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Accelerating the Transfer of Wheat Breeding Gains to Farmers: A Study of the Dynamics of Varietal Replacement in Pakistan

edited by: PAUL W. HEISEY

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RESEARCH REPORT NO. 1

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Acronyms

ADA	Agricultural Development Authority
ADC	Agricultural Development Corporation
AERU	Agricultural Economics Research Unit
CDRI	Cereal Disease Research Institute
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo International Maize and Wheat Improvement Center
CRS	Crop Reporting Service
FSCD	Federal Seed Certification Department
ISWYN	International Spring Wheat Yield Nursery
MINFA	Ministry of Food and Agriculture
NUWYT	National Uniform Wheat Yield Trial
NWFP	North West Frontier Province
PAD&SC	Punjab Agricultural Development and Supplies Corporation
PARC	Pakistan Agricultural Research Council
PERI	Punjab Economic Research Institute
PSC	Punjab Seed Corporation

Preface

This publication is the first in a new series of reports that document specific CIMMYT research efforts. This series is directed toward technical audiences, and each publication synthesizes the results of research that has usually occurred over an extended period. Although this series will normally feature the research of CIMMYT staff alone, collaborative research is sometimes reported. Such is the case with this *Report*, which describes work done by Dr. Paul Heisey and Dr. Derek Byerlee in conjunction with colleagues in Pakistan. Their investigation focused on slow wheat varietal replacement and related problems that have gradually increased the risk of serious rust epidemics in Pakistan.

The issues analyzed here initially came to the attention of researchers when they began to conduct diagnostic surveys of the farming systems of Pakistan. Special follow-up surveys to understand the problem of slow varietal replacement recorded, for the first time, data on the sources of the seed that farmers grew, on how farmers gained access to sources of seed, and on how they managed wheat seed once they obtained it. Additional surveys identified which varieties farmers actually planted and explored farmers' motives for changing varieties. Part of the analysis of the survey results required that researchers develop a model for determining optimum rates of varietal replacement. This analysis of the informal seed system was complemented by a study of the formal system for breeding, producing, and distributing seed in the Punjab and North West Frontier Province.

This report moves from the interpretation of survey results to an exploration of numerous organizational issues impinging on efforts to improve rates of varietal replacement. By showing just how the processes of breeding, seed production, seed distribution, information transfer, and adoption of new varieties function in Pakistan, and by indicating how more appropriate policies could make these processes more efficient, the authors reveal both the complexity and urgency of the varietal replacement problem. It is anticipated that this study, whose methods and results are relevant beyond the borders of Pakistan, will enhance the ability of developing world research, seed, and extension systems, as well as farmers, to translate the gains achieved in plant breeding research into the economic benefits associated with more efficient and more stable crop production.

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Executive Summary

In wheat growing areas, slow replacement of older varieties with newer ones in farmers' fields delays the transfer of benefits from breeding research to farmers and heightens the risk of disease epidemics, especially when the diversity of varieties in an area is limited. Determining the optimal time period in which farmers should replace older varieties and understanding which factors in the seed system may impede rapid varietal replacement are vital to bringing the gains of breeding research to farmers' fields.

During the post-Green Revolution period, yield gains attained in wheat through genetic improvement have been about 0.75% per year, although there is a certain variability around trend. At this rate of yield gain it will pay farmers to change varieties every four years, given reasonable assumptions about current levels of many of the parameters influencing their choices. Differences in microenvironments, different lengths of time between periods of actual yield gains, and fluctuations in observable rust losses mean that in some cases the desired period for farmers to change varieties could be longer.

In Pakistan since the Green Revolution in wheat, varietal replacement has been slow compared to areas with similar ecological circumstances, such as the Punjab of India and northwestern Mexico. Furthermore, wide areas in Pakistan are often dominated by a single variety and diversity occurs only during the transition from one dominant variety to another. In the Punjab from 1977 to 1986, the proportion of wheat area planted to varieties that are no longer recommended because of rust susceptibility averaged over 40%, and from 1982 to 1986 the area planted to varieties with leaf rust ratings of 50S or higher was nearly 60% of the total area. Apart from the losses that could be caused by an epidemic, annual losses in yield to rust are also serious. They are not widely reported but may add up to a substantial annual loss.

To examine the dynamics of the varietal replacement problem in Pakistan, four complementary studies were designed to analyze the wheat varietal and seed system from the breeding of new lines to adoption by farmers. The studies focus on the Punjab, which contains 71% of Pakistan's total wheat area and 75% of all the irrigated wheat area in Pakistan, because relatively more data are available and the seed system is most developed. Both the methods and results of this research should be useful to researchers outside of Pakistan who are seeking a framework for analyzing the interrelated problems of slow varietal replacement, limited varietal diversity, and ineffective seed systems.

The first study examines the problem of slow varietal replacement from the perspective of the research system. It considers measures of varietal replacement and spatial diversification and applies them to the Punjab. These measures are used to investigate whether there is an optimal rate of varietal replacement and to assess the level of disease exposure. Other measures for assessing the progress of a wheat

breeding program are also presented, including the rate of release of new varieties and the rate of yield gain over time attributable to the development of new varieties. It appears that in the Punjab varietal replacement has been much slower than a reasonable target—once every five or six years—and the area planted to rust susceptible varieties has been unacceptably high (over 50% of the Punjab's wheat area in the first half of the 1980s).

The second study assesses problems in obtaining basic data on the area covered by different varieties. Since varietal monitoring competes with many other agricultural data collection needs, any large scale estimation of varietal coverage is likely to be a byproduct of surveys designed for other purposes. Physical identification of varieties by skilled personnel is quite expensive, so usually identification depends on the statements of farmers, who may not always know varietal names or may identify cultivars incorrectly. Cluster sampling designs tend to create large standard errors in estimates of varietal coverage because variances within the primary sampling units (e.g. villages) tend to be lower than variances across the primary units.

The third study concentrates on seed multiplication and marketing by the Punjab Seed Corporation (PSC). Data are presented on past and current seed production and the present seed marketing network in the Punjab. The PSC has effected a clear increase in production capacity for wheat seed in the Punjab. In the late 1960s and early 1970s, before the PSC was established, on average only a little more than 16,000 t of seed were sold each year. In the five years after it was established, the PSC raised production from 4,000 to 44,000 t, where it has remained since. Even in North West Frontier Province (NWFP), where there is no specialized seed production industry, the ability to produce wheat seed has advanced: the Agricultural Development Authority (ADA) in NWFP procures 3,000-4,000 t/yr. Formerly much of this seed came from the Punjab; in 1986/87 all of it came from NWFP.

Major problems remain in planning seed production and in promoting and marketing seed. The early stages of seed multiplication could be speeded up, but the seed authorities cannot be sure which varieties to multiply. Production is not expanded because the PSC cannot sell the additional seed that is procured. The goal for marketing wheat seed appears to be to supply pure certified seed to farmers, rather than to facilitate the rapid replacement of varieties. The evidence suggests that farmers use the formal seed system more to change varieties than to get new seed of varieties they already grow. Nevertheless, an active seed network, closely linked with both agricultural research and extension, is a prerequisite for more rapid varietal replacement in the post-Green Revolution period.

The commission paid to private dealers for handling seed is much less than for fertilizer, an input in greater and more regular demand. Hence seed is the input whose distribution at the farm level is still largely handled by the public sector. Very little effort is made by the seed industry to promote its product.

Greater promotional effort, a wider distribution network, and higher commissions to dealers are necessary to spread new seed more rapidly. These changes will probably require an increase in seed price. Though higher seed prices will reduce farmers' demand for seed in the short term, the net effect could be more rapid varietal replacement if higher prices lead to more promotion and a better distribution network, and so reduce the amount of time before new varieties reach the farmers. The Punjab of India has both higher wheat seed prices and faster varietal replacement than the Punjab of Pakistan.

The fourth study concentrates on farmers' perceptions. Just one-quarter to one-half of farmers sampled in three major cropping systems thought some wheat varieties were more disease resistant than others. Only one-quarter or fewer farmers thought resistant varieties could lose their resistance.

Farmers' awareness of new wheat varieties was best explained in the rice-wheat zone of the Punjab, where the diffusion of new varieties has proceeded the farthest. In this zone awareness of new wheat varieties is positively influenced by education, extension contact, and location in a village where many fields are planted to new varieties. Some of these variables, notably education or literacy, as well as village factors, are influential in the other surveyed zones, the Punjab cotton-wheat area and irrigated Mardan, NWFP.

In the presence of other variables, farm size usually becomes a less significant determinant of varietal awareness or adoption in areas where new varieties have spread the farthest. Smaller farmers will adopt new varieties once they are aware of them, but large farmers are more likely to become aware earlier because of their higher literacy and better contact with extension and other sources of information. One noticeable way in which farm size is important in all areas is that large farmers are more likely to plant both old and new varieties rather than to specialize in one or the other. Small farmers who do adopt a new variety are more likely to plant all their wheat area to that variety.

Yield was by far the most common reason stated by farmers in all three zones for changing varieties. Most farmers simply believed that the yield of the new variety was superior, although a few farmers related this perceived yield advantage to reduced yield in their old varieties because of disease or other factors. In multivariate analysis, farmers' perception that new varieties yield better is usually the strongest factor influencing adoption. Performance at late planting dates is also important, particularly in the cotton zone.

In the three sampled areas in 1985/86, when all the sampled farmers' wheat fields were considered, 50-60% were planted with retained seed. An additional 20-30% were planted with seed obtained from neighboring farmers. Farmer-to-farmer transfer is clearly a major method of varietal diffusion. Some 45-55% of the farmers in all three zones who were planting post-1978 releases initially got seed from other

farmers. Of farmers planting new varieties, over 33% in the rice-wheat zone, 50% in the cotton-wheat zone, but only 14% in Mardan initially got seed from the depot.

In all three zones, literacy and extension contact were the two variables most likely to be related significantly and positively to correct knowledge of where the seed depot was located. Distance from the seed depot may have been related negatively in the Punjab to knowledge of the depot's location. In the Punjab, farmers aware of new varieties were also more likely to be aware of the seed depot; in NWFP there was no relationship, confirming the relative lack of importance of the seed depot in Mardan in spreading new varieties.

Only 40-50% of the farmers in all three zones who used their own seed managed it through techniques such as selecting a special field or threshing seed separately from grain. Very few significant relationships existed between farmer characteristics and seed management.

Extension contact was not very important in explaining awareness and adoption of new varieties. Varietal demonstrations by the extension service have probably not been spread widely enough and have not always been tailored to different agroecological circumstances or cropping system constraints. The promotional efforts of research, the seed industry, and extension have not been well coordinated.

Taken together, the results of all four studies emphasize the importance of regular varietal replacement for farmers and for the nation of Pakistan. The methods used in this research—institutional analysis, analysis of research data, and farmer surveys—offer a means to evaluate the complex relationships between wheat breeding, varietal testing, and release; seed production and distribution; extension; government policy; and varietal change at the farmer level. Although the conclusions presented in this report are specific to a particular crop, place, and time, they may also be viewed as hypotheses that in some cases might be applicable in different situations, perhaps after modification.

