Punjab was examined. It was found that with a fertiliser dose of 90 kgs. the semi-dwarf wheat, Kalyan 227 produces 32.7 per cent higher yield than C 306 and 42 per cent more yield than C 273. It was further observed that at the recommended level of fertiliser application for C-306, i.e. 60 kg. of N and 30 kg. of P_2O_5, per hectare yield from this variety was 36.83 quintals while with the same amount of fertiliser it came to 40.90 quintals for Kalyan-227. Thus, because of the superior plant type, the HYV gave good performance even at the low level of fertilisation.

Herdt examined the response to fertiliser applied at optimal and half-optimal level with various price discounts, to contrast the yields from the HYV and the local varieties. The study was based on experimental results. Cost of fertiliser used was taken as the only input cost and net returns were arrived at by deducting from total returns the cost of fertilizer. This study also corroborated the results available from similar other studies [13].

Using the data obtained from the fertiliser experiments conducted at the U.P. Agricultural University on the Mexican red and Indian amber wheats for three years, 1965-66, 1966-67 and 1967-68 Singh and Sharma studied the response of the three Mexican red varieties, Sonora-63, Sonora-64 and Lerma Rojo, and three Indian amber wheats, NP-876, NP-887 and C 306, to nitrogen, by fitting a quadratic production function [38]. It was concluded that the Mexican red wheats gave relatively much higher response to nitrogen at all levels of application than the Indian amber wheat. At the level of nitrogen giving maximum yield per hectare, the Mexican red wheat yields about 1.6 times more than the Indian amber varieties. The level of nitrogen application giving the maximum possible profit was 1.5 times more for the Mexican than for the Indian wheats. The total revenue and total cost per hectare incidental to the application of nitrogen were respectively 2.5 and 1.5 times higher for the Mexican wheat than for the Indian varieties. On an average the Mexican dwarf gave 17.7 kgs. for each kg. of nitrogen applied compared to 14.1 kgs. for the best of the local varieties at their respective most profitable levels of nitrogen application. Finally, it was observed that the dwarf varieties use fertiliser more efficiently than the best of the tall varieties even at 40 kgs. per hectare application of nitrogen.

Most of the above studies examine the yields of the Mexican wheat under irrigated conditions. No field data are available for the rainfed conditions. However, the results of the All India Coordinated Agro-Economic Experiments showed that with the application of same dosage of fertilisers increase in the yield from Mexican varieties even under rainfed conditions was higher. In Meerut with the application of 50 kg. of nitrogen the additional yields were 667 kgs. from Sonalika. In Ambala, additional yields were 480 kgs. as against 460 kgs. for the deshi varieties.

An important implication of these findings is that the returns from the HYV, other things remaining the same, would depend upon the extent of use of fertilisers. Although even at the low level of fertilisation and even in rainfed conditions the HYV are likely to yield higher returns, the gains are larger when higher dosage of fertilisers are used under irrigated conditions.

Range of Variations in Income from HYV

An important finding of various studies in the economics of the HYV wheat is that average returns from an acre under the HYV wheat varied widely among the adopters. Significant variations between different regions growing the HYV wheats was brought out in a number of studies. For example, the IADP data suggested that the highest yields obtained in one district, viz., Shahabad were barely equal to the lowest obtained in another district, viz., Ludhiana[1]. Although these comparisons are based on group averages, and within the groups wide variations prevail, yet the difference between the two areas is too wide to be overlooked. The AERC studies exhibited a wide variations between the returns and yield in different regions. The per hectare returns ranged between as low as Rs. 344.12 in Kota to about Rs. 1500 in Karnal. The yields per hectare ranged between 8.06 qntls. in Kota to 38.45 qntls. in Amritsar. Similarly, the PEO study has shown that six out of the 14 wheat blocks in 1967-68 and seven in 1968-69 recorded higher than average returns per acre.

Equally remarkable variations were observed among the adopters within the same area. Some idea of these variations can be obtained from the group averages given in the Table 2.2. A more accurate picture emerges from the data from the Cost of Cultivation Scheme. More than 90 per cent of the area under wheat covered under this study were already brought under the High Yielding Varieties. Following data from the Cost of Cultivation Survey gives an indication of range in cost of cultivation, yield and cost of production (See Table 2.3).

These variations can be explained by three distinct groups of factors. First of these pertains to the spatial aspects, particularly agro-climatic factors and development of public infrastructure in different areas. Second relevant factor is the use of different high yielding varieties. And third, probably the most important, factor is the extent of the use of modern inputs.

From the available accounts, yields obtained from HYV wheats in Punjab were significantly higher than those from the similar varieties in other regions, say, Uttar Pradesh or Madhya Pradesh. Such differences were observed even before the advent of new varieties (because of agro-climatic factors and the development of infrastructure in some of the areas). The IADP studies have brought out the difference in yields in these areas before and after the advent of the HYV. The average wheat yield in IADP district of Ludhiana in 1964-65 was 24.6 quintals per hectare. In the same year, the average yield in Shahabad was only 10.9 quintals. In 1968-69, the high-yielding varieties yielded 35.5 quintals per hectare in Ludhiana and 18.1 quintals per hectare in Shahabad. The net increment in income realised by the adoption of HYV, after deducting cost of only fertilisers and ancilliary costs, was Rs. 680 in Ludhiana, that in Shahabad was Rs. 550.6. Similar differences can be brought out from the comparison of yields in different districts before and after the adoption of the HYV. As a rule, the regions where crop yields were higher in the pre-HYV period have also registered larger increases in yields after the adoption of the HYV.

Within the same region, differences in yields can be partially explained by the use of different high yielding varieties. In some areas, for example, in Amritsar district, Sonalika obtained the highest per acre net returns [38] while in another area, Udaipur district (in Rajasthan), Kalyansona proved to be the superior variety [46]. In yet another area, of the three varieties studied, viz., Kalyansona, PV-18 and Sonalika, Kalyansona not only gave higher return but also relatively more stable net returns per acre. In A.P. Rao's study also, Sonalika and Kalyansona varieties were found to be more productive compared to either Lerma Rojo or C-591 varieties [37]. Sisodia's study in Indore district [43] showed that the gross output for Kalyansona, Lerma Rojo and Sonora-64 worked out to about Rs. 4,100, Rs. 2,740, Rs. 2,480 per hectare respectively. It is difficult to say whether these differences in returns are due to instrinsic superiority of different varieties or they can be ascribed to the varying quantities of inputs used by different adopterа. Although, it might be mentioned that in all research trials Kalyansona established its superiority over other varieties in terms of yield, however, it was also found to be more susceptible to leaf-rust once the disease appeared on the scene. In any case, the very fact that about 10 important high yielding varieties of wheat are in vogue suggests that no one variety is uniformly superior in all the wheat growing regions.

The more fundamental difference, and on that there is substantial evidence to support, is the differing use of inputs by the adopters. Starting with seeds, though the recommended dose is 35 to 40 kgs. per acre, the actual use among most of the adopters was found to be lower; in some cases, as low as eight to 15 kgs. While such extreme cases might reflect limited availability and high prices of the improved seeds, the general pattern as revealed in a number of AERC studies was the use of 25 to 30 kgs. of seeds per acre. The quality of seed also was not found to be as good as one would have expected. It was noted that the seeds from the registered or certified seed growers could be obtained only by a limited number of cultivators and the rest had to depend on "natural spread", i.e., either on their own selections or from the selections of other fellow cultivators. Very few instances of treatment of seeds to protect them from the likely attacks of pests were observed. Even in a few cases where the seeds were treated, subsequent spray of pesticides was practically non-existent. Both Farm Management Surveys and Cost of Cultivation Surveys have recorded less than one per cent of total cost on insecticides and pesticides. Low expenditure on pesticide may be due to the general belief that the new varieties are inmune from pests and diseases. (This belief was shaken after the reports of the appearance of rusts in the new varieties in some of northern wheat growing regions in the winter of 1973).

In general, however, Indian wheat farmers suffer little field damage from insects and there are no chemical treatments for rust which are economically viable in the Indian context. To date, rust can only be confronted through efforts in plant breeding.

Although HYV have been adopted mainly on irrigated areas, the extent and the nature of irrigation have varied. Large profits from the dwarf wheats depends heavily on assured supplies of water. In fact, irrigation at fixed times in the growth cycle of the plant is essential to the realisation of its high-yield potential. Only cultivators with assured

Table 2.3. **Maximum, minimum and average values of cost of cultivation, yield and cost of production of wheat,* 1970-71.**

		Haryana	Punjab
Cost of Cultivation	Maximum	2,127.00	2,692.16
(Cost C)** per	Minimum	401.45	758.84
hectare (Rs)	Average	1,093.59	1,489.46
Yield per hectare	Maximum	58.57	53.94
(quintals)	Minimum	9.23	8.27
	Average	22.74	24.40
Cost per quintal	Maximum	121.84	150.97
(Cost C) (Rs.)	Minimum	17.29	25.35
	Average	48.10	61.04

*Reprinting farmers had 90 per cent of their area in HYV's

**Net of the value of the by-product.

In Indian Farm Management Studies coverage of different costs is as follows:

Cost A_1: Hired human labour, bullock labour, machine labour, seed, manures, fertilisers, pesticides, irrigation, depreciation on implements and farm buildings, interest on crop loans and other working capital, land revenue and other taxes and miscellaneous items such payment to artisans etc.