Future studies to expand knowledge of factors relating to varietal replacement might develop methods for determining rough objectives for the number and genetic diversity of varieties to be released by mature plant breeding programs in countries with large areas planted to the crop in question. More case studies of seed systems with different degrees of success in marketing seed of different crops would also be useful. Such studies do exist; what is needed is to add the perspective of varietal replacement to the legal and institutional description they often contain. Additional research is also required to verify empirically the relative strengths of the factors influencing farmers' demand for replacement seed. Finally, studies of other countries and particularly of other crops would sharpen our understanding of the features of varietal replacement that are universal and of the changes in assumptions and methods necessary to analyze factors more specific to time, place, and particular crops.

Resumen

En las zonas productoras de trigo, la sustitución lenta de las variedades más viejas por las nuevas en los campos de los agricultores retrasa la transferencia de los beneficios de la investigación fitotécnica a los agricultores e intensifica el riesgo de que se presenten epifitias, en especial cuando es limitada la diversidad genética de las variedades cultivadas en la zona. La determinación del período óptimo después del cual los agricultores deben reemplazar sus variedades y la comprensión de los factores del sistema de producción de semilla que pueden impedir la rápida sustitución de las variedades son esenciales en la transferencia de los beneficios de la investigación a los agricultores.

En el período después de la Revolución Verde, los aumentos del rendimiento de trigo que se han logrado mediante el mejoramiento genético han alcanzado cerca del 0.75% anual, aunque existe cierto grado de variabilidad en la tendencia. A ese ritmo de aumento, les conviene a los agricultores cambiar las variedades cada cuatro años, con base en suposiciones razonables sobre los niveles actuales de muchos de los parámetros que influyen en sus opciones. Las diferencias en los micro-ambientes, los intervalos variables entre los períodos en que se dan los aumentos del rendimiento y las fluctuaciones en las pérdidas observables causadas por la roya, significan que, en algunos casos, el período más conveniente para que los agricultores cambien sus variedades podría ser más largo.

Desde la Revolución Verde en el trigo, el reemplazo de variedades en Pakistán ha sido lento en comparación con zonas ecológicamente semejantes, como el Punjab de la India y el noroeste de México. Además, en grandes extensiones de Pakistán suele dominar una sola variedad, y hay diversidad sólo durante el período de transición de una variedad dominante a otra. De 1977 a 1986, en el Punjab la proporción de la superficie de trigo cultivada con variedades que ya no se recomiendan debido a su susceptibilidad a las royas, fue en promedio de más del 40%, y de 1982 a 1986, la superficie sembrada con variedades cuya calificación de infección con roya de la hoja fue de 50S o más, constituyó casi el 60% de la superficie total. Aparte de las pérdidas que una epifitia podría causar, son graves las pérdidas de rendimiento que la roya provoca cada año, y aunque no suelen registrarse extensamente, podrían constituir una grave pérdida anual.

Los cuatro estudios complementarios que se describen en este informe fueron diseñados para analizar los problemas del reemplazo de variedades de un cultivo, el trigo, en un solo país, Pakistán. Dichos estudios examinan los sistemas de reposición de variedades y de producción de semilla de trigo, desde que se generan líneas nuevas hasta que los agricultores las adoptan. Estas investigaciones se centraron principalmente en el Punjab, que abarca el 71% de la superficie total cultivada con trigo en Pakistán, y el 75% de toda la superficie de trigo irrigada en el país. Existe una cantidad relativamente mayor de datos sobre esta zona, y su sistema de producción de semilla es el más desarrollado. No obstante, tanto los métodos como los resultados de esta investigación serán útiles para científicos fuera de Pakistán

que buscan un marco de referencia para el análisis de los problemas interrelacionados que surgen de un reemplazo lento de variedades, poca diversidad de variedades cultivadas y sistemas de producción de semilla ineficaces.

En el primer estudio se examina el problema del reemplazo lento de variedades desde el punto de vista del sistema de investigación, y además se consideran las formas de medir el reemplazo de variedades y su diversificación temporal y espacial, y se aplican al Punjab. Estas mediciones se usan para averiguar si existe un ritmo óptimo de reemplazo de variedades y para evaluar el nivel de exposición a las enfermedades. Se presentan también otras mediciones que se usan para evaluar el progreso de un programa de mejoramiento de trigo, entre ellas, la tasa de lanzamiento de nuevas variedades y la tasa de aumento del rendimiento a lo largo del tiempo que puede atribuirse al desarrollo de variedades nuevas. En el Punjab, la sustitución de variedades ha sido mucho más lenta de lo que se considera razonable -cinco o seis años- y la superficie que se cultiva con variedades susceptibles a la roya ha sido demasiado extensa (más del 50% de la superficie de trigo del Punjab en la primera mitad del decenio de 1980).

El segundo estudio evalúa los problemas de obtener datos básicos sobre la superficie que se siembra con las distintas variedades. Como la observación de las variedades que se cultivan compite con muchas otras necesidades de recolección de datos, cualquier estimación en gran escala de la superficie cultivada suele derivarse de encuestas que se realizaron con otros propósitos. La identificación física de las variedades por personal especializado resulta muy costosa y, por tanto, suele hacerse con base en lo que dicen los agricultores, quienes no siempre conocen los nombres de las variedades y a veces las identifican incorrectamente. Los diseños de muestreo en conglomerados tienden a crear grandes errores estándar en las estimaciones de la superficie sembrada con cada variedad porque la varianza dentro de las unidades primarias de muestreo (por ejemplo, las aldeas) tiende a ser menor que la varianza a través de esas unidades.

El tercer estudio se centra en la multiplicación y comercialización de semilla por la Empresa de Semilla de Pakistán (Punjab Seed Corporation, PSC). Se presentan datos sobre la producción actual y anterior de semilla, así como sobre la presente red de comercialización de semilla en el Punjab. Es evidente que la PSC ha logrado aumentar la capacidad de producir semilla de trigo en el Punjab. A fines de los 60 y principios de los 70, antes de que se estableciera la PSC, se vendía cada año un promedio de poco más de 16,000 t de semilla. En los primeros cinco años después de su creación, la PSC incrementó la producción de 4,000 a 44,000 t, y ese nivel se ha mantenido desde entonces. Incluso en la Provincia de la Frontera del Noroeste (North West Frontier Province, NWFP), donde no existe una industria especializada de producción de semilla, la capacidad de producir semilla ha aumentado, pues la Autoridad de Desarrollo Agrícola en la NWFP adquiere entre 3,000 y 4,000 t/año. Anteriormente, la mayor parte de la semilla provenía del Punjab; en 1986/87, casi toda procedió de la NWFP.

Siguen existiendo problemas en la planificación de la producción de semilla y la promoción y comercialización de la misma. Quizá fuera posible acelerar las primeras etapas de la multiplicación, pero las autoridades no están seguras cuáles variedades deben multiplicarse. La producción no aumenta porque la PSC no puede vender el excedente de semilla que se produce. El objetivo de la comercialización de semilla parece ser suministrar semilla pura y certificada al agricultor, no facilitar la sustitución rápida de variedades. Las pruebas sugieren que los agricultores utilizan el sistema formal de semilla más para cambiar sus variedades que para obtener semilla nueva de las variedades que ya cultivan. No obstante, se requeriría un sistema activo de producción de semilla que tuviera nexos cercanos con la investigación y la extensión para lograr una reposición más rápida de variedades en el periodo posterior a la Revolución Verde.

La comisión que reciben los distribuidores privados por el manejo de la semilla es mucho menor que la que se les paga por vender fertilizante, un insumo que tiene una demanda mayor y más regular. Por tanto, la semilla es un insumo cuya distribución a nivel de fincas todavía es efectuada por el sector público. La industria privada hace muy poco esfuerzo para promover su producto.

Para difundir la semilla nueva más rápidamente, son necesarios un mayor esfuerzo promocional, una red de distribución más extensa y una comisión más elevada para los distribuidores. Estos cambios probablemente requerirán que se incremente el precio de la semilla. Aunque un precio más alto reducirá a corto plazo la demanda de semilla entre los agricultores, el efecto neto podría ser un reemplazo de variedades más rápido, siempre que los precios más altos condujeran a una mayor promoción, a una mejor red de distribución y, por tanto, a una reducción del tiempo necesario para que las nuevas variedades lleguen al agricultor. En el Punjab de la India, los precios del trigo son mayores y hay un reemplazo de variedades más acelerado que en el Punjab de Pakistán.

El cuarto estudio examina las percepciones de los agricultores. Sólo una tercera o cuarta parte de los agricultores encuestados en los tres principales sistemas de cultivo opinaron que algunas variedades eran más resistentes a las enfermedades que otras, y sólo una cuarta parte o menos pensaba que las variedades podían perder su resistencia.

La razón de que los agricultores conocieran las nuevas variedades fue más clara en la zona del Punjab donde se cultiva arroz y trigo, y donde la difusión de las nuevas variedades ha sido extensa. En esta zona, el conocimiento de las nuevas variedades se ve influido por el nivel de educación, el contacto con los servicios de extensión y el hecho de vivir en una aldea donde muchas parcelas se siembran con estas variedades. Algunas de estas variables, en especial el nivel de educación o escolaridad y los factores relacionados con la aldea, también tienen influencia en otras zonas encuestadas, como la zona productora de algodón y trigo del Punjab y la región irrigada de Mardan, NWFP.

Frente a otras variables, el tamaño de la finca suele ser una determinante menos importante del conocimiento o adopción de variedades en aquellos lugares donde las nuevas variedades se han extendido más. El pequeño agricultor adoptará las variedades nuevas una vez que las conoce, pero los grandes agricultores son los que suelen enterarse primero, por su mayor nivel de escolaridad y su contacto más asiduo con la extensión y otras fuentes de información. El tamaño de la finca es importante en todas las zonas en el sentido de que los grandes productores tienden a sembrar tanto variedades viejas como nuevas, sin especializarse en ninguna. Los pequeños agricultores que adoptan una nueva variedad por lo general cultivan con ella todas las tierras que dedican al trigo.

La razón más común que dieron los agricultores en las tres zonas de cambiar variedades fue el rendimiento. La mayoría de ellos creía que el rendimiento de las nuevas variedades era superior, pese a que unos cuantos percibieron que este aumento del rendimiento sobre los rendimientos reducidos de sus antiguas variedades tenía que ver con la resistencia a las enfermedades y otros factores. En el análisis multivariado, por lo general el factor que más influye en la adopción es la percepcion de los agricultores de que las nuevas variedades rinden más, aunque también es importante su comportamiento cuando se usan fechas de siembra tardías, sobre todo en la zona algodonera.

En las tres zonas encuestadas en 1985/86, el 50 ó 60% de todos los campos de los agricultores encuestados se sembraron con semilla reservada de la cosecha anterior. Otro 20 ó 30% se cultivó con semilla obtenida de agricultores vecinos. Es evidente que la transferencia de agricultor a agricultor constituye un medio importante de difusión. En las tres zonas, entre el 45 y 55% de los agricultores que sembraban variedades lanzadas después 1978 habían conseguido inicialmente semilla de otros agricultores. De los productores que sembraban variedades nuevas, obtuvieron inicialmente semilla del depósito más del 33% en la zona productora de arroz y trigo, pero sólo el 14% de los que viven en Mardan.

En las tres zonas, la escolaridad y el contacto con los servicios de extensión fueron las dos variables que más se relacionaron en forma positiva y significativa con el conocimiento correcto de dónde se localizaba el depósito de semilla. Es posible que en el Punjab la distancia del depósito estuviera negativamente relacionada con el conocimiento de dónde se encuentra éste. En el Punjab, los agricultores que conocían las variedades nuevas también eran los que probablemente sabían dónde quedaba el depósito; en Mardan no hubo tal relación, lo cual confirma la falta relativa de importancia del depósito de semilla en la difusión de las variedades nuevas.

En las tres zonas, sólo el 40 ó 50% de los agricultores que siembran su propia semilla utilizan técnicas como la selección de una parcela especial o la trilla por separado de la semilla y el grano. Hubo muy pocas relaciones significativas entre las características del agricultor y el manejo de la semilla.

El contacto con los servicios de extensión no fue una causa muy importante del conocimiento y adopción de las variedades nuevas. Las demostraciones de las variedades por los servicios de extensión quizá no se han difundido lo suficiente y además no siempre se han adecuado a las distintas circunstancias agrecológicas o factores adversos de los sistemas de cultivo. Por otra parte, no se han coordinado bien los esfuerzos de promoción de la investigación, la industria semillera y los servicios de extensión.

En conjunto, los resultados de los cuatro estudios realzan la importancia que tiene el reemplazo regular de variedades para los agricultores y para todo Pakistán. Los métodos que se usaron en esta investigación -análisis institucional, análisis de los datos de la investigación y encuestas entre los agricultores- ofrecen un medio de evaluar las complejas relaciones entre el fitomejoramiento de trigo, la verificación y el lanzamiento de las variedades, la producción y distribución de semillas, la extensión, las políticas gubernamentales y los cambios de variedades que hacen los productores. Si bien las conclusiones que se presentan en este informe son específicamente de un cultivo, un lugar y un período determinados, se les puede considerar también como hipótesis que se podrían aplicar en distintas situaciones, quizá con alguna modificación.

En el futuro, en los estudios realizados para ampliar el conocimiento de los factores que afectan el reemplazo de las variedades, se podrían crear métodos para establecer el número aproximado de variedades que serán lanzadas por los programas fitotécnicos más avanzados de países con grandes zonas productoras del cultivo en cuestión, y la diversidad genética que esas variedades deberán poseer. Asimismo, sería muy útil un mayor número de estudios de los sistemas de semilla que han logrado cierto nivel de eficacia en comercializar semillas de distintos cultivos. De hecho, existe ya este tipo de estudios; lo que habría que hacer es agregar la perspectiva del reemplazo de variedades a la descripción legal e institucional que a menudo contienen. También es necesario realizar más investigaciones para verificar empíricamente el efecto relativo de los factores que influyen en la demanda de semilla para reemplazar variedades por parte de los agricultores. Por último, estudios de otros países y en especial, de otros cultivos, mejorarían nuestro entendimiento de los aspectos del reemplazo de variedades que son universales, y de los cambios en las suposiciones y métodos que son necesarios para analizar factores más específicos respecto al tiempo, al lugar y a determinados cultivos.

Résumé

En raison même de la lenteur avec laquelle s'effectue dans les exploitations agricoles des contrées productrices de blé la substitution des plus anciennes variétés par de nouvelles, les agriculteurs ne bénéficient qu'avec retard des résultats de la recherche en phytotechnie et sont, de plus, exposés au risque de voir se présenter des épidémies, notamment quand la diversité génétique des variétés cultivées dans la région est limitée. Pour que les agriculteurs puissent effectivement profiter des résultats de la recherche, il faut avant tout déterminer la période optimale pour le remplacement des variétés qu'ils cultivent et bien connaître les facteurs du système de production de la semence susceptibles de faire obstacle à une rapide substitution des variétés.

A la suite de la Révolution Verte, les augmentations de rendement en blé obtenues à la faveur de l'amélioration génétique ont été de près de 0,75% par an, encore que cette tendance n'ait pas été uniforme partout. Une telle augmentation suggère qu'il est de l'intérêt des agriculteurs de changer de variétés tous les quatre ans, sur la base de suppositions rainsonnables quant aux niveaux actuels de nombreux paramètres qui influencent leurs décisions. Les différences de microenvironnement, la variabilité des intervalles entre les périodes de meilleur rendement et les fluctuations des pertes occasionnées par la rouille font que, dans certains cas, les agriculteurs devront prolonger la période précédant le changement des variétés.

Depuis la Révolution Verte la substitution de variétés de blé au Pakistan s'est opérée plus lentement que dans d'autres zones dont les conditions écologiques sont analogues, telles le Punjab indien et le nord-ouest du Mexique. De plus, une seule variété est généralement cultivée au Pakistan sur de grandes étendues et il n'y a de diversité que dans la période de transition d'une variété dominante à une autre. En ce qui concerne le Punjab, de 1977 à 1986, la culture de variétés de blé - qui ne sont d'ailleurs plus conseillés parce que susceptibles aux diverses rouilles - occupait en moyenne plus de 40% des terres; de 1982 à 1986 la superficie ensemencée en variétés pour lesquelles le taux d'incidence de la rouille de la feuille était de 50S ou plus représentait près de 60% de la totalité des terres cultivées. Sans parler des pertes que peut provoquer toute épidémie, les pertes de rendement occasionnées chaque année par la rouille sont considérables et, bien que relativement limitées, elles pourraient donner lieu à de lourdes pertes annuelles.

Les quatre études complémentaires dont on trouvera ici le compte rendu ont pour objet l'analyse des problèmes associés au remplacement de variétés dans la culture du blé dans un seul pays, le Pakistan. Les systèmes de substitution de variétés et de production de semence y sont examinés, depuis l'obtention de nouvelles lignées jusqu'à l'adoption de ces dernières par las agriculteurs. Les recherches ont été principalement centrées sur le Punjab dont les cultures de blé couvrent 71% de la superficie totale des terres ensemencées en blé au Pakistan et 75% des terres de blé irriguées du pays. Les informations concernant cette zone sont relativement plus abondantes et le système de production de semence y est plus développé. Néanmoins, les méthodes et résultats de cette recherche pourront être utiles aux chercheurs qui, en dehors du Pakistan même, ont besoin d'un cadre de référence pour l'étude de

problèmes qui peuvent se présenter en liaison avec une lente substitution de variétés, une faible diversité des variétés cultivées et des systèmes de production de semence déficients.

La première étude est consacrée au problème de la substitution tardive de variétés du point de vue du système de recherche; de plus, les diverses manières de mesurer le remplacement de variétés et leur diversification dans le temps et dans l'espace, appliquées au Punjab, y sont exposées. Ces méthodes de mesure servent à déterminer si il existe un rythme optimal pour la substitution de variétés et à évaluer le degré de vulnérabilité de ces dernières aux maladies. D'autres types de mesures sont également proposés pour évaluer l'avance d'un programme d'amélioration du blé, tels le taux de lancement de nouvelles variétés et le taux d'augmentation du rendement pendant la période requise pour que se développent de nouvelles variétés. Au Punjab, la substitution de variétés a été beaucoup plus lente qu'ont pouvait raisonnablement l'espérer - de 5 ou 6 ans - et la culture de variétés sensibles à la rouille s'est étendue sur une très grande superficie (plus de 50% des terres à blé du Punjab pendant les premières années 80).

La deuxième étude traite des problèmes que pose l'obtention de données relatives à la superficie des terres ensemencées avec diverses variétés. L'observation des variétés cultivées coïncide souvent avec la nécessité de recueillir d'autres types de données, de sorte que toute estimation globale de la superficie cultivée provient souvent d'enquêtes menées dans une toute autre perspective. L'identification de visu des variétés cultivées par un personnel spécialisé étant fort onéreuse, il faut se fier généralement aux dires des agriculteurs, lesquels ne connaissent pas toujours les noms des variétés et parfois ne les identifient pas correctement. Les échantillonnages issus d'ensembles de cultures peuvent induire une grande erreur standard dans l'estimation de la superficie cultivée avec chaque variété, du fait que la variance dans les unités primaires d'échantillonnage (les villages, par exemple) tend à être inférieure à la variance globale de ces unités.

La troisième étude porte sur la multiplication et la commercialisation des semences par la société de production de semence au Pakistan (Punjab Seed Corporation, PSC). Les chiffres correspondant à la production antérieure et à la production actuelle sont présenté, ainsi que les données relatives au réseau de commercialisation des semences au Punjab. De toute évidence la PSC a élevé la production de semence de blé au Punjab. A la fin des années 1960 et durant les premières années 1970, avant que soit créée la PSC, les ventes annuelles de semences dépassaient à peine 16 000 tonnes en moyenne. Au cours des cinq premières années d'activité, la PSC a porté la production de 4 000 à 44 000 tonnes et l'a maintenue à ce niveau, y compris dans la Province de la Frontière du Nord-Ouest (Northwest Frontier Province, NWFP) où il n'existe pas d'industrie spécialisée dans la production de semences, la capacité de production a augmenté et l'Autorité de développement agricole de la NWFP acquiert 3 000 à 4 000 tonnes par an. Auparavant, la majeure partie de la semence provenait du Punjab, mais dès 1986/87 elle a été fournie presque en totalité par la NWFP.

Des problemes importants subsistent dans la planification de la production de la semence, de même que dans la promotion et la commercialisation. Peut-être serait-il possible de faciliter les premières étapes de la multiplication, mais les autorités ne savent pas exactement quelles sont les variétés qu'il serait bon de multiplier. La production n'augmente pas parce que la PSC ne peut vendre l'excédent de sa production. Fournir à l'agriculteur une semence pure et dûment certifiée semble être le premier objectif en matière de commercialisation et non faciliter la substitution rapide de variétés. Apparemment les agriculteurs ont plus recours au système officiel pour changer de variété que pour obtenir de nouvelles semences de variétés qu'ils cultivent déjà. Néanmoins, un système de production de semence travaillant en étroite liaison avec les centres de recherche et les services de vulgarisation serait fort utile pour activer la substitution de variétés dans la période suivant la Révolution Verte.

La commission que perçoivent les distributeurs privés dans le cadre de la commercialisation de semence est très inférieure à celle qui leur est accordée pour la vente d'engrais, produit qui fait l'objet d'une demande plus important et plus régulière. De ce fait, la distribution de semence au niveau des exploitations agricoles est effectuée par le secteur public. L'industrie privée, pour sa part, ne fait pas grand effort pour promouvoir sa production.

La diffusion plus rapide de semence nouvelle requiert une plus grande activité promotionnelle, un réseau de distribution plus étendu et l'octroi d'une commission plus élevée aux distributeurs. Sans doute ces modifications donneront-elles lieu à une majoration du prix de la semence laquelle, à court terme, motivera la réduction de la demande de la part des agriculteurs mais pourra, néanmoins, avoir pour effet l'accélération du remplacement de variétés, si toutefois cette hausse des prix favorise la promotion et l'extension du réseau de distribution, d'où une réduction du temps nécessaire pour que les nouvelles variétés soient mises à la disposition des agriculteurs. Au Punjab indien les prix du blé sont plus élevés et la substitution de variétés plus rapide qu'au Punjab pakistanais.

Le point de vue des agriculteurs fait l'objet de la quatrième étude. Un tiers ou un quart seulement des agriculteurs auprès desquels ont eu lieu les enquêtes dans les trois principaux systèmes de culture considéraient que certaines variétés étaient plus résistantes que d'autres aux maladies, et un quart d'entre eux - peut-être même moins - pensait que les variétés pouvaient perdre leur résistance.