Cost A_2. Cost A_1 plus rent paid on leased in land

Cost B: Cost A_2 plus rental value of owned land plus interest on owned fixed capital (excluding land)

Cost C: Cost B plus imputed value of family labour.

N.B. More than 90 per cent area in the sample was under the HYV wheats.

water, i.e., those having private tubewells, could reap full advantages from the cultivation of the Mexican varieties. Ladejinsky observed that in Purnea district (in Bihar) cultivators who not only derived irrigation water from canals but also had access to privately owned tubewells did significantly better and felt more assured than those who were exclusively dependent on public canals [22]. This was mainly due to the lack of coordination between the agricultural department and the irrigation department. Often canals are closed when there is a critical need for water. In Rajasthan also, the districts with larger concentration of private tubewells, e.g. Alwar and Jaipur, showed greater proportion of wheat area under new varieties compared to the districts relying mostly on government canals for irrigation [3]. Wherever the HYV programme has gained momentum and other conditions, such as adequate size of farm, the availability of power etc., have been fulfilled, the farmers have invested heavily on creating their own supplementary sources of water supplies. The superiority of tubewells irrigation to canal irrigation in terms of higher profitability was also established by the Farm Management Studies of the Ferozepur district [44], and in the cost of cultivation study for the Punjab, although in Haryana canal irrigation proved to be cheaper [28].

Partly because of the non-availability of adequate water supplies from public irrigation system, the HYV adopters in many areas could not give adequate irrigation. Administration of the canal system often brings water to the farmer when he does not need it and makes water completely unavailable in periods when needs are critical. In the AERC study of Saharanpur district (in Uttar Pradesh) during 1968-69 season, it was observed that most of the farmers irrigated their wheat only four times, while the recommended number of watering was six [37]. Similarly the Kota study reported that farmers who were mostly served by canals, irrigated their wheat crop three times, whereas four to five waterings were recommended. It was also noted that many farmers could not give irrigation at proper time [3].

Practically all the studies of HYV have concluded that the use of fertiliser is much below the recommended levels. Probably, on most of the soils K is not needed but the use of P is also found to be grossly inadequate. Even the use of N varies widely among the adopters. The PEO study concluded that the application of fertilisers ranged widely from 15 to 137 per cent (of the recommended doses) in 1967-68 and 12 to 102 per cent in the following year [23]. One of the reasons for not using adequate quantities of P is reported to be the fact that the ready made mixture constituting the required proportion of N, P and K for the Mexican varieties were not available, and, therefore, the farmers had to purchase different types of fertilisers and mix them in proportions they thought proper [37]. The IADP study has shown that between 1967-68 and 1968-69 fertiliser utilisation increased from 230,000 tonnes to 880,000 tonnes. However, only 30 per cent of the farmers applied the recommended quantity of nitrogenous fertiliser and hardly any farmer used the recommended quantity of P [19]. Similarly, in Purnea district of Bihar the utilisation of fertiliser between 1964-65 and 1968-69 jumped from 62 to 900 tonnes. This nearly 15-fold increase, however, does not mean that the farmers have applied fertilisers at the recommended level. If they had done so, the consumption would have been nearly 2,700 tonnes [20].

It has been shown that the farmers who had adopted all the ingredients of new technology along with HYV seeds, viz., seed treatment, proper irrigation, adequate fertilisers, preventive plant protection, etc. had reaped excellent harvests, but the farmers adopted all these ingredients were, according to PEO study, only 20 per cent among the adopters of HYV paddy and wheat.[23].

Beneficiaries of High-Yielding Varieties Programme

The wide variations in incomes from HYV wheat naturally raises the question as to who has benefited the most from this programme. The available information is not clear enough to permit any categorical answer or to define, in a precise manner, the factors which could be associated with successful adoption of the HYV programme at the field level. A major difficulty in analysing the data arises because in most of the Indian studies, farmers are categorised only by the size groups of land holdings. Operational area of land is one of the several resources owned or hired by an agricultural producing unit and access to cultivable area is one of the several attributes of a decision maker. But the available data is so organised that one has little option but to look into the performance in relation to the size of land holdings. There is, however, some justification in proceeding with the size of land holding as the first approximation of the resource base of an agricultural firm in rural India. This is because most other assets as well as access to the scarce or the subsidised resources hold close and positive relationship with the size of holdings. The subsequent discussion, therefore, categorise the farmers on the basis of the extent of land they own operate and the limitations of such an uni-dimensional classification should be borne in mind while interpreting results. Another qualification needs to be added. From the studies it seems that the areas where land consolidation has taken place, the pace of adoption has been made rapid. The consolidate holdings increased the prospect of digging shallow tube wells, at least on the medium sized holdings [40].

Judged by the first year of adoption of new varieties or the proportion of adopters in each group in any particular year, the large farmers show a clear lead in their involvement with the programme. Thus, in the PEO study of the HYV programme, it was found that a much larger proportion of the adopters among the larger holding groups had adopted the HYV in the very first or in the subsequent year of its introduction. Reverse was true in case of the small farmers (see Table 2.4). That the large farmers are early adopters is borne out by a number of other studies. The IADP study for Ludhiana (in the Punjab) observed that

Table 2.4. **Percentage of adopters by size of holding groups.**

Name of Study/Centre	Year	Size Group	Percent of HYV adopters
A.E.R.C. Studies:		Below 5 acres	43
1. Kota (Rajasthan)	1968-69	5–10	60
		10–15	50
		15–20	69
		20–30	64
		30–40	63
		40–60	80
		Above 60	100
		All farms	60
2. Faizabad (U.P.)	1968-69	0–1 acres	23
		1–3	65
		3–5	88
		5–10	91
		10–15	100
		15 and above	100
		Overall	70
3. Karnal (Haryana)	1967-68	0–5 acres	100
		5–10	100
		10–15	100
		15–25	100
		25–50	100
		50–75	100
		75–100	100
		100–200	100
		Total	100
4. Amritsar (Punjab)	1967-68	5–10 acres	100
		10–15	100
		15–20	100
		20–25	100
		25–30	100
		30–45	100
		45 and above	100
		Total	100
5. Saharanpur (U.P.)	1967-68	Below 5 acres	-
		5–10	36
		10–15	61
		15–20	83
		20–25	83
		25–50	71
		50 and above	100
		Total	67
Farm Management Studies			
1. Ferozepur (Punjab)	1969-70	Below 6 acres	94
		6–9	91
		9–14	97
		14–24	95
		24 and above	100
		Total	95
2. Muzaffarnagar	1968-69	0–2.87 ha.	38
		2.88–4.71	36
		4.72–6.96	52
		6.97–10.65	58
		10.66 and above	57
		Total	48
PEO Studies			
1. Bihar	1967-68 (Rabi)	Below 2.5 acres	42
		2.5–5	67
		5–10	62
		10–20	89
		20–50	100
		50 and above	100
		Total	59
2. Haryana	1967-68 (Rabi)	Below 2.5 acres	0
		2.5–5	4
		5–10	6
		10–20	13
		20–50	28
		50 and above	31
		Total	16

Table 2.4 (continued)

Name of Study/Centre	Year	Size Group	Percent of HYV adopters
3. Punjab	1967-68 (Rabi)	Below 2.5 acres	58
		2.5–5	68
		5–10	66
		10–20	85
		20–50	92
		50 and above	100
		Total	80
4. Rajasthan	1967-68 (Rabi)	Below 2.5 acres	0
		2.5–5	12
		5–10	4
		10–20	20
		20–50	43
		50 and above	51
		Total	30
5. Uttar Pradesh	1967-68 (Rabi)	Below 2.5 acres	25
		2.5–5	36
		5–10	41
		10–20	65
		20–50	75
		50 and above	62
		Total	42
6. All States	1967-68 (Rabi)	Below 2.5 acres	27
		2.5–5	36
		5–10	38
		10–20	53
		20–50	51
		50 and above	47
		Total	43

generally the farms with larger holdings were the first to adopt HYV [26]. In fact, one of the reasons for rapid expansion of HYV in Ludhiana is ascribed to a relatively larger number of holdings in the medium, i.e. four to eight hectares, and large size groups. Very small holdings, say, of less than one hectare, are very few and even holdings of the size of one to four hectares are relatively fewer. On the other hand, in Pali (in Rajasthan) where the programme did not made much of a headway, most of the holdings, i.e., 62 per cent, were below four hectares.

A much sharper picture emerges when the size of holdings of the adopters and non-adopters in the same year and in the same area are compared. Invariably the large size holders are represented more than proportionately among the adopters. For example, Lockwood, Mukherjee and Shand utilizing data for three successive PEO studies from 1967-68 to 1969-70 concluded that the data revealed a strong positive linear association between the proportion of farmers adopting the HYV seed and the size of farm for all these three years. Correlation analysis carried out on the relationship showed highly significant R^2 value. While this farm size relationship holds generally valid, particular instances of variations were cited especially in those districts where the adoption was virtually universal, for example, for the four Punjab wheat district—Amritsar, Ferozepur, Patiala and Ludhiana. However, even in these districts the general relationship could be observed in the early years, but by 1969-70, the small farmers had also caught up with their large neighbours [23].

Using the same data base, i.e., PEO reports, Schluter studied the relationship between adoption of HYV and farm size. He found that the hypothesis that adoption is unrelated to farm size stood rejected at 0.5 per cent level, indicating that a significant positive relationship exists. Even when 98 per cent of the farmers in an area had adopted HYV, as it happened in the rabi season of 1968-69 in the Punjab, the slope of the co-efficient is still positive, thus, suggesting that at every level of adoption those few who remained outside the fold have small farms [39]. Farm Management Studies for Ferozepur and Muzaffarnagar also substantiate this view, particularly when data for 1968-69 and 1969-70 are taken into account [16].