Les agriculteurs du Punjab dans la zone de culture de riz et de blé étaient plus informés des nouvelles variétés parce que ces dernières y ont fait l'objet d'une plus large diffusion. Le niveau d'instruction des agriculteurs dans cette zone, leur contact avec les agents de vulgarisation et le fait de vivre dans une agglomération où ces variétés sont cultivées dans de nombreux champs, sont autant de facteurs qui ont favorisé la connaissance des variétés par ces agriculteurs. Certaines de ces variables, le niveau d'instruction ou de scolarité notamment, ainsi que certaines condition dans les villages où vivent les agriculteurs, exercent également une influence dans

d'autres zones ainsi que l'ont révélé les enquêtes effectuées dans la zone de culture de coton et de blé du Punjab et la région irriguée de Mardan, NWFP.

Comparée à d'autres variables, la taille de l'exploitation agricole ne semble pas jouer un rôle déterminant en ce qui concerne la connaissance ou l'adoption de nouvelles variétés dans les zone où celles-ci se sont répandues. Le petit cultivateur n'adopte de nouvelles variétés que s'il les connait, mais les grands agriculteurs en sont informés les premiers et ce pour trois raisons: leur degré d'instruction plus élevé, leurs contacts plus fréquents avec les services de vulgarisation, enfin les autres sources d'information auxquelles ils ont accès. Mais, dans toutes les zones, les dimensions de l'exploitation agricole sont importantes du fait que les grands producteurs ont tendance à cultiver aussi bien les variétés anciennes que les nouvelles, sans distinction, alors que les petits agriculteurs qui adoptent une nouvelle variété la cultivent sur toutes les terres qu'ils destinent à la production de blé.

Le rendement a été la raison la plus généralement donnée pour changer de variété par les agriculteurs des trois zones. La plupart d'entre eux pensait que le rendement des nouvelles variétés était supérieur aux rendements insuffisants des variétés qu'ils cultivaient jusqu'alors; mais pour certains cette augmentation du rendement n'était pas sans rapport avec la résistance aux maladies et d'autres facteurs. L'analyse de tous les aspects envisagés fait apparaitre que le facteur qui détermine le plus généralement l'adoption d'une nouvelle variété réside dans le fait que les agriculteurs pensent que les nouvelles variétés ont un meilleur rendement bien que, dans les zones de culture de coton surtout, leur comportement est important quand les dates de semis sont tardives.

Dans les trois zones où ont eu lieu les enquêtes en 1985/86, 50 à 60% des champs des agriculteurs consultés étaient ensemencés en graines provenant de la récolte antérieure et réservées à cet usage; 20 à 30% etaient ensemencés en graines obtenues d'agriculteurs voisins. De toute évidence, le transfert de semence entre voisins constitue un important moyen de diffusion. Dans les trois zones, 45 à 55% des agriculteurs qui semaient des variétés lancées après 1978 se les étaient procurées auprès d'autres agriculteurs. Plus de 33% des agriculteurs de la zone de production de blé et de riz avaient obtenu les premières semences du dépôt officiel, mais cette proportion n'était que de 14% parmi les agriculteurs de Mardan.

Dans les trois zones, le degré d'instruction des agriculteurs et leurs relations avec les services de vulgarisation ont été les deux variables les plus étroitement et positivement liées au fait que les agriculteurs savaient où se trouvait le dépôt de semence. Il est possible qu'au Punjab l'éloignement du dépôt ait eu une relation négative avec la connaissance de son emplacement exact. Ceux des agriculteurs du Punjab qui connaissaient les variétés nouvelles étaient également ceux qui savaient où se trouvait le dépôt. Il n'en est pas de même à Mardan, ce qui prouve l'importance relative du dépôt dans la diffusion de variétés nouvelles.

Dans ces trois zones, 40 à 50% seulement des agriculteurs qui utilisent leur propre semence emploient des techniques telles le choix d'une parcelle spéciale ou le bettage séparé de la semence et du grain. On n'a observé que très peu de relations significatives entre les caractéristiques de l'agriculteur et la façon dont il gére ses semences.

Les contacts établis avec les services de vulgarisation n'ont pas joué un rôle très important dans la connaissance des variétés nouvelles et leur adoption par les agriculteurs. Les démonstrations dont ont été l'objet les variétés nouvelles de la part des services de vulgarisation n'ont peut-être pas été assez largement diffusées et n'ont pas toujours été adaptées aux conditions agro-écologiques des systèmes de culture ni n'ont tenu compte de contraints de culture. Il n'y a pas eu de bonne coordination entre les efforts de promotion de la recherche, l'industrie de production de semence et les services de vulgarisation.

Dans l'ensemble, la conclusion à tirer de ces quatre études est que le remplacement progressif de variétés est important non seulement pour les agriculteurs, mais pour tout le Pakistan. Les méthodes appliquées dans cette recherche - analyse institutionnelle, analyse des donnees de la recherche et enquêtes auprès des agriculteurs - offrent le moyen d'évaluer les relations complexes qui existent entre la recherche visant à améliorer la qualité et le rendement du blé d'une part et, d'autre part le contrôle et le lancement de variétés, la production et la distribution de semences, la vulgarisation, les politiques officielles et les changements de variétés par les agriculteurs. Bien que les conclusions présentées ici se réfèrent spécifiquement à une region, une culture et une période déterminée, elles peuvent être considérées comme autant d'hypothèses valables - non sans quelque modification peut-être - dans d'autres situations.

Dans les études effectuées à l'avenir en vue de faire conaître mieux les facteurs qui entravent la substitution de variétés, des méthodes pourraient être proposées pour établir le nombre approximatif des variétés issues des programmes d'amélioration les plus avancés de pays producteurs où les cultures de blé couvrent de grandes surfaces, ainsi que la diversité génétique que devraient présenter ces variétés. De même, il serait fort utile de mener de plus nombreuses études sur les systèmes de production de semence qui ont prouvé une certaine efficacité dans la commercialisation de semence de diverses cultures. En fait, ce type d'études existe déjà, mais il serait souhaitable qu'elles ne soient pas limitées à la description légale et institutionnelle qu'elles contiennent le plus souvent et qu'elles soient conçues dans la perspective du remplacement de variétés. Il serait également nécessaire de procéder à des recherches qui auraient pour objet de vérifier de façon empirique l'influence des facteurs qui interviennent dans la demande de semence des agriculteurs désireux de remplacer certaines variétés. Enfin, des études émanant d'autres pays et portant sur d'autres cultures nous permettraient de mieux connaître les aspects universels de cette substitution de variétés et les changements à apporter tant aux suppositions qu'aux méthodes nécessaires pour analyser des facteurs plus spécifiques en ce qui concerne le temps, le lieu et des cultures déterminées.

Chapter 1

Introduction

Paul W. Heisey

The speed with which new varieties are released and diffused to the farming population is an important factor influencing the benefits realized from plant breeding. Diffusion of new varieties ensures continuing increases in productivity through the increased yield potential of new varieties; it reduces the time lapse from the investment in research to the time the benefits are realized, thereby increasing the returns to research; and it helps maintain genetic resistance to diseases and pests.

The last benefit is particularly important in wheat. The resistance of released varieties often breaks down within a few years because pathogens, especially of leaf rust (*Puccinia recondita*) and stripe rust (*P. striiformis*), are continually evolving. To guard against loss when varietal resistance breaks down, it is useful to diversify varieties 1) over time, by rapidly replacing the varieties available to farmers, and 2) at a given point in time, by ensuring the availability of several varieties with different sources of genetic resistance to the dominant pathogens so that farmers can plant several varieties and reduce the risk of losses, or change varieties quickly if an epidemic breaks out. Varietal replacement over time and varietal diversification at a given point in time are both important targets of any program to develop and diffuse new wheat varieties.

Pakistan is one country in which varietal replacement has been slow. Though farmers quickly adopted semidwarf wheats at the time of the Green Revolution, since then varietal change has lagged compared with similar wheat-growing environments such as the Indian Punjab and northwestern Mexico. Wheat researchers have been aware of the problem of slow varietal replacement for some time. Pathologists, plant breeders, and other scientists have warned that a rust epidemic similar to the one that occurred in 1977/78 is likely to occur. However, the exact dimensions of the problem could not be determined; although some information on area planted to specific varieties is collected in Pakistan, at least for the Punjab, data are not made available publicly or in a timely fashion.

In the early 1980s, the Pakistan Agricultural Research Council (PARC)/International Maize and Wheat Improvement Center (CIMMYT) Collaborative Wheat Project, in cooperation with provincial research institutes, undertook a program of "integrated research in farmers' fields in areas representing dominant cropping systems in which wheat is grown in Pakistan" (Byerlee et al. 1986). As part of this program, agronomic-economic surveys were used to diagnose farmers' wheat production problems and to set priorities for research (Byerlee et al. 1984, Hussain et al. 1985, and Akhter et al. 1986a; **Figure 1.1** shows the survey areas). The surveys discovered that large areas of wheat in northern Pakistan were planted to old, rust-susceptible varieties. According to these researchers, variety is an important factor affecting farmers' yields and is also among the factors given the highest priority for immediate technology transfer.

These findings emphasized the need to develop methods and conduct research to understand the problem of limited varietal diversification and replacement more thoroughly. Additional research was warranted for many reasons. Seed is a basic but relatively uncomplicated and inexpensive component of wheat production technology. The contrast between the rapid initial adoption of high yielding varieties and the present slow rate of varietal replacement, and between rates of varietal replacement in Pakistan and in other countries, certainly suggested further study. Economic losses caused by disease in normal years in Pakistan, let alone the losses that could be incurred in an epidemic, are severe enough to make the subject of varietal replacement a serious policy issue. Pakistan was therefore a good location for exploring these issues in greater depth.

The results presented in this report come from four complementary studies designed to analyze the wheat seed system in Pakistan from the development of new lines by researchers to adoption by farmers. The report focuses on the Punjab, which contains 71% of Pakistan's total wheat area and 75% of all the irrigated wheat area in Pakistan, because relatively more data are available and the seed system is most developed.

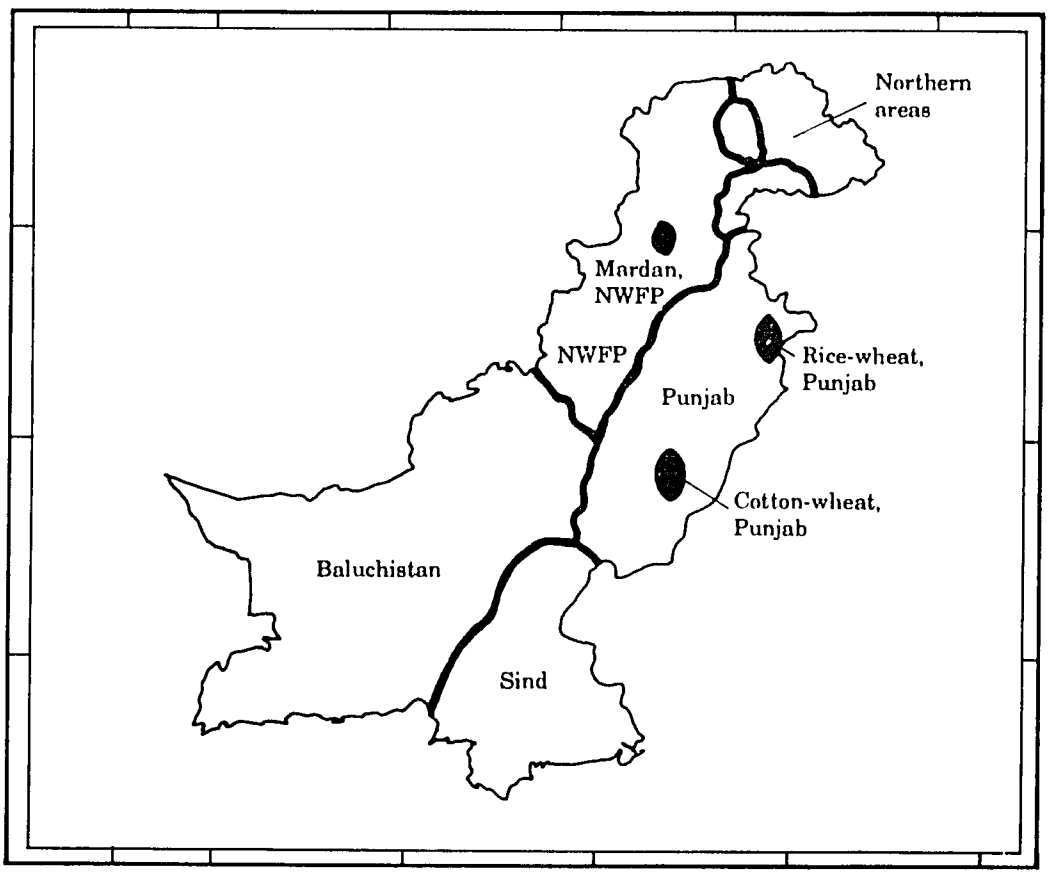

Figure 1.1. Survey areas, Pakistan.

The first study, summarized in Chapter 2, analyzes slow varietal replacement from the perspective of the research system. Measures of varietal replacement and spatial diversification are presented and used to investigate whether there is an optimal rate of varietal replacement in the Punjab and to assess the level of disease exposure. Other measures of assessing the progress of a wheat breeding program are also discussed, including the rate of release of new varieties and the rate of yield gain over time attributable to the development of new varieties.

The second study, most of which is presented in Chapter 3, assesses problems in obtaining the raw data on varietal coverage required for much of the subsequent analysis in this report. The study is the result of a series of special surveys conducted by social scientists from PARC. The surveys were designed to monitor wheat varietal coverage and change in the three cropping systems covered by the agronomic-economic diagnostic surveys.

Chapter 4 discusses the third study, which concentrates on seed multiplication and marketing by the Punjab Seed Corporation (PSC). Data are presented on past and current seed production and the present seed marketing network in the Punjab.

The fourth study, discussed in Chapters 5 and 6, concentrates on farmers. Chapter 5 looks specifically at farmers' seed sources and seed management, describing farmers' contacts with the formal seed system and the operation of the informal seed system. Chapter 6 concentrates on farmers' use of seed in the context of the literature on technology adoption. Farmers' perceptions of wheat technology in general, varieties in particular, and the wheat disease threat are presented and analyzed. Farmer characteristics are analyzed statistically for their effects on farmers' awareness and adoption of new varieties.

The four studies presented in this report look explicitly at the research system, the formal seed system, the informal seed system, and the varietal monitoring system. The relationships between these systems and the rate of varietal replacement in farmers' fields is diagrammed in **Figure 1.2.** No separate analysis of agricultural extension is conducted. However, evidence of extension's role in varietal diffusion is available from the discussion of extension as a source of technological information and the effect of extension contact on farmers' awareness and adoption of new varieties.[1]

The final chapter of this report presents some conclusions and recommendations aimed at varietal monitoring; wheat breeding, varietal testing, and release; seed production and distribution; extension; and government policy. Although the studies described in the pages that follow focus on the Punjab of Pakistan, the results and recommendations should be useful for all who are concerned with speeding the benefits of breeding research to its ultimate clients, the farmers.

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1 General evaluations of agricultural extension for the Punjab can be found in Khan et al. (1984) and Haq et al. (1986), and for Mardan in Freedman et al. (1986).

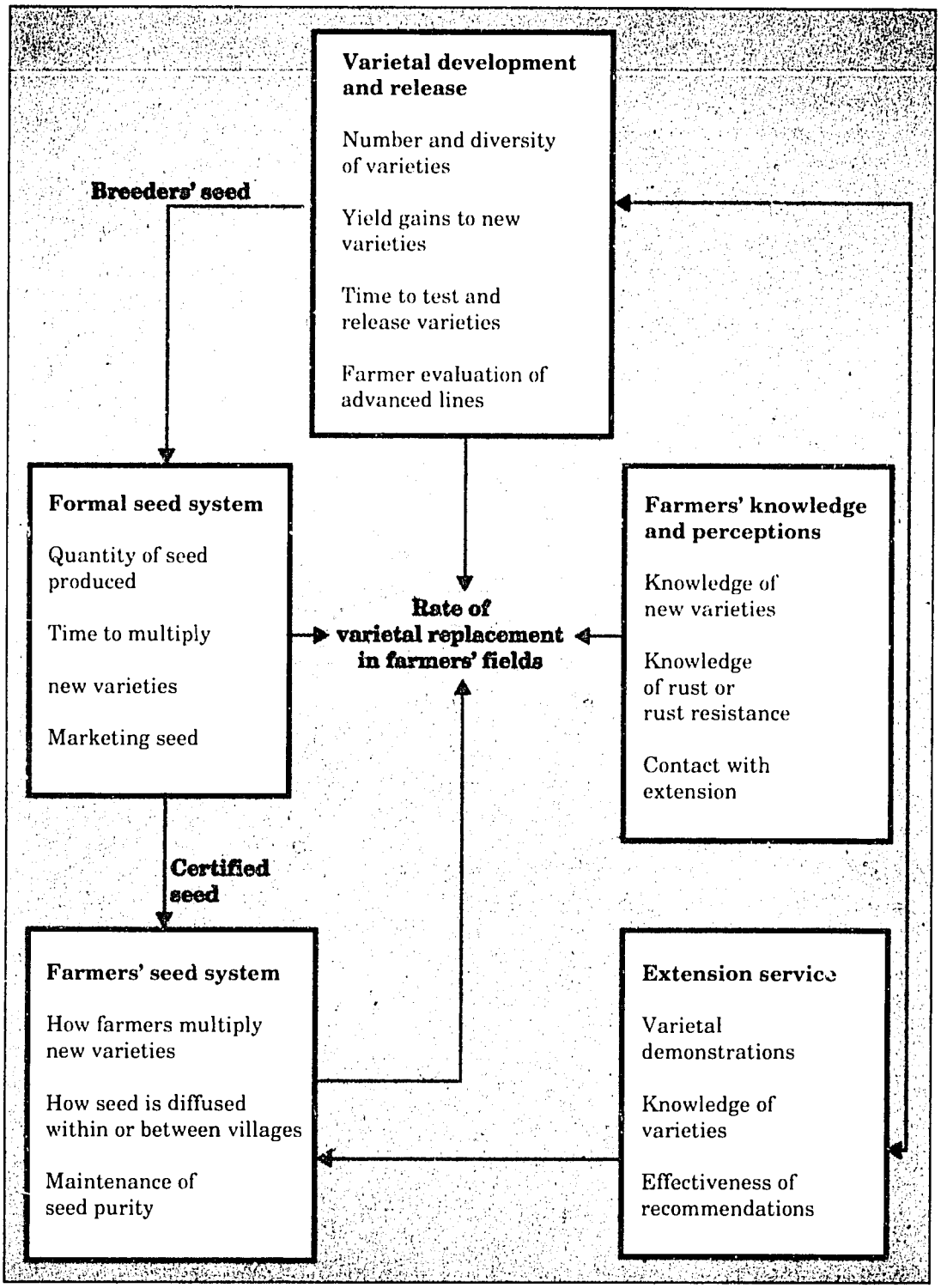

Figure 1.2. Analysis of the system.

Chapter 2

Wheat Varietal Diversification over Time and Space as Factors in Yield Gains and Rust Resistance in the Punjab

Derek Byerlee and Paul W. Heisey

Several studies have analyzed the overall returns to wheat breeding research (e.g., Nagy 1984 and Zentner and Peterson 1984). However, the concepts of a target or optimal rate of varietal replacement and of the degree of varietal diversification over space have received little attention, and appropriate measures to monitor replacement or diversification in farmers' fields also merit further study. This chapter addresses those issues, first by introducing some basic concepts and measures of varietal replacement and diversification, and then by applying them to recent trends in wheat varietal diffusion in the Punjab of Pakistan.

Optimal Varietal Replacement

Any plant breeding program will have an optimal time span during which new varieties are released and old ones are replaced. The length of this period depends on the benefits and costs of releasing new varieties. The benefits in turn depend on 1) the yearly genetic gains in yield or improvement in other desirable characteristics such as maturity, 2) the rate of varietal decay caused by breakdown in disease resistance, and 3) the genetic diversity for disease resistance in varieties that are currently grown. Because these factors, particularly the third one, change from year to year, the optimum period for varietal replacement will vary over time. The costs of replacement depend on the costs of breeding new varieties, multiplying seed of those varieties, providing extension to substitute new varieties for old ones in farmers' fields, and farmers' seed purchase and learning costs.

All of those factors are quite specific to a given situation. The genetic gains in yield per year in a plant breeding program vary substantially. Annual yield gains may average 2% or more in exceptional periods, as in the 1960s and 1970s when the semidwarf character was widely exploited by wheat breeding programs, but over the long term, genetic yield gains are unlikely to average more than 1% annually (CIMMYT 1989).

To make it worthwhile for a farmer to change varieties, some threshold yield increase—aside from the attractions of improved disease resistance and other superior characteristics that a new variety might have—is usually needed. The number of years before farmers should change varieties depends upon several factors, which are shown in **Figure 2.1** and discussed in Heisey and Brennan (1989).

If we make the simplifying assumption that farmers' seed does not deteriorate over time, we can use the yield threshold criterion in a straightforward manner. Assuming that the price of seed of a new variety is twice the price of seed of the old

variety, and assuming a minimum marginal return on capital of 100% (CIMMYT 1988), the threshold yield increase would be between 7.5% and 10% for a base wheat yield of 2 t/ha in farmers' fields.[1] If the annual rate of genetic gain in yield is 1%, a varietal replacement period of 8-10 years is implied. If breeding gains are more rapid, or base yields are higher, prices of seed of improved varieties lower, or if farmers' seed deteriorates, the desired varietal replacement period is considerably shorter.