However, it may be pointed out that the positive association between farm size and the extent of adoption obtained mainly because of the diffusion policy of the government. It was mentioned in section I that for the initial spread of HYVs farmers with adequate irrigation facility and other resources were selected. Therefore, there is no wonder if the association was positive. The low participation by the small farmers in the later stages may be explained by unavailability of irrigation facilities; most of the small farmers who did not grow HYV wheat did not have irrigation facility [3].

Not only the large farmers are early adopters and at every stage they have more than proportionate representation among the adopters but also as a general rule the large farmers seem to adopt HYV on proportionately larger wheat areas cultivated by them. This, however, is not universally true although the weight of evidence is unmistakable. Studying the relationship between proportion of acreage under HYV and farm size and using PEO data Schluter observed that in wheat growing areas, there is a significant positive relationship between the proportion of acreage under new varieties and farm size indicating that the proportion of acreage under new varieties increases as farm size increases[2] [39]. The PEO studies, IADP Aligarh study and AERC studies in Karnal and Amritsar support this trend. On the other hand, AERC studies in Kota, Bijapur, Faizabad and Saharanpur exhibited the reverse trend. The Farm Management Study of Ferozepur suggested a positive relationship between farm size and the proportion of wheat area under HYV, although no such evidence was forthcoming in another Farm Management Study, i.e., of Muzaffarnagar. Findings from some of these studies are summarized in Table 2.5.

The third conclusion of a similar nature is that, by and large, the larger size groups obtain larger per hectare net income from HYV wheats than the smaller size groups. Thus, Ferozepur Farms Management Survey revealed that while the per hectare net income for size group below six hectares was Rs. 676, it was around Rs. 1,100 in case of holdings above 24 hectares [16]. Similar conclusions could be reached from the Farm Management Study of Muzaffarnagar, although the difference among various size groups in that case was not very sharp. Most of the AERC's studies have also arrived at the similar findings.

In the Haryana study of HYV wheats during 1969-70, it was found that the farm business incomes increase with the size of holdings, from Rs. 1,428 for less than five acres farm to Rs. 13,028 for farm above 30 acres [5]. Shah and Ali's study of 60 farmers selected according to the probability proportional to a number of farmers in each size group from three clusters of villages in Nainital district (in Uttar Pradesh) showed that the value of per acre production in the HYV increases with the size group of holding [40]. Lavania and Dixit's study on Aligarh district (in Uttar Pradesh) showed that the cost of production of wheat suggested a declining trend with increase in the size of farm. The net income (gross output-total cost per acre) for the local wheat showed a declining trend with an increase in the size of farm. The net income (gross output-total cost per acre) for the local wheat showed a declining trend with an increase in the size of farm, while for the HYV wheat it was maximum for the large farms and minimum for the medium size farms [22]. In another study, it was concluded that taking into account all the inputs increasing returns to scale were indicated for HYV wheat whereas the local variety revealed decreasing returns to scale [1]. The AERC Study of Saharanpur (in Uttar Pradesh) also concluded that the cultivators in the largest size group of holdings achieved relatively higher yield with lesser expenditure as compared to those in the smallest size group. The AERC Studies of Kota (1971-72), Saharanpur, Karnal and the PEO study also showed that large farmers realised significantly higher per hectare yield as compared to the yield obtained by the small farmers; Bijapur and Aligarh studies exhibited opposite trend. However, the weight of evidence suggests a positive association of per hectare income and the size of holding (See tables 2.6 and 2.7).

These findings are, however, not universally observed. Some of the studies, for example, the PEO study, have shown that there was a clear and positive association between farm size and the HYV participation in terms of adopting farmers, but no such consistent pattern emerged between farm size and levels of fertiliser use. This was particularly true in the Punjab, although the same study observed that in Uttar Pradesh, Rajasthan and Bihar, per hectare use of fertilisers tended to increase with farm size. The AERC study of Saharanpur district revealed that all the cultivators irrespective of their land holding size obtained the same per hectare output. From this study, it was concluded that the returns to scale were constant and, also, that cultivators in different size groups were using the same level of inputs and as a result the per acre output from a particular variety did not differ significantly among different size groups of cultivators.

In the absence of universally observed results, one will have to resort to the qualitative assessment of the factors which contribute to the increase of income from the HYV and to relate the availability of these factors on different size groups of holdings. This task is attempted in following paragraphs.

Table 2.5. **Area under HYV wheat as percentage to total wheat area in different size of holding groups.**

Name of Study/Centre	Year	Size Groups*										
		Below 5	5.01-10.0	10.01-15.0	15.01-20.0	20.01-30.0	30.01-40.0	40.01-60.0	60.01-& above	Total		
I. A.E.R.C. Studies:												
Kota (Rajasthan)												
(Sultanpur Panchayat)	1968-69	25.49	14.21	33.78	26.00	36.31	34.11	21.45	21.62	25.77		
(Ladpur Panchayat Samiti)	1968-69	81.25	59.04	34.67	23.73	51.45	62.36	6.25	30.00	41.72		
		0-5	*5-10*	*10-15*	*15-25*	*25-50*	*50-75*	*75-100*	*100-200*	*Total*		
Karnal (Haryana)	1967-68	20.00	59.49	61.39	65.07	57.82	75.71	85.56	94.47	74.80		
		0-1	*1-5*	*3-5*	*5-10*	*10-15*	*15 & above*		*Total*			
Faizabad (U.P.)	1968-69	94.44	50.02	46.94	46.03	7.77	33.12		47.33			
		Below 5	*5-10*	*10-15*	*15-20*	*20-25*	*25-50*	*50 & above*		*Total*		
Saharanpur (U.P.)	1967-68	-	60.4	56.6	58.3	58.2	58.2	45.6		59.3		
	1968-69	51.20	49.76	56.87	68.44	-	70.85	-		63.05		
		Below 10	*10-20*	*20-30*	*30-50*	*50-75*	*75 & above*		*Total*			
Bijapur (Mysore)	1967-68	65.21	77.78	55.00	71.03	57.64	66.20		65.95			
		Below 5	*5-10*	*10-15*	*15-20*	*20-25*	*25-35*	*35-45*	*45-60*	*60-75*	*75 & above*	*Total*
Amritsar (Punjab)	1968-69	85.87	87.14	84.49	93.80	100.00	95.37	99.37	100.00	100.0	100.0	95.60
		ha. 0-2.87	*2.88-4.71*	*4.72-6.96*	*6.97-10.65*	*10.66 & above*	*Overall*					
II: Farm Management Studies:												
1. Muzaffarnagar (U.P.)	1966-67	40.54	36.56	32.60	47.70	32.75	37.77					
	1967-68	20.66	50.44	21.91	26.23	18.53	23.49					
	1968-69	43.02	56.74	36.08	30.94	38.86	37.92					
	Average	34.74	47.58	30.20	34.96	20.05	33.06					
		Below 6	*6-9*	*9-14*	*14-24*	*24 & above*	*Total*					
2. Ferozepur (Punjab)	1967-68	10.18	10.26	12.26	11.01	11.92	11.14					
	1968-69	27.73	27.58	29.77	30.38	36.88	30.70					
	1969-70	31.85	34.05	31.66	35.88	32.66	33.74					
	Average	23.25	23.96	24.56	25.75	27.15	25.27					
		Below 2.5	*2.5-5.0*	*5.0-10.0*	*10.0-20.0*	*20.0-50.0*	*50.0 & above*	*Total*				
III: P.E.O. Studies												
Evaluation study of the HYV Programme, 1968-69	1967-68	10.64	28.29	25.74	27.02	30.17	36.96	29.05				
	1968-69	66.07	58.38	62.53	61.97	66.80	79.74	65.88				
		Below 2 ha.	*2-4*	*4 & above*	*Total*							
IV: I.A.D.P. Studies:												
Aligarh (U.P.)	*1967-68*	*31.66*	*45.81*	*38.69*	*39.46*							

*Acres, unless otherwise noted.

Table 2.6. **Net Income by Size of Operational Holding Groups:** Farm Management Studies

Name of Study Centre	Year	Size Group	Net Income average
Ferozepur (Punjab)	1967 70	Below 6 acres	676*
		6 9	585
		9 -- 14	431
		14 -- 24	758
		24 & above	758
		Average	719
Muzaffarnagar (U.P.)	1966 69	Below 2.85 ha.	1651**
		2.86 4.71	2005
		4.72 6.96	1864
		6.97 10.65	1892
		10.66 & above	1861
		All farms	1898

* Rs. per acre.
** Rs. per hectare.

Table 2.6 (cont'd). A.E.R.C. Studies, Bijapur, 1967-68 (Rs./Acre)

Size Group (acres)	Mexican	Participants Irrigated	Non-participants Unirrigated
Below 10	699	368	100
10 20	350	181	61
20–30	652	234	99
30-30	408	241	60
50–75	426	279	84
75 & above	536	547	65
Average	464	287	74

Table 2.6 (cont'd). A.E.R.C. Studies, Saharnapur (U.P.) 1968-69 (Rs./Acre).