The period in which farmers should grow one variety before changing to another is shown for various assumptions in **Table 2.1**. The seed-to-grain price ratio of 1.5 reflects the current ratio of wheat seed to commercial grain in Pakistan; the ratio of 1.75 is nearer the worldwide average. The base yield of 2 t/ha is near current levels for irrigated wheat in the Punjab; the higher yield (comparable to farmers' yields in

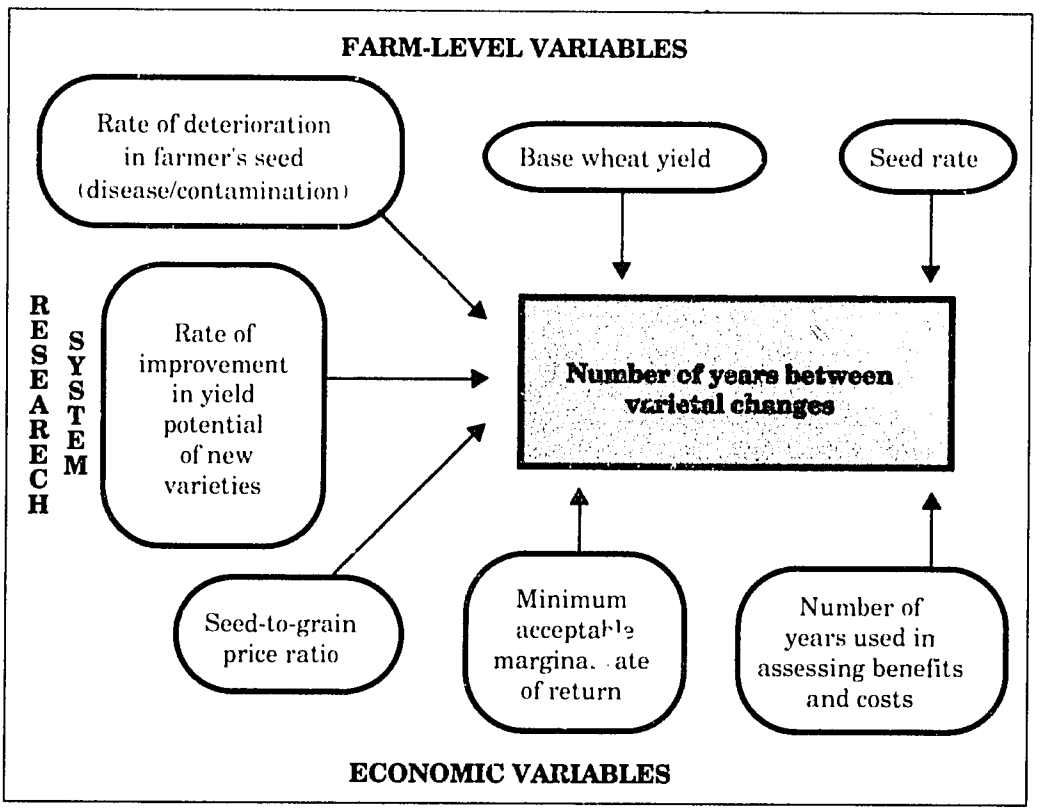

Figure 2.1. Factors influencing the number of years between varietal changes.

1 The higher figure (10%) considers only benefits in the year of adoption. The lower figure (7.5%) assumes that seed of the new variety can be kept for future years with no decline in yields.

northwestern Mexico) illustrates the effects of a substantially higher base yield. Seed pricing does not affect varietal replacement so significantly when base yields are higher.[2]

Another factor influencing the benefits of varietal replacement is the rate at which varieties decay as their disease resistance breaks down. The degree of longevity is obviously quite specific to a given variety and environment. Nonetheless, a recent review (Khan 1987) suggests that the life of a wheat variety before leaf rust and/or stripe rust resistance breaks down averages about five to six years in northern Pakistan (**Table 2.2**). In the highly favorable wheat growing environment of northwestern Mexico, where leaf rust is a major problem, the average longevity of a variety is only three to four years. Data summarized by Kilpatrick (1975) for many countries suggest that races of rust pathogens change on average about once every five years in wheat growing areas of the Third World. Because some cultural practices that increase yields also promote conditions for rust to occur, wheat varietal longevity is decreasing over time (Khan 1987).

The longevity of new resistant wheat varieties also decreases if they are grown alongside susceptible varieties. The buildup of inoculum on susceptible materials is likely to raise the probability of a change in rust races (PARC 1987). In Queensland, Australia, wheat breeders noted that varietal longevity with regard to stem rust increased from about five to 10 years when nearly all farmers grew varieties resistant to the disease and the level of inoculum was kept low.

Table 2.1. Target varietal replacement to meet farmers' minimum requirements for yield increases (MRR = 100%)

Genetic gain in yield (%/yr)	Base yield 2 t/ha Seed-to-grain price ratio		Base yield 5 t/ha Seed-to-grain price ratio	
	1.50	1.75	1.50	1.75
	Number of years to make replacement profitable			
0.5	8	11	4	3
1.0	4	6	2	3
1.5	3	4	2	2

Note: Assumes a minimum marginal rate of return (i.e., farmers' minimum return on capital) of 100%; also assumes that the ratio of price of seed of improved variety to price of seed of old variety (i.e., commercial grain price) is 1.50 or 1.75; a seed rate of 100 kg/ha; no deterioration in farmers' seed; and inclusion of benefits in years subsequent to a change.

2 For more discussion of the effects of the various parameters, see Heisey and Brennan (1989).

Table 2.2. Duration of resistance in wheat varieties to stripe and leaf rusts, Punjab, Pakistan, 1984

Variety[a]	Year released	Field life of variety[b] (years)
Mexipak	1965	7
Chenab-70	1970	9
Barani-70	1970	4
Blue Silver	1971	11
SA-42	1971	6
Pothowar	1973	4
Pari-73	1973	12
Sandal	1973	12
Yecora	1975	5
SA-75	1975	4
Nuri-70	1975	6
Punjab-76	1976	1
WL-711	1978	3
Chenab-79	1979	3
Bahawalpur-79	1979	6
Average[a]		**6.3**

Source: Khan (1987)

a Excludes varieties (mostly recent releases) in which rust resistance has not yet broken down.
b Longevity of variety in terms of leaf or stripe rust resistance.

But frequent varietal replacement also incurs costs, since it requires both a well-developed breeding program and an established seed multiplication, distribution, and extension system. Such a system should be able to provide sufficient seed of new varieties two to three years after their release, although limitations on seed multiplication can often increase this period to four years or more. The rate of diffusion is likely to be a function of improved yield or another superior characteristic of the new varieties, rather than disease resistance. However, in periods when yield gains are attained slowly in breeding programs, varietal replacement may have to be undertaken largely to protect against disease rather than to exploit new yield gains. In that case, the cost of extension to replace old, susceptible varieties may be quite high if farmers are unaware that the resistance of their varieties has broken down until a disease epidemic occurs. On the other hand, when new varieties clearly give higher yields, they may spread quite rapidly with little input from extension, as occurred when semidwarf wheats were first released (Lowdermilk 1972).

The costs and benefits of varietal replacement in Pakistan suggest that wheat varieties should turn over every five to six years, which is somewhat longer than the target of three to five years set in Pakistan after the 1978 rust epidemic (Muhammad 1981). The five- to six-year target period would meet the hypothesized threshold at which it becomes profitable for farmers to change varieties and maintain rust resistance. The target period would also be practical, given the limitations in releasing, extending, and multiplying seed of new varieties.

Even a target period of five to six years poses considerable challenges to plant breeders. For example, in the Punjab alone there are three varietal zones—irrigated southern Punjab (leaf rust zone), irrigated northern Punjab (leaf rust and stripe rust zone), and the *barani* (rainfed) tract—as well as two distinct planting periods (normal and late) in the irrigated tracts. To meet a target replacement time of five to six years in all zones, one new variety should be released each year. Some varieties

are adapted across zones, thereby reducing the number of varieties needed, but this advantage is countered by the fact that some varieties are not accepted by farmers or are grown on only a negligible area.

Appropriate Varietal Diversification over Space

Assuming that varietal diversification reflects genetic diversity, varietal diversification over space is desirable mainly to reduce the risk to farmers and to a nation should a rust epidemic occur. If a susceptible variety covers only a minor proportion of the planted area, losses in the year of an epidemic are reduced, and in the next year the variety can be replaced more quickly and cheaply than if it had been planted on a wider area. Replacing a susceptible variety grown on half or more of the planted area usually takes more than one year and requires an accelerated program to procure and distribute seed. Large-scale seed imports may even be necessary, as during the rust epidemic in Pakistan in 1978.

To actually reduce the risk of an epidemic, diversification must be practiced at the field level, perhaps by planting multilines or varietal mixtures in a given field.[3] There is some difference of opinion over whether planting adjacent fields with genetically different material slows the spread of disease, but plant pathologists generally agree that diversification above the field level will probably not influence the rate at which a rust epidemic spreads.

To monitor both the impact of a plant breeding program and exposure to rust epidemics, some measures of varietal replacement and diversification are needed. Measures used in other studies are reviewed here and some are applied to the situation in Pakistan. Examples are sometimes calculated using hypothetical data from **Table 2.3**.

Table 2.3. Proportion of wheat area sown to given varieties at five-year intervals (hypothetical data)

Variety	Year of release	Percentage area covered by variety			
		1970	1975	1980	1985
1	1962	50	20	10	10
2	1966	30	50	30	10
3	1968	20	30	50	30
4	1978	0	0	10	50
All		**100**	**100**	**100**	**100**

3 A multiline is a mixture of phenotypically similar plants that have different genes for rust resistance. A multiline could be developed by crossing a variety to a series of varieties with different sources of resistance and then backcrossing to the original variety to regain phenotype. However, each component of a multiline or varietal mixture must be tested to ensure it has at least one resistance gene that is different from those in the other components of the mixture/multiline.

Measures of Varietal Replacement

Many different measures of varietal replacement have been proposed, beginning with an index developed by Johnson and Gustafson (1963). Some of the more important measures are discussed by Brennan (1984) and Brennan and Byerlee (1989). The two measures used in this study are the proportion of recent varieties and the weighted average age of varieties; they are analyzed in the sections that follow.

Proportion of recent varieties This index (Brennan 1984) is quite simple to construct. If we use a five-year period for varietal replacement, then this index, N_t, is simply the proportion of the area planted to varieties released in the previous five years.

The following hypothetical example illustrates the method. Assume that a target is set to grow only varieties released in the previous seven years (n = 7) (two years for seed multiplication and five years for varietal longevity). Then the indices of varietal newness (N_t) calculated from Table 2.3 are as follows:

N_{85}	=	50	=	50
N_{80}	=	10	=	10
N_{75}	=	30	=	30
N_{70}	=	30 + 20	=	50

That is, except for 1980, about one-third to one-half the area is generally sown to new varieties.

Weighted average age of varieties This index consists of the average age, A_t, of varieties grown by farmers, measured in years from varietal release and weighted by the proportion of area sown to each variety. Again, using the data from Table 2.3, the calculation of A_t can be made as follows:

A_{85}	=	.10*23	+	.10*19	+	.30*17	+	.50*7	=	12.8
A_{80}	=	.10*18	+	.30*14	+	.50*12	+	.10*2	=	14.0
A_{75}	=	.20*13	+	.50*9	+	.30*7	=	9.2		
A_{70}	=	.50*8	+	.30*4	+	.20*2	=	5.6		

This index is easy to construct and does not require a "target" replacement period, n, to be pre-selected. It will be the main index used here.

It is important to note that this is an *aggregate* measure. Though it is related to the optimal replacement period for an individual farmer (see above), it is not the same. In particular, aggregate weighted average age is affected by the amount of time from varietal release until a substantial amount of seed first reaches farmers, and by the fact that the actual year when farmers change varieties may differ from farmer to farmer.

Measures of Varietal Diversification

It is possible to construct crude indices of varietal replacement that do not consider the genetic makeup of disease resistance in released varieties. The simplest measure is the proportion of area devoted to the most popular variety. Targets may be set to keep this proportion in any given area to, say, 33% or less (Duvick 1984). As more is known about the specific genes conferring rust resistance, this index can be considerably refined by grouping varieties that carry the same gene sets for resistance against known rust races to make the calculations (Priestley and Bayles 1980).