Size Groups (acres)	LR	S 308 (Sonalika)	S-227 (Kalyana)	591
Below 5	324	233		280
5--10	293	500	430	283
10--15	360	550	698	396
15-25	357	390	470	280
25 & above	245	637	555	400
Average	314	480	572	314

Table 2.6 (cont'd). A.E.R.C. Studies, Saharanpur (U.P.), 1967-68 (Rs./Acre)

Size Group	Net Returns Mexican	Local HYV	Desi
5-10	527	356	304
10-15	461	334	372
15--20	622	331	462
20-25	566	355	479
25-50	418	308	273
50 & above	605	468	280
Average	533	357	339

Table 2.6 (cont'd). A.E.R.C. Studies, Faizabad (U.P.), 1968-69 (Rs./ha)

Size Group (acres)	Participants	Total HYV 1968-69	Total HYV 1967 68	Desi 1968 69	Desi 1967-68
0-1	P	181	208	-205	47
	NP			-10	-2
1-3	P	64	200	98	43
	NP	--		-25	13
3–5	P	68	163	74	34
	NP	--		255	6
5--10	P	232	112	241	-36
	NP	--		92	117
10–15	P	238	148	47	14
	NP	--	--		--
15 & above	P	78	293	-10	108
	NP	--			
Overall	P	79	192	1*	57
	NP	--		68	29

P = Participants in HYV programme.
NP = Non-participants in HYV programme.

Table 2.6 (cont'd). A.E.R.C. Studies, Amritsar (Punjab), 1968-69 (Rs./Acre).

Size Groups (Acres)	Kalyan	PV-18	S-308 (Smolika)	Desi
Below 5	624	482	956	–
5-10	446	343	275	--
10--15	724	511	480	229
15--20	621	496	427	152
20–25	500	363	303	123
25-35	646	427	333	286
35–45	640	820	939	276
45--60	607	557	366	183
60--75	721	706	502	--
75 & above	564	470	411	423
Average	608	488	532	218

Table 2.6 (cont'd). A.E.R.C. Studies, Kota, 1971-72 (Rs./Acre)

Size Group (Acres)	Mexican (Sona Kalyan)	Desi Variety Irrigated	Desi Variety Unirrigated
Below 5	50	-106	-27
5–10	146	-108	99
10–15	153	55	56
15–20	98	306	29
20–30	59	-5	-13
30–40	117	47	
40–60	279	282	35
60 & above	245	98	-17
Average	144	85	17

Factors Determining High Incomes from High-Yielding Varieties

The resource base: Evidence of proportionately larger incomes from HYV wheats on the larger farms is provided by certain indirect indications. As will be shown presently, the most important distinguishing feature of adopters from the non-adopters is an access to assured water supply, typically from one's own tubewell, in the case of former. In a State like Punjab, the command area of a private tubewell is reckoned at 20 to 25 acres. This places holdings above or around this size in a clearly advantageous position, excepting in areas where purchase of water from neighbouring tubewells is a common practice. Extension workers at Punjab Agricultural University suggest that the optimum size of holding for efficient cultivation of HYV wheats, assuming a tubewell, but not necessarily mechanical power, i.e. tractor, is about 20 to 25 acres. This floor can be reduced with efficient management, to 15 acres [9]. But the prospects of availing fullest economies of modern technology on holdings below this level are not very encouraging in the present state of factor markets and availability of public infra-structure (See Table 2.8).

Apart from an optimum size of holding indicated by economic operation of a tubewell, new wheats also require improved farm equipments to produce highest yields, e.g., improved ploughs, discs, and harrows for proper land levelling and seed and fertiliser drills for shallow planting and exact spacing of seedlings; and only the large farmers, most of whom have already made capital investments in tubewells and improved equipments are initially in a position to adopt new high-yielding varieties and also to exploit their potentialities to the maximum.

Irrigation: Practically every study of the economies of HYV wheat has emphasised the importance of irrigation and its timing. In the areas where HYV programme has succeeded, irrigation has received considerable impetus, particularly in terms of encouragement of private investment in tubewells and pump-sets. Concommitant with this, there has been a complete reorientation of the rural electrification programme which is now directed, mainly towards energising pumps and water lifting devices.

The effect of irrigation facitilies on the adoption of the HYVs is well brought out in a survey of the farm economy of Haryana [5]. For this study, the State was divided into three regions—Northern, which comprises districts of Ambala, Jind and Karnal; Centre, which comprises districts of Hissar excluding Bhiwani and Loharu tehsils, and district of Rohtak excluding Jhajjar tehsil; and Southern, which comprises district of Gurgaon and Mohindergarh and Bhiwani, Loharu and Jhajjar tehsils. The Northern region has nearly 67 per cent of the cultivated areas irrigated, this compared with 21 per cent of the Southern region and 55 per cent of the Central region. Wherever better irrigation facilities exist, a much larger percentage of cultivators have taken to improved methods of agriculture and have thus increased their incomes and output. For

Table 2.7. **Yield of Mexican Wheat by Size of Holding.** A.E.R.C. Studies.

Size Group	Yield (q/ha)
Kota (Rajasthan) 1971-72 (Sone Kalyan)	
Below 5 acres	9.78
5-10	14.28
10-15	15.41
15-20	14.30
20-30	14.87
30-40	14.05
40-60	22.70
60 & above	19.88
Average	15.71
Bijapur (Mysore) 1967-68	
Upto 10 acres	23.00
10.1-20	17.54
20.1-30	24.82
30.1-50	18.53
50.1-75	16.55
75.1 & above	17.07
Average	18.62
Saharanpur (U.P.) 1968-69	
0-5 acres	12.94
5-10	19.34
10-15	25.61
15-25	19.94
25 & above	21.49
Average	21.17
Karnal (Haryana) 1968-69	
Below 5 acres	25.59
5-10	25.29
10-20	28.45
20-30	25.39
30-40	34.58
40-50	31.22
50 & above	29.64
Average	28.35

Table 2.7 (cont'd). P.E.O. Studies.

Size Groups	Yield (q/ha) 1967-68	1968-69
Below 2.5 acres	23.64	22.90
2.5-5	22.70	19.27
5-10	23.91	20.08
10-20	24.72	25.19
20-50	28.21	25.74
50 & above	31.10	26.16
Average	26.55	24.63

Table 2.7 (cont'd). I.A.D.P. Study, 1967-68.

Size Groups	1967-68 Yield (q/ha)
Below 2 hectares	30.05
2-4	25.98
5 & above	26.06
Average	26.52

Table 2.8. **Percentage of area under irrigation by size of operational holding groups.**

Name of Study	Year	Participant	Size Group *								
A.E.R.C. Studies			0-1	1-3	3-5	5-10	10-15	15 & above	Total		
1. Faizabad (U.P.)	1968-69	P	38.8	29.6	31.2	25.9	23.9	32.4	28.6		
		NP	32.3	26.3	33.5	23.8	–	–	28.3		
			0-5	*5-10*	*10-15*	*15-25*	*25-50*	*50-75*	*75-100*	*100-200*	*Total*
2. Karnal (Haryana)	1967-68	P	100	100	94	94	97	100	93	100	97
			5-10	*10-15*	*15-20*	*20-25*	*25-30*	*30-45*	*45 & above*	*Total*	
3. Amritsar (Punjab)			52.4	51.1	52.5	57.0	48.0	47.1	47.4	49.3	
			Below 5	*5-10*	*10-15*	*15-20*	*20-25*	*25-50*	*50 & above*	*Total*	
4. Saharanpur (U.P.)		P	–	96	92	95	90	97	90	–	
		NP	81	97	97	91	100	100	–	–	
			Total								
5. Tikamgarh (M.P.)		P	99.2								
		NP	70.3								
			Below 5	*5-10*	*10-15*	*15-20*	*20-30*	*30-40*	*40-60*	*60 & above*	*Total*
6. Kota (Rajasthan)	1971-72		95.0	60.6	64.0	76.5	56.6	73.0	36.0	44.5	58.8
			Below 10	*10-20*	*20-30*	*30-50*	*50-75*	*75 & above*	*Average*		
7. Bijapur (Mysore)	1967-68	P	83.3	37.4	28.2	25.1	22.5	10.6	23.4		
		NP	–	4.9	9.2	2.0	4.0	5.2	5.1		
			Size group								
Farm Management Studies			*Below 6*	*6-9*	*9-14*	*14-24*	*24 & above*	*Overall*			
1. Ferozepur (Punjab)	1967-68	Mexican	40.3	52.3	52.3	32.0	57.0	52.6			
		Desi	23.4	20.0	21.3	22.0	20.0	21.3			
			Below 2.87 ha.	*2.88-4.71*	*4.72-6.96*	*6.97-10.65*	*10.66 & above*	*Overall*			
2. Muzaffarnagar (U.P.)	1966-67		79.8	81.6	86.1	81.4	88.3	84.7			
	1967-68		90.7	96.0	93.0	87.1	99.3	93.8			
	1968-69		94.1	100	99.1	97.7	100	97.1			
	Average		88.2	92.5	92.8	86.4	95.57	91.9			

P = Participants in HYV programme. NP = Non-participants in HYV programme.
*Acres, unless otherwise noted.

Table 2.9. **Total cash Expenditure and Expenditure on Fertiliser.** P.E.O. Study 1967-68 (rupees per acre).