Varietal Replacement and Diversification in the Punjab, 1965-86 and 1978-86

Data for analyzing varietal diversification in the Punjab were provided by the Crop Reporting Service (CRS), Lahore. Since the 1978 rust epidemic, the CRS has recorded the area planted to specific varieties in randomly selected farmers' fields in the Punjab. These data are not without limitations; in particular, the CRS does not allow for the fact that, on average, 12-15% of farmers cannot reliably identify which wheat variety they grow (Chapter 3). A tendency to rely on physical identification has probably led to an overestimation of some varieties, especially Yecora, a sister line of Pari, from which it is almost physically indistinguishable. Nonetheless, data at the provincial level reasonably reflect general trends in varietal use. At the zonal level, estimated area in each variety is also fairly consistent with estimates from independent surveys conducted by wheat breeders and economists from 1985 to 1988 (Chapter 3).

Rate of varietal release Upon its release in 1965, Mexipak became the first commercially successful semidwarf wheat in Pakistan. Around 1970 the rate of varietal release increased substantially with the rapid development of other semidwarf materials. Two decades later, some 27 new varieties, all but one of them semidwarf, had been approved for cultivation in the Punjab (**Tables 2.4** and **2.5**). Nonetheless, the rate of release in Pakistan is low relative to other countries. In the Punjab and for Pakistan as a whole, 0.29 varieties have been released per year per million hectares of wheat cultivated. This figure can be compared to an average of 0.72 varieties/yr/million ha for 15 developing countries and 0.45 varieties/yr/million ha for 7 developed countries (**Table 2.6**). The lower rate of varietal release in the Punjab partly reflects its relative agroclimatic uniformity and large wheat area.

In addition to a relatively slow rate of varietal release, the rate of acceptance of varieties in the Punjab may be a problem. Of 20 varieties released from 1965 to 1981, six can be considered failures as they were never planted to more than 1% of the area, and only nine were adopted on 5% or more of the area (**Table 2.7**). The latter figure is consistent with adoption in other countries, where only about half of the varieties released are expected to become commercial successes. Nonetheless, the number and quality of varieties released in the Punjab would probably have been sufficient to allow reasonable varietal diversification over space and time, if each variety had been rapidly adopted by farmers on roughly equivalent areas.

Table 2.4. Varieties released since 1965 and year banned for rust susceptibility, Punjab, Pakistan

Variety	Year released	Year banned	Special recommendations
Mexipak	1965	1978	- -
Barani-70	1970	1978	Rainfed areas
Chenab-70	1970	1979	- -
Blue Silver	1971	1989	Late planting
SA-42	1971	1978	Late planting
Pothawar	1973	1978	Rainfed areas
Sandal	1973	Current	- -
Lyallpur-73	1973	Current	Rainfed and irrigated areas
SA-75	1975	1980	Late planting
Pari-73	1973	Current	- -
Yecora	1974	1982	- -
Nuri	1975	1982	- -
LU-26	1976	Current	Southern Punjab
Punjab-76	1976	1978	- -
HD-2009	1978	1979	- -
WL-711	1978	1982	Southern Punjab
Sonalika	1978	1989	Late planting
Indus-79	1979	1989	- -
Bahawalpur-79	1979	1989	Southern Punjab
Punjab-81	1981	Current	Southern Punjab
Pak-81	1981	Current	Also for rainfed areas
Pavon	1980	Current	- -
Faisalabad-83	1983	Current	Late planting
Kohinoor	1983	Current	- -
Barani-83	1983	Current	Rainfed areas

Table 2.5. Release of wheat varieties in the Punjab, 1955-84

		Varieties recommended for:		
Period	Total number of varieties released	Irrigated normal planting	Irrigated late planting	Rainfed areas
1955-59	2	2	0	0
1960-64	0	0	0	0
1965-69	1	1	0	1
1970-74	9	8	2	4
1975-79	9	7	3	1
1980-85	6	3	2	2
Total	**27**	**19**	**7**	**8**

Note: Some varieties are recommended for both normal and late planting or for both irrigated and rainfed wheat.

Varietal replacement, 1978-86—Varietal adoption and disadoption curves for the Punjab are given in **Figures 2.2** and **2.3** and the years needed for each variety to reach peak adoption are reported in Table 2.7. Clearly the rate of varietal replacement in Pakistan has been relatively slow (compare replacement in Mexico, **Figure 2.4**). The average number of years from the release of a variety to peak adoption is nearly eight (Table 2.7). Only one major varietal change has occurred since Mexipak was introduced 20 years ago. Chenab-70, released in 1970, was successful but only partially replaced Mexipak. The severe rust epidemic of 1978

Table 2.6. Rate of varietal release in Pakistan and other countries

	Number of varieties released per year per million ha wheat
Pakistan, 1965-85	0.29
Punjab, Pakistan, 1965-85	0.29
15 developing countries, 1967-75	0.72
7 developed countries, 1967-75	0.45

Source: Calculated from Kilpatrick (1975) and other sources.

Table 2.7. Extent and rate of diffusion of wheat varieties released in the Punjab, 1965-81

Variety[a]	Peak year	Peak area (%)	Years from release to peak
Mexipak	1971[b]	58.0	6
Chenab-70	1978[b]	na (>10.0)	8
Blue Silver*	1987[c]	13.9	16
Sandal	1982	5.0	9
Lyallpur-73	1985	11.3	12
Yecora**	1980	55.6	6
SA-75	1979	2.6	4
Nuri	1979	1.4	4
LU-26	1984	1.6	8
WL-711	1986[c]	18.4	8
Bahawalpur-79	1985	2.0	6
Punjab-81	1986[c]	14.0	5
Pak-81	1991[d]	>50.0[c]	10

a Excludes varieties that never covered more than 1% of the area (Pothawar, SA-42, HD-2009, Pavon, Punjab-76, Indus-79).
b Based on alternative reports.
c Projection based on surveys by Akhter et al. (1987).
d Extrapolation based on data to 1987.
* Includes Sonalika.
** Includes Pari-73.

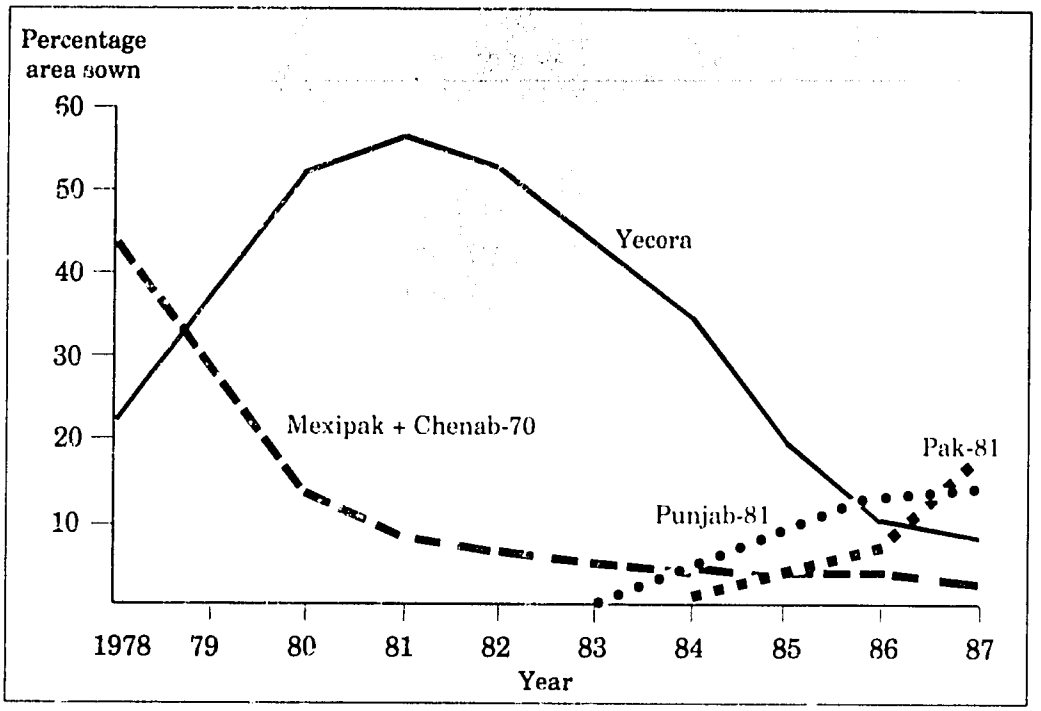

Figure 2.2. Percentage of wheat area sown to major varieties, Punjab, Pakistan, 1978-87.

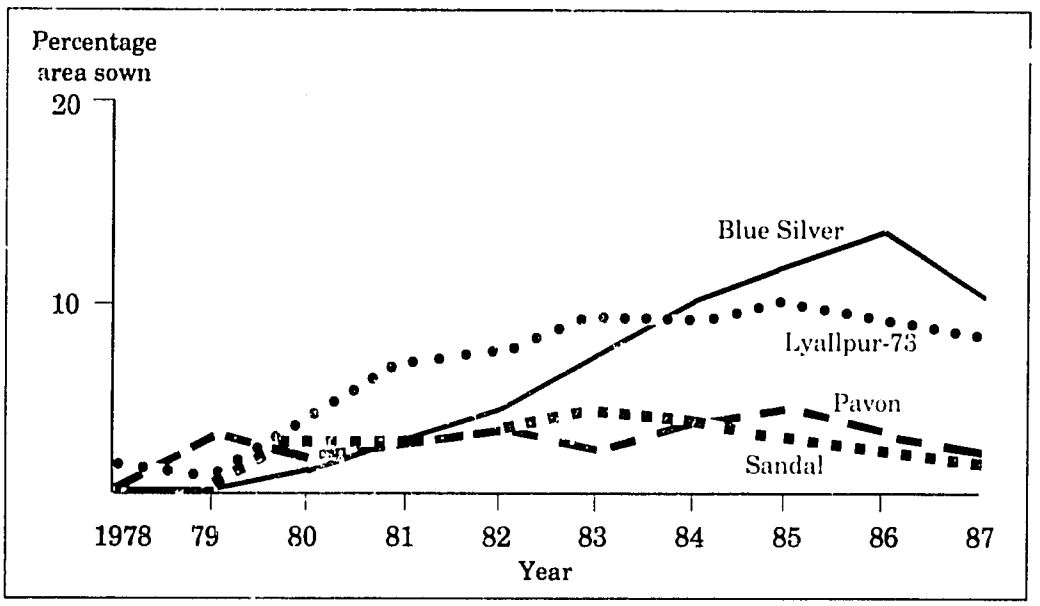

Figure 2.3. Percentage of wheat area sown to other varieties, Punjab, Pakistan, 1978-87.

caused both Mexipak and Chenab-70 to be replaced by Yecora (seed of Yecora was imported on a large scale, and it became the dominant variety) and by WL-711 (which came to dominate the southern Punjab). Although both Yecora and WL-711 were removed from the list of recommended varieties in 1982, up to 1985 they were widely grown. Newer releases, especially Pak-81 and Punjab-81, are replacing them. The area under Punjab-81 has probably peaked because of that variety's stripe rust susceptibility and tendency to shatter at harvest, and it is estimated that the area under Pak-81 will peak at over 50% in 1991. Adoption of Pak-81 is growing quite rapidly in some areas (e.g., the rice-wheat area of northeastern Punjab) and more slowly in others.