Size Group (acres)	Total Expenses H.Y. Holding	Other Holding	Fertilisers H.Y. Holding	Other Holding
Less than 2.5	202	28	82	11
2.5-5	215	24	66	7
5-10	227	33	83	9
10-20	215	28	82	7
20-50	270	36	102	9
50 & above	281	45	111	10
All Farmers	244	34	92	8

example, households of the Northern region achieved average output level of Rs. 1,004 per acre. The corresponding figures for Central region are Rs. 506 and for Southern region Rs. 148.

In two brief trips through two of the principal districts of the Punjab in early 1969, Ladejinsky observed that the tubewells were the core of the agricultural transformation of the State. Their number increased from 7,500 in 1960-61 to 110,000 in 1968-69. A tubewell and "miracle" seed and fertiliser stand for 20 to 24 quintals of wheat to an acre. In another field trip through Purnea and Saharsa districts (in Bihar) the same author observed that there were areas in these districts where next to the uncertain rainfall there was hardly any other source of irrigation. Even there wherever limited irrigation facilities existed modernised agriculture was centred, "of necessity at a reduced tempo; better but not upto standard quality seed; only slightly more than a third of the prescribed fertiliser dosage, a token of pesticides, and so on" [20].

In practically all the studies conducted by the AERCs, adopters are found to have a higher proportion of their land under irrigation than non-adopters, indicating that the access to irrigation has an important influence on adoption behaviour. For example, the Kota study of 1971-72 brought out that the proportion of adopters among large farmers was more, and the cause of low adoption on small farms was lack of irrigation facility on many small farms.

Barbara Hariss also observed direct correlation between extension of irrigation facilities and increase in the rate of adoption of the HYV programme. According to her, although effects of irrigation on production benefits have been over-estimated the participating farmers value its role in minimising weather risks [12]. In a series of interviews, she found that doubt about the availability of adequate irrigation was one of the important reasons preventing non-participants from using the improved inputs.

Similarly, Blackenburg, in his study of progressive farmers in the Punjab and Mysore observed that the adoption of new technology was strongly influenced by the availability of irrigation facilities. There was no progressive farmer in the sample areas who cultivated only dry land [6].

Lack of irrigation facilities have deterred small farmers in Southern Rajasthan to adopt new technology. A study conducted by Vidya Bhavan Rural Institute, surveying the spread of high-yielding varieties of seeds in Udaipur region, concluded that one of the reasons for the reluctance of farmers to take-up the HYV wheat cultivation was their belief that the failure of rains inflicted more damage to fields sown with the HYV, and this scared many small farmers who did not have their own irrigation facilities [46]. Acharya's study in the same area revealed that most of the adopters were large farmers and had their own pumping-sats for irrigation [1].

Larger costs: The increase in incomes from HYV wheat can be directly attributed to larger usage of modern inputs. From the available studies, it is clear that the per hectare cost of cultivation is significantly larger in the case of the HYV wheat compared to that of local varieties. This is evidenced from the AERC's studies (See Table 2.9). Significant difference in the cost[3] per hectare have also been revealed by the Farm Management Studies. While the total cost (on per hectare basis) in the case of the HYV wheat in Muzaffarnagar was Rs 1,413.00 that in the case of local wheat was Rs. 1268.00. The corresponding figures for Ferozepur district were Rs. 1,596.85 for HYV wheat, and Rs. 1192.40 for local wheat [18 & 44]. Thus while HYV wheats produce more income than deshi wheat under most of the circumstances, large increases in incomes from the HYV can be directly attributed to larger usages of modern inputs.

It was estimated by Bhalla in his Haryana study that with one acre increase in operational area, the progressive cultiva-

Table 2.9 (cont'd). Farm Management Studies (rupees per hectare).

Size Group	Total Cash Expenditure	Fertiliser
Ferozepur (Punjab) 1968-69 to 1969-70		
0-6 acres	531	92
6-9	467	105
9-14	504	115
14-24	519	120
24 & above	442	130
All sizes	482	114
Muzaffarnagar (U.P.) 1966-67 to 1968-69		
0-2.87 hectares	334	62
2.88-4.71	299	44
4.72-6.96	311	42
6.97-10.65	279	41
10.66 & above	258	54
All sizes	282	40

Table 2.9 (cont'd). A.E.R.C. Studies (Rupees per acre)

Size Groups (acres)	Expenditure					
	Cash					
	PV-18	*LR*	*S-64*	*Kalyan*	*Other Mexican varieties*	*Desi*
Amritsar (Punjab) 1967-68						
0–5	218	176	390	271	463	131
5–10	228	157	124	186	155	116
10–15	127	142	103	264		123
15–20	203	144	–	364	744	104
20–25	139	152	120	727	761	192
25–35	207	171	130	539	861	122
35–45	156	66	212	269		93
45 & above	178	136	182	390	437	124

	Kalyan	*PV-18*	*S-308 (Sonalika)*	*Desi*
Amritsar (Punjab) 1968-69				
Below 5	297	303	333	154
5–10	279	267	357	163
10–15	285	233	271	136
15–20	294	256	321	194
20–25	358	387	420	–
25–35	301	281	295	91
35–45	352	296	395	117
45–60	309	296	335	–
60–75	273	285	272	–
Above 75	277	267	294	–
Average	304	278	327	146

	Expenditure on Fertiliser				
	S-227	*S-64*	*Kalyan Sona*	*Deshi P*	*Deshi NP*
Kota (Rajasthan) 1968-69					
0–15	74	49	–	16	13
15–40	72	68	116	22	22
40 & above	128	82	167	42	7
Average	91	61	163	28	17

	Kalyansona
Kota (Rajasthan) 1971-72	
0–5	62
5–10	61
10–15	95
15–20	129
20–30	130
30–40	97
40–60	126
60 & above	85
Average	98

	LR	*S-308 (Sonalika)*	*S-227 (K.S. Sib)*	*591*
Saharanpur (U.P.) 1968-69				
Below 5	143	216	–	136
5–10	210	244	278	157
10–15	205	305	286	181
15–25	166	259	286	157
25 & above	174	249	224	188
Average	180	258	253	167

	Fertiliser expenditure on					
	R-18	*LR*	*S-64*	*Kalyan*	*Other Mexican varieties*	*Desi*
Amritsar 1967-68						
0–5	55	73	45	54	–	–
5–10	55	73	45	54	108	47
10–15	158	92	48	63	50	41
15–20	64	89	38	129	–	58
20–25	110	90		157	–	40
25–30	83	70	67	141	144	62
30–45	109	102	66	297	114	40
45 & above	104	25	84	127	–	49
Average	103	72	72	106	77	48

	Participants Cash Expenditure	
	Mexican Wheat	*Desi Wheat (irrigated)*
Bijapur (Mysore) 1967-68		
Upto 10	399	277
10–20	462	281
20–30	556	120
30–50	460	185
50–75	347	121
75 & above	261	148
Average	412	166

	Fertiliser Expenditure on			
	Kalyan	PV-18	S-308	Desi
Amritsar 1968-69				
Below 5	112	108	91	36
5-10	92	77	91	44
10-15	93	93	104	25
15-20	93	104	124	102
20-25	114	108	122	–
25-35	120	117	114	43
35-45	138	130	165	57
45-60	130	148	132	–
60-75	124	145	130	–
75 & above	107	105	110	–
Average	117	113	131	46

	HYV wheat			Desi	
	S-64	S-277	Kalyan-sona	P	NP
Kota (Rajasthan) 1968-69					
0-15	110	138	–	53	34
15-40	127	140	333	69	51
40 & above	165	294	427	116	112
All farmers	121	219	432	83	51

	Sona Kalyan* (Kalyansona)
Kota (Rajasthan) 1971-72	
Below 5	254
5-10	293
10-15	303
15-20	331
20-30	379
30-40	307
40-60	390
60 & above	350
Average	327

	Cash Expenditure		
	Mexican	Local HYV	Desi
Saharanpur (U.P.) 1967-68			
0-5	–	–	–
5-10	210	141	97
10-15	154	117	101
15-20	222	136	93
20-25	204	171	103
25-50	252	131	119
50 & above	168	159	106
Total	197	147	107

	Expenditure on fertiliser			
	Mexican	Local HYV	Deshi	NP
Saharanpur (U.P.) 1967-68				
0-5	–	–	–	–
5-10	121	70	36	19
10-15	50	39	20	–
15-20	99	50	37	–
20-25	123	94	37	–
25-50	161	48	48	–
50 & above	87	84	39	–
Average	107	62	42	14

	LR	S-308 (Sonalika)	S-227 (K.S. Sib)	591
Saharanpur (U.P.) 1968-69				
Below 5	35	69	–	27
5-10	73	90	114	46
10-15	63	85	84	57
15-25	50	61	82	47
25 & above	49	95	75	64
Average	55	86	82	50

	Expenditure on Fertiliser	
	Mexican	Desi (irrigated)
Bijapur (Mysore) 1967-68		
Upto 10	129	82
10-20	162	67
20-30	161	25
30-50	152	48
50-75	137	47
75 & above	108	8
Average	146	45

	Mexican
Faizabad (U.P.) 1967-68	
0-1	205
1-3	128
3-5	111
5-10	126
10-15	83
15 & above	63
Average	103

*Cost A_2: Cash expenditure is approximately three/fourth of cost A_2.

tors, i.e., those cultivating the HYV, incurred an additional expenditure of Rs. 197.80 compared with an expenditure of only Rs. 80 by the non progressive cultivators. The increase in the material cost by the adopters is mainly attributable to more intensive application of inputs like new seeds, chemical fertilisers, insecticides, pesticides and more irrigations [5].

Larger cash component: Apart from the level of inputs used, another significant difference is a much larger cash component in the cost of production of HYV. While in the case of local wheat, the cultivators spend more than 50 per cent of the total cost on traditional, mostly owned inputs, such as human labour and bullock labour, for HYV wheat share of modern, and basically purchased, inputs is significantly larger. In the case of Haryana, for example, the level of material costs, i.e., expenditure on material inputs and hired labour, was larger to the tune of nearly Rs. 200 per acre in the case of progressive farms adopting high-yielding varieties compared to those who were cultivating the traditional varieties. According to the same study, the progressive cultivators used Rs. 142.8 worth of additional fertilisers with an increase of one acre of operational area. The figure for non-progressive cultivators was only Rs. 12.49 [50].

Similar evidence is produced by the PEO study according to which cash expenditure on an acre devoted to HYV wheat was substantially larger than that incurred on non HYV areas. This was brought out by comparing per acre cash expenditure on HYV wheat with that for the entire farm. Actually total farm expenditure figures include costs on the HYV and if these were excluded, the difference would be much more substantial [23].

According to Chourasia and Singh, the per acre cost of cultivation of the local and HYV wheats was Rs. 267 and Rs. 499 respectively. The HYV wheat had 86.84 per cent higher expenses over the local varieties. Considering the operational costs alone, the HYV utilized 90.35 per cent higher operative expenses than the local varieties, mainly due to higher expenditure on fertilisers and manures [8].

According to the Cost of Cultivation Survey in the Punjab and Haryana, where more than 90 per cent of the area under wheat of the sample farmer was already under HYV, the biggest items in the operational cost were expenditure on hired human labour and fertilisers and manures. The fertilisers alone accounted for nearly 12.6 per cent of the total cost based on a comprehensive definition of costs. Similar conclusions can be derived from the composition of costs as given in the Farm Management Surveys of Muzaffarnagar (in Uttar Pradesh) and Ferozepur (in the Punjab) (See Table 2.10 and 2.11 below).

The superiority of Mexican varieties over the local variety stems, as noted earlier, from their capacity to withstand much higher doses of chemical fertilisers without lodging. While the Mexican varieties show an average response ratio of 8 to 9 kg. with an additional application of a kg. of nitrogen upto 50 to 60 kg., the fertiliser response ratio of local varieties is roughly 1:10, with yields declining after an application of about 20 to 25 kg. per acre. This explains higher dosages of fertilisers on HYV areas.[4]

Apart from fertiliser, the other important item of expenditure on HYV farms is human labour, particularly the expenditure on hired labour. More labour intensive method of sowing, larger application of fertilisers and the generally high standard of husbandry coupled with larger output to be harvested and threshed means higher employment of labour—at least till the labour displacing machinery appears on the scene.

Shah and Ali's study of Uttar Pradesh suggest that the expenses on human labour on the small and the medium farms were nearly equal. For large and very large farms, they increased with the size of holding. The expenditure on modern inputs consisting of HYV seed, irrigation and fertiliser was nearly the same on small and medium farms, but was higher on large and very large farms. The expenditure on animal labour fell with the rise in the size group, indicating an increasing use of tractors for land preparations. Consequently the expenditure on machinery rose with the increase in the size of holdings [40].

According to Chourasia and Singh, the material cost was about one and half time that in the case of the HYV as compared to that in the cultivation of the local varieties. The details of operating costs from the same study show that the HYV were more labour intensive than the local varieties. The per acre human labour required were 61 and 41 man days on the HYV and local varieties respectively [8].

In the Haryana study, cited above, a regression equation of paid out labour costs on the progressive, i.e., those adopting the HYV, and non-progressive farmers indicated that hired labour cost of the progressive farmers was significantly higher than that for the non-progressive cultivators. For each additional acre of operational area, the progressive cultivators spent Rs. 81.90 on hired labour compared with only Rs. 29.80 spent by the non-progressive cultivators [5].

The larger operational cost, most of which is constituted by the cash inputs, puts serious constraint on the intensive use of inputs by those who do not have either their own saving funds or any easy access to credit. In fact, these handicaps explains more than any other factor the difference between the range of income obtained by different groups of adopters.

Credit: With a heavy cash component in a substantially enlarged cost base, the availability of credit becomes an important consideration in adoption of the HYV. To the extent the organised credit, particularly from cooperatives is cheaper, cultivator's preference will be on this source of supply, that is, if they can avail of credit facilities from these institutions. Though cooperative credit has lower interest rates and longer pay back periods than other forms of credits, but credit worthiness is judged by short-term repayment capacity and even though the Government policy is that credit should be based on harvest expectation, land is the collatoral for advancing loans. Also, credit is

extended to HYV participants and non participants on a uniform scale regardless of their operating at different levels of risks and with different capacities to repay loans within a given time

In spite of these limitations, most of the investigations have revealed a larger dependence of HYV growers on cooperative and other institutional credit. It was shown in the PEO studies that all the adopting farmers would like to have cooperative credit, but owing to a shortage of supply, mismanagement or political factor entering into loans disbursement, only a small proportion of farms were able to obtain loans from this source. In the areas studied by the PEO, there was a positive relationship between the proportion of farmers who were members of the cooperatives and the farm size. This means that the larger farmers were able to have access to cheaper source of credit. For example, the AERC study in Kota exhibited that of the total operational cost large farmers financed proportionately higher percentage from credit societies; reverse was true for the small farmers. It was explained that such outcome was a result of the biased policies of the cooperatives which were dominated by large farmers [3]. In some areas, it seems that a few small farms could also succeed in obtaining cooperative credit—and those who had, met a high proportion of their cash expenditure from this source Among the small farmers it is these farmers who have adopted new varieties [23].

In the areas where the HYV have succeeded, the classical case being that of Ludhiana district in the Punjab, the cooperative system has shown much greater resilence According to the IADP study of this district, by 1969 all the villages were covered by cooperatives and 96 per cent of the farmers in the district were members of the cooperatives. Crop loan system was introduced in the district in 1966-67 which lessened the constraints imposed by the requirement of tangible security, mostly land, on the borrowers. Tenant cultivators were also made eligible for cooperative loans. The proportion of cultivators who availed of credit facilities increased in all the size groups, nearly 60 per cent or more of the farmers of all size groups took

Table 2.10. **Per hectare cost of cultivation of wheat in Punjab and Haryana (in 1970-71).**

Cost Items	Haryana Rs. per hectare	Percentage of total cost	Punjab Rs. per hectare	Percentage of total cost
Operational cost	**792.76**	**62.66**	**926.99**	**56.02**
Human labour				
Casual	25.19	1.99	84.95	5.13
Attached	54.65	4.32	79.89	4.83
Family	152.47	12.05	163.46	9.88
Total	232.31	18.36	328.30	19.84
Bullock labour				
Hired	1.07	0.09	0.94	0.06
Owned	167.51	13.24	141.91	8.57
Total	168.58	13.33	142.85	8.63
Machine labour				
Hired	16.32	1.29	40.68	2.46
Owned	38.02	3.01	39.75	2.40
Total	54.34	4.30	80.43	4.86
Seed	96.74	7.65	65.35	3.95
Fertiliser and manure				
Fertiliser	111.09	8.78	208.60	12.61
Manure	4.48	0.35	10.48	0.63
Total	115.57	9.13	219.08	13.24
Insecticides	--	.	0.41	0.02
Irrigation charges	109.60	8.66	71.95	4.35
Interest on Working Capital	15.62	1.23	18.62	1.13
Fixed Cost	**472.36**	**37.34**	**727.60**	**43.98**
Rental value of owned land	301.35	23.82	543.12	32.83
Rent paid for leased-in land	11.45	0.91	33.43	2.02
Land revenue, cesses and taxes	3.17	0.25	4.14	0.25
Depreciation on Implements and Farm Buildings	63.99	5.06	57.87	3.50
Interest on Fixed Capital	92.40	7.30	89.04	5.38
Total Cost	1,265.12	100	1,654.59	100

Source Comprehensive cost of cultivation studies, op. cit.
Note More than 90 per cent of the area covered in the sample was sown HYV wheats.

Table 2.11. **Per hectare cost of cultivation of HYV wheat in Punjab (average for the years 1967-68 to 1969-70) and U.P. (average for the years 1966-67 to 1968-69).**

Items	Punjab 1967-68 to 1969-70		U.P. 1966-67 to 1968-69		
	Rs./ ha.	Percentage of total cost	Rs./ ha.	Percentage of total cost	Average
Hired human labour	220.16	13.79	74	5.24	9.52
Bullock labour	174.52	10.93	297	21.02	15.97
Machine labour	55.55	3.48	7	0.49	1.98
Seeds	95.74	6.00	160	11.32	8.66
Fertilisers and manure	177.68	11.13	96	6.79	8.96
Miscellaneous	7.08	0.44	..	–	0.22
Insecticides	0.42	0.03	..	..	0.02
Irrigation	73.13	4.58	41	2.90	3.74
Interest on working capital	10.73	0.67	18	1.27	0.97
Depreciation	55.36	3.46	54	3.82	3.64
Land revenue, cess, etc.	2.28	0.14	9	0.65	0.40
Rent paid	47.39	2.97	3	0.21	1.59
Rental value	438.27	27.44	496	35.11	31.27
Interest on fixed capital	67.23	4.21	83	5.87	5.04
Family labour	171.33	10.73	75	5.31	8.02
Total Cost C	1596.85	100	1413	100	100

Source: Farm Management Studies of Punjab and U.P. opp. cit.

loans from the cooperatives. The average loan taken per hectare of cultivated area was the highest for the medium cultivators having holdings between two to four hectares. It increased in their cases from Rs. 74 per hectare in 1962-63 to Rs. 147 per hectare in 1967-68. For small farmers, having less than two hectares, the amount of loan increased from Rs. 59 per hectare to Rs. 101 during the same period [26].

In contrast, a study of the credit structure in Purnea and Saharsa districts shows that Government taccavi loans accounted for 17.8 per cent of the total credit advance. Cooperatives lent 13 per cent and money-lenders 67.6 per cent. The commercial banks advances were of negiligible order of 1.6 per cent. Taccavi and commercial bank loans were mainly to large farmers with 15 to 20 acres of holdings. Cooperative loans went mainly to farmers with 10 to 15 acres of holdings and loans from money-lenders went mainly to farmers with less than 10 acres, in particular to farmers with very small holdings. Such loans, however, do not seem to have been spent on fertiliser or for any other developmental purposes. On such loans the interest rates are quite high. If a farmer gets such loans for the purpose of fertilisers, he pays, in effect 70 to 80 per cent more than the normal cost. Naturally the credit facilities in these areas were not conducive to optimum utilisation of fertilisers and other modern inputs [20].

According to another sutdy in the same area, the percentage of agricultural households in Purnea not using the HYV was 68 to 69. Lack of resources to invest in better practices and failure of credit facilities to fill the gap were the main explanations for the low rate of adoption. In this district cultivable holdings of five acres and less accounted for 52 per cent of the investigated households and 74 per cent possesed holdings of less than 7.5 acres. Such holdings found it difficult to acquire institutional loans. Therefore, the HYV even with its greater profitability is hardly of any practical consequence to them [20].

Even in the Punjab, as the study of Jullundur district shows, for small farmers who had only one or two acres, credit was not integrated with inputs. Seeds and fertilisers were sold on cash basis much before the sowing season (i.e. in October) while the credit facilities were extended only in January [11]. Practically, all the AERC studies have brought out the difficulties of obtaining credit, especially by the small farmers. It seems that because of the rigid loaning practices, credit has not acted as an incentive to innovate.

Tenancy: Another major handicap in the extension of new varieties could be the extent of tenancy. But in fact, in most of the cases, tenancy has not proved to be a handicap for the acceptance of new varieties. In many areas, the reverse seems to be the case. Blackenburg observed, from his study of the Punjab, an association between frequency of tenancy and progressiveness. Average farmers have significantly less proportion of leased-in land (i.e 46 per cent) compared to the progressive or the improved farmers (65 to 67 per cent) [6]. Mishra and Ryagi, in their study of Kota district of Rajasthan, found that the percentage of owners-cum-tenants was more among the adopters than among the non-adopters. Conversely pure-owners were in larger proportion among the adopters,

e.g., 77.5 per cent compared to 60.0 per cent among the adopters [26]. In another study, by Mukherjee, no significant difference was observed as between the performance of the owners and tenants. If anything, it appeared that the tenant farmers had used on an average more fertilisers per hectare than the owners [30].

On the basis of the PEO data, Mukherjee concluded that the rate of adoption is not significantly different between owner and tenant farmers. It is logical to assume that in the initial years of the programme, it will be the more innovative and enterprising farmers, who will come forward. By and by, others will join. When then differential response will be more significant as between big, middle and small farmers and not so much between owners and tenants [23]. This is because of the high potential that the new seeds have for achieving substantial higher yields which can more than compensate for the onerous terms of tenancy[5] [31]. Commenting on Mukherjee's paper, Parthasarthy and Harnath Babu maintain that it is necessary to distinguish between two types of tenancies—pure tenancy and owner tenancy. Several studies show that owners-cum-tenants perform better in many respects, e.g., use of fertilisers, agricultural investment, etc. than pure owners or pure tenants [33].

Literacy: The other reported handicap, viz., illiteracy, again does not seen to be such a deterrent for the adoption of new varieties. In Karnal district, according to an AERC study, of the 60 adopters, 52 per cent were illiterate, 20 per cent educated upto primary level and 28 per cent upto middle level. In a relatively more progressive Kosi area (of Bihar) literacy rate was below the already low state average of 15 per cent [20]. It appears that at an early stage of agricultural revolution, literacy is not as crucial a variable as one might have been led to believe. This is mainly because in the initiation into the new technology or in subsequent experimentations with the level of inputs, the written word plays a minor role. The role of neighbours, relatives and opinion leaders is any time more important [12]. The weight of the evidence suggests that while the early adopters are relatively more literate, these who follow rely more on observation and spoken word. Besides, role that the radio broadcasts have played in the extension of HYV is also remarkable.

Conclusions

Due to different coverage, concepts and methodologies used in the studies reviewed above, it is difficult to arrive at firm assessment of the HYV programme as it operates at the field level. However, certain tentative inferences can be advanced. These should be considered more in the nature of hypotheses rather than empirically verified and tested results.

From available literature it is clear that the main reason for rapid adoption of new varieties of wheat is the higher net income that is expected from their adoption. The basic reason for larger profitability is not so much the difference in the unit cost as the larger output with the application of modern inputs. As a result, the overall differences from raising new varieties on a hectare of land are demonstrably larger than that obtained from growing local varieties. The very nature of response of new varieties to the use of modern inputs results in a wide range of incomes among the adopters, depending mainly on the level of use of these inputs.

Larger cash resources used to grow high-yielding varieties on the one hand and risk which is implicit in the adoption of any new practices on the other makes it almost inevitable that only those who have their own savings or an easy access to borrowed funds should be the early adopters. In the Indian context, it is the farmers owning or operating large holdings who qualify for this purpose. The weight of evidence suggests, though it does not prove conclusively, that not only large farmers were early adopters and in any given year they constituted larger proportion among the adopters, but they also seem to have devoted proportionately larger extent of their wheat areas under HYV. And finally, per acre returns obtained from HYV on the large farms seem to be higher than that obtained on the small farms.

The reasons for an advantageous position enjoyed by the large farmers are imbedded in the nature of HYV technology. Although this technology is not so much dependent on the indivisible inputs, like tractors or machines, it does make investment in these machines and particularly in a tubewell quite remunerative. Therefore, in areas where custom service of machines is not in vogue, high-yielding varieties programme concentrates on the farms of larger cultivators who can afford to have these machines on their own. More important than the indivisible assets, it is irrigation which is the crucial determinant in the adoption of new technology. The paucity of resources to invest in irrigation is overcome in areas where public irrigation system exists. However, even in these areas a supplementary source of irrigation, viz., a tubewell, compounds the returns from the adoption of new technology. The magnitude of operational costs and a larger cash component in the total cost favours those who have their own liquid resources or access to easy sources of credit. In fact, the availability of cheap credit comes out as one of the key factors in determining returns from the adoption of new technology.

Fortunately, tenancy and illiteracy do not seem to be unsurmountable handicaps for those who want to adopt new technology. In the case of the former, high returns from the adoption of HYV can compensate even the onerous terms on which the tenancy is contracted apart from the fact that the tenants are not necessarily the poorest aming the cultivators. The second disability is not a major hurdle as in a traditional rural society the importance of oral communications is far greater than that of the written word.

Because of the limitations cited earlier, the small farmers have been able to avail of the superior technology only upto a limited extent. The root of most of their

problems lies in the non-availability of the public infrastructure and in the functioning of the factor markets. It is principally to these issues that the policy makers will have to address themselves along with some other issues which will be referred to in the following section.

Notes

1. In a private communication, Anderson explains "Since Ludhiana has about the poorest soils in India and Shahabad has about the best, the differences are even more striking. However, in the early period, wheat was being multiple cropped with rice in Shahabad leading to poor seed bed and soil structure, whereas the sandy soil of Ludhiana being unsuitable for paddy did not present this difficulty. The shorter season in Shahabad also accounts for lower yields."

2. However, it was noted in the same study that in case of bajra, paddy, maize and jowar, proportion of acreage under the new varieties is unrelated to the size of farm.

3. For definitions of costs see Table 2.3. The total cost used in this text refers to cost C of the Farm Management Studies.

4. There is also evidence showing that HYV's are more responsive than local varieties even up to 20-25 kilos of nitrogen per hectare. See, e.g., I.J. Singh and K.C. Sharma, *"Production Functions and Economic Optima in Fertiliser Use for Some Dwarf and Tall Varieties of Wheat,"* Research Bulletin No. 5, February, 1969, College of Agriculture, Pantnagar.

5. The changing role of tenancy in the progressive areas is discussed in greater detail by this author.

III GUIDELINES FOR FUTURE ACTION

A number of carefully conducted studies and a reasonably good statistical reporting system enable one to have broad ideas about the performance of high-yielding varieties of wheat in India. In the previous section, we have mentioned some of the handicaps which inhibit fuller extension of new varieties in the country. On the basis of this discussion, certain lines for further action are indicated.

Varietal Improvement: The instrinsic superiority of the Mexican varieties and the adaptive research conducted in India have resulted in a number of new varieties which have clear advantages over the local varieties. However, the very fact that practically all these are derived from one stock, puts them at a disadvantage when it comes to fighting the host of likely pests and diseases. Sometimes a fear is expressed that if some types of rusts were to attack these varieties for which the resistance is not built, the whole crop of wheat from Punjab to West Bengal can be destroyed in an indiscriminate manner. That this fear is not altogether hypothetical is proven by the fact that in this year (1973) there is a suspicion that some rusts to which the present stock is not immune have attacked and damaged the yield potential in the Punjab and Haryana. Whether this year's stagnation in yield is only a temporary phenomenon—may be due to moisture stress at the time of ripening—or it is something more serious is yet to be ascertained. In any case, the varietal research will have to continue to have a major emphasis on building resistance against the likely damages.

The prevalence of nearly nine varieties in a more or less homogenous tract, that the wheat growing regions are, suggests that more local research is needed to adapt new varieties to the specific environment. Since different varieties have different attributes in regard to dates of sowing, duration of maturity, initial and optimum response to inputs, resistance to pests and diseases, etc., there is a need, first, to understand these qualities at the field level and, later on to extend the varieties in a more discriminative manner. There is therefore a need for a more careful release policy. Besides, an organised seed industry, supplying high quality seeds suitable for different locations can give a definite fillip to movement.

An important development in the recent years is that new wheat varieties are spreading in areas which are traditionally rice growing areas. Also, in the traditionally wheat growing areas in *kharif*, i.e., the wet season, increasingly HYV paddy are sown. Since HYV paddy matures late, sowing period of wheat is also postponed, sometimes by a fortnight to three weeks. This has apparently affected the yields from new varieties. Since this tendency is likely to continue and gain strength, it is necessary that suitable adaptations are made both in paddy and wheat varieties so that they can be dovetailed in a rotation which is more economic from an overall point of view.

Inadequate Use of Inputs: The wide range in input application, particularly fertilisers, and lack of standardisation of agronomic practices have made many people comment that what we have obtained in this country is a varietal revolution rather than a technological revolution. The idea of a "package of inputs" which was sought to be popularised from the early 1960's has not yet found a

general acceptance at the field level. There are innumerable combinations and permutations of different inputs on individual farms. Some such differences are bound to exist and may be even economically justified. But the main reason for this diversity is the lack of knowledge or incapacity to produce adequate quantities of difference inputs. This suggests that the task before the extension workers is not to bring out "one package" of optimum doses but a number of combinations approximating to the optimum dosages, as well as to evolve various combinations of inputs for different levels of cost and returns. It is true that too numerous or too complicated recommendations are likely to confuse the farmers. Yet a few well-thoughtout choices rather than a package has a greater merit.

Importance of public infra-structure: If there is one single lesson to be learnt from the success of HYV programme in wheat in India, it is the role that the public infrastructure, particularly irrigation, transport and power, plays in the extension of new technology. Without any exception, the areas where these facilities were adequate were the first to adopt new technology. Also, it is only in these areas that irrespective of owned resources everyone could avail of the benefits accruing from the adoption of new varieties. In fact, the more meagre the resource base of individual cultivators, the greater are likely to be the gains, both private and social, from the investment in public infrastructure. The policy makers in this country and countries similarly placed will have to carefully assess the returns from resources invested in creating these facilities as against the returns from the same amount of resources, invested in either subsidising the inputs or paying higher prices for the output. On a *priori* ground, the investment in public infra-structure is likely to yield larger returns.

Reducing institutional handicaps: Since the returns from new varieties are notably higher even after paying rents on leased-in land, these varieties can spread alike on tenant and the owner operated farms. However, this does not mean that the new technology can overcome all the institutional hurdles or inequities in the relationship in land. In areas where the relationship is particularly exploitative even with the availability of public infra-structure, new varieties have not succeeded (e.g. in Kosi project area of Bihar) [49].

Institutional handicap of another type plagues the small farmers more seriously. And this is the functioning of the markets for inputs, particularly credit. Here too, it is not the dearth of the institutions but the procedures and policies followed which come in the way of realising the stated objectives. For example, a mammoth cooperative structure is created and supported by public policy to provide credit and other facilities to all sections of cultivators, particularly to the small farmers. But in effect this has not happened. The security oriented credit policy, procedural tangles and, the extent power equation in the country-side compromise the effectiveness of these institutions. What applies to credit also applies, more or less, to other inputs, particularly those which are in short supply. Whenever any input is in short supply the larger farmer pre-empts the available quantities. This is inspite of the declared objectives of giving an equitable share in all scarce inputs to the smaller farmers.

It does not follow that only a new set of institutions specifically created for the small farmers can benefit them. In a country where the small farmers constitute the majority, the existing institutions can also be made to work for their benefit provided that the small farmers can be organised to avail of the facilities which are essentially meant for them. The farmers' organisation should aim at not only a fair share in the subsidised or the scarce inputs but also at maximising returns from individual inputs. There is a scope, rather a necessity, for a great variety of organisational innovations for ensuring collective action by the small and the weak. Very little is known about the nature and form of collective efforts which in many circumstances can be an effective substitute for individually owned assests and resources.

From all available accounts, HYV programme in India so far has been mainly confined to what might be called progressive areas. Even in these areas, some of the problems mentioned above, have been coming to the fore. If the momentum of the programme is to be sustained, it will have to be extended to relatively backward areas where the handicaps narrated above will be all the more intractable. It is necessary, therefore, at this stage to take stock of things, identify the problem areas, appraise various alternatives and define a set of consistent policy measures which can continue the spread of this indeed very remarkable technology which promises to contribute towards production and, if suitably oriented, also towards the social justice.

Appendix **Information on Scope & Methods of the Evaluation Studies.**

Study	Conducted by	District	State	Reference years	Sample Design	Size of sample: No. of villages	Size of sample: No. of farmers	Costs concepts, used for derivation of income
AERC Studies A study of High Yielding Varieties programme in the Kota District (Rajasthan) (Rabi 1968-69)	AERC, Vallabh Vidyanagar	Kota	Rajasthan	1968-69	Good blocks and villages were selected. In each village stratified sampling of participants and non-participants of HYVs.	4	100	Cash and kind expenditure (equivalent to Cost A_2 in Farm Management Studies).
2) Economic & Social Implications of Green Revolution, A Case Study of the Kota District.	AERC, Vallabh Vidyanagar	Kota	Rajasthan	1971-72	Good blocks and villages were selected. In each village stratified sampling of participants and non-participants of HYVs.	4	100	Cash and kind expenditure (equivalent to Cost A_2 in Farm Management Studies).
3) Evaluation of the High Yielding Varieties Programme—Rabi 1968-69—A Study of Mexican wheat in Karnal District (Haryana)	AERC Delhi	Karnal	Haryana	1968-69	Multi-stage stratified sampling. The ultimate unit was participant farmer.	4	60	Expenditure on seed, farm yard manure, fertilisers, pesticides, irrigation only were considered.
4) Economics of High Yielding Wheat in Punjab (Special reference to Amritsar District) Haryana.	AERC Dehli	Amritsar	Punjab	1968-69	Multi-stage stratified random sampling. Five blocks were selected.	10	100	Variable expenditure, This includes seeds, fertilisers, irrigation charges, labour charges (e.g. FYM, pesticides).
5) Report on HYVP in Saharanpur Dist. (U.P.) Rabi 1968-69 (with reference to Mexican wheat)	AERC Delhi	Saharanpur	U.P.	1968-69	Two good blocks and two good village, selected. In each village stratified sample of participants was taken.	4	60	The inputs taken into account were, seeds, chemical fertilisers, farmyard manures, pesticides, irrigation, land revenue and human labour.
6) The social & economic implications of the large Scale Introduction of of High Yielding Varieties of wheat in Haryana (the UNDP Global Project)	AERC Delhi	Karnal	Haryana	1971-72	Good district was selected. Three villages studied earlier were selected. Stratified sampling at the farm level.	3	120	Direct cost was used which included labour, kind rent, fertilisers seeds, irrigation charges etc.

Appendix ' continued.

7) Study of High yielding varieties programme in Mysore (Rabi: 1967-68). Mexican wheat in Bijapur District.	Gokhle Inst. of Economics & Politics, Poona	Bijapur	Mysore	1967-68	Purposive Selection of talukas. Villages stratified random sampling of farmers.	4	101	Cash expenditure on seed, manures & fertiliser, land revenue human labour and bullock labour.
PEO Studies: 1) Evaluation study of High-Yielding varieties Programme-Report for the Rabi, 1968-69—wheat, Paddy & Jowar	Programme evaluation Organisation Planning Commission Govt. of India, New Delhi	Different districts in the selected States	Bihar, Haryana, Maharashtra, Punjab Rajasthan U.P.	1967-68	Six stratified and 15 sample blocks (Multi-stage stratified sampling)	45	441 (P)	Cash expenditure, material inputs, such as seed, fertilisers, pesticides etc.
2) Evaluation of High Yielding Varieties Programme: Report for the Rabi; 1968-69—wheat, Paddy & Jowar	Programme evaluation Organisation Planning Commission	Gaya Hissar Rohtak Ahmednagar Amritsar Ludhiana Ferozepur Patiala SriGanga-nagar Besti Muzaffarnagar Aligarh Saharanpur Sirapur Allahabad	Bihar Haryana Haryana Maharashtra Punjab Punjab Punjab Punjab (Rajasthan) U.P. U.P. U.P. U.P. U.P. U.P.	Rabi 1968-69	Multi-stage stratified sampling, Selection of Farm by systematic sampling.	—		Cash expenditure, material inputs, such as seed, fertilisers, pesticides, etc.

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