Three other varieties have been and continue to be important, covering 10% or more of the area, but usually for specific situations. Blue Silver, also known as Sonalika, is grown widely and recommended especially for late planting. Lyallpur-73 is prominent in the rainfed areas. The area planted to older, taller, and *desi* (local) varieties has continuously declined and their cultivation is now largely confined to the driest rainfed areas.

Two measures of varietal replacement (the percentage area sown to new varieties released in the past five years, N_y, and the average age of varieties, A_y) were calculated for 1978-86 using the indices of varietal replacement described earlier.

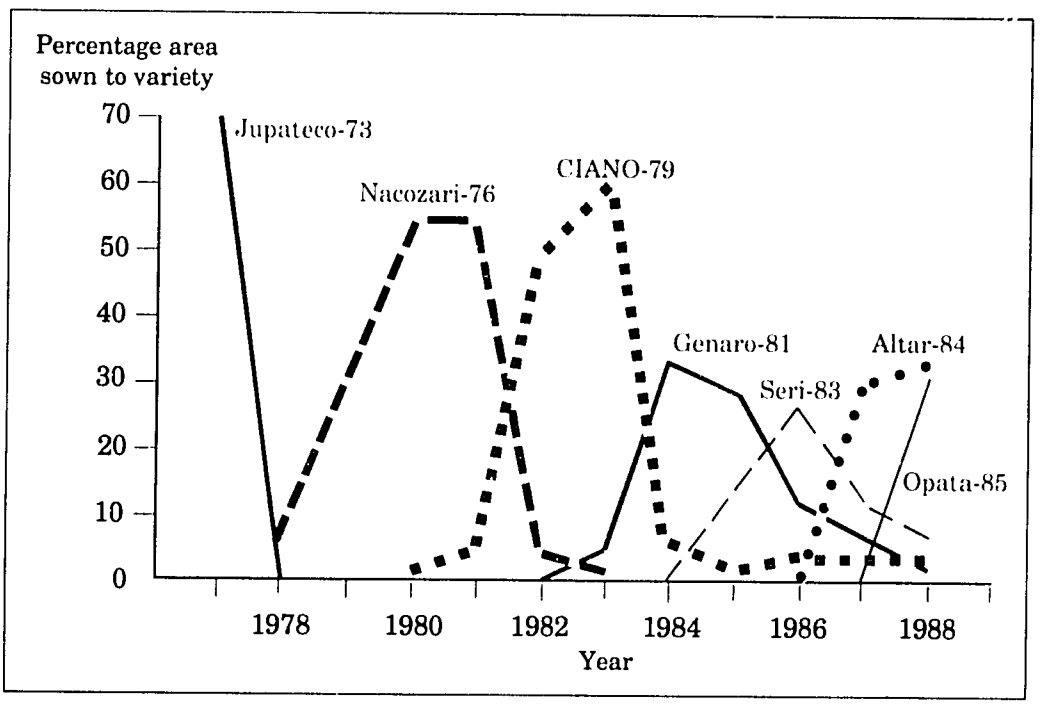

Figure 2.4. Wheat varietal replacement in the Yaqui Valley, Mexico, 1977-88.

When varietal replacement is calculated using the conventional definition of new varieties (those released in the previous five years: $n = 5$), the area planted to new varieties has averaged only 11%. Even if the definition is relaxed to include varieties released in the past seven years ($n = 7$), the area sown to new varieties is relatively small.

The average age of varieties was calculated as about 10 years for all varieties and about nine for semidwarfs only (**Figure 2.5**). The average age of all varieties has not changed even though newer semidwarfs have replaced some of the old tall varieties. Over 95% of the irrigated area is now sown to semidwarfs and the average age of semidwarf varieties has actually tended to *increase* over time (Figure 2.5). This trend is disturbing because disease pressure is greatest in irrigated areas.

These statistics on varietal replacement in the Punjab compare unfavorably with data from similar wheat growing areas. For example, in the Indian Punjab, the percentage of area sown to varieties released in the previous five years averages 30% compared to 11% in the Punjab of Pakistan. Correspondingly the average age of new varieties in the Indian Punjab (6.5 years) is less than three-quarters of the average age of new varieties in the Punjab of Pakistan. In the smaller, more uniform wheat growing environment of northwestern Mexico, the rate of varietal replacement is much faster than in either India or Pakistan (**Table 2.8**).

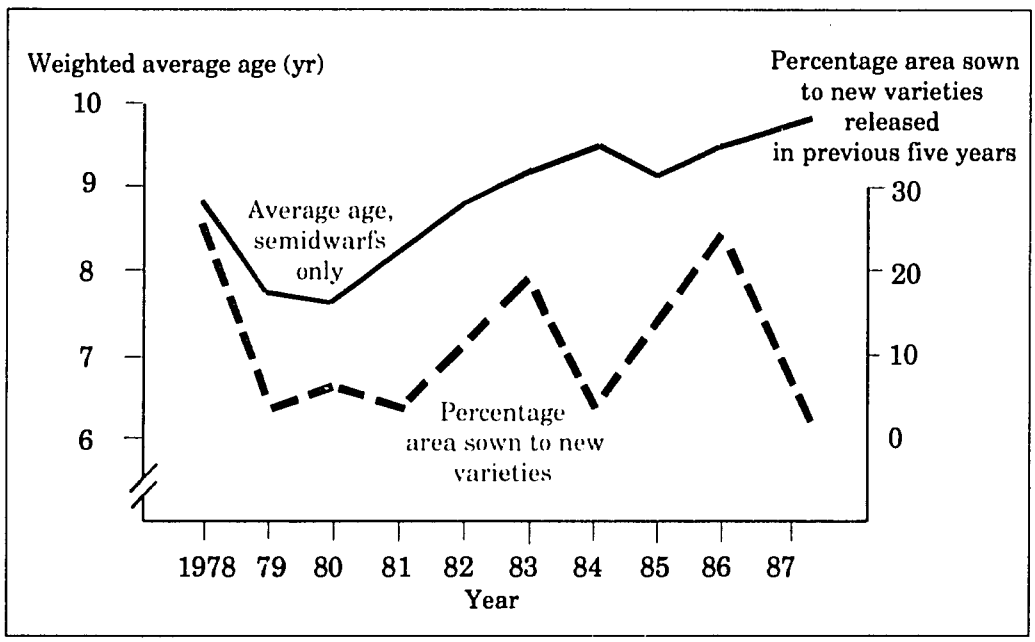

Figure 2.5. Weighted average age of varieties and percentage area sown to new varieties, Punjab, Pakistan, 1978-87.

Exposure to risk of disease—The slow rate of varietal replacement has left much wheat area in the Punjab exposed to severe risk of a rust epidemic for most of the past decade. From 1977 to 1986 the area sown to varieties that are no longer approved because of disease susceptibility averaged 42%. This figure underestimates the risk of a rust epidemic, since several recommended varieties are also susceptible to the disease. It also does not include the related problem of growing approved varieties outside of their recommended zones. The Cereal Disease Research Institute (CDRI) inoculates plots in farmers' fields to measure the susceptibility of commercial varieties to leaf rust (PARC 1987). These data suggest that the percentage area planted to varieties rated at 50S or above (50% severity with a susceptible field response, based on the modified Cobb scale) averaged 59% between 1982 and 1986 (**Table 2.9**). Another measure of exposure to an epidemic is the average coefficient of infection (ACI) for leaf rust over the total provincial wheat area, based on varieties (weighted by area) sown in farmers' fields. In 1984/85, a relatively high value of 36 was registered for this indicator.[4]

Aside from the devastating losses that a rust epidemic could cause, actual losses to leaf rust are already substantial. Scientists estimated a 10% loss (equivalent to 400,000 t of wheat) in 1986/87 in fields planted to such susceptible varieties as WL-711, Blue Silver, and Yecora; this occurred mostly in the Punjab. Losses of such magnitude not only justify increased investment in wheat research but also in seed multiplication, seed promotion, and extension.

Diversification in space—A simple measure of diversification over space is the percentage area sown to one variety at a given time. This measure can be calculated at various levels of aggregation—the farm level, district or divisional level, or

Table 2.8. Indices of wheat varietal replacement in the Punjab of Pakistan, the Punjab of India, and northwestern Mexico, 1977-86

Location	Weighted average age of varieties (years)	Area planted to new varieties[a] (%)
Punjab, Pakistan		
All area	11.0	11
Area under semidwarf varieties	8.8	11
Punjab, India	6.5	30
Yaqui Valley, Mexico	4.1	85

a Varieties released in the past five years.

4 For information on how ACI is calculated, see Stubbs et al. (1986).

provincial level. At the provincial level, one variety usually tends to dominate half or more of the total wheat area. For example, Mexipak is estimated to have covered nearly 60% of the area in 1971 (Nagy 1984).

The dependence on one variety is even more striking at the divisional level. Surveys in the rice-wheat zone showed that Yecora covered 60% of the area in 1984 (Byerlee et al. 1984). The CRS, Punjab, records an even higher percentage planted to Yecora in 1982 and 1983 in that zone. In individual villages there is also evidence that farmers concentrate on one variety (Heisey et al. 1987). At the farm level, where varietal diversification is a function of farm size, even large-scale farmers with more than 10 ha plant an average of 75% of their wheat land to one variety (**Table 2.10**).

Yield Gains in the Punjab, 1965-86

Since varietal replacement appears to be slow in the Punjab, it is important to investigate one of the most critical factors in farmers' uptake of new varieties, gains in yield.

Methods—A number of methods are available for measuring yield gains due to new varieties (for a review see Godden 1987). Ideally, recording yield gains due to breeding will require a varietal trial in which important varieties released over the period of interest are grown under practices of representative farmers (e.g., date of planting, fertilizer rate, etc.). In practice, such data are rarely available, and other less satisfactory approaches must be used.

Two methods of analysis were employed to analyze information from varietal yield testing trials conducted over years, although only the second method, the vintage regression model, is reported here. Varieties included in these trials varied from year to year. In the first method an index is constructed by comparing the yield of each variety relative to the check variety (see Schmidt 1984 and Orazem and

Table 2.9. Measures of exposure of the wheat crop to a rust epidemic in the Punjab in recent years

Average percentage area sown to banned varieties, 1978-87[a]	42
Percentage area sown to varieties with leaf rust rating of 50S or higher in a given year, 1982-87[b]	59
Weighted average coefficient of infection for leaf rust of varieties grown by farmers in 1984/85[c]	36

a Banned varieties are those removed from the recommended list of varieties by the Varietal Evaluation Committee.
b Based on recordings of the Cereal Disease Research Institute and data reported in Pakistan Agricultural Research Council (1987).
c Based on data provided by Cereal Disease Research Institute, Islamabad, and on area sown to each variety.

Table 2.10. Percentage of total wheat area sown to a major variety at the farm level, 1985/86

Farm size	Rice zone	Cotton zone
< 5 ha	89	93
5-10 ha	82	88
≥ 10 ha	76	82

Source: Survey described in Chapter 5.

Jameson 1981). The second method employs multiple regression analysis to estimate a vintage model following Godden and Brennan (1987). They used the following general model:

$$Y_{it} = a + \sum_t b_t D_t + \sum_j c_j D_j + u_t$$

where Y_{it} is yield of variety i in year t (as above), D_t are a set of dummy variables (0,1) for the experimental year t and D_j are a set of (0,1) dummy variables for the "vintage" or period of release of a variety. Godden and Brennan divided D_j into five-year periods. The Godden/Brennan formulation allows for nonlinear yield increases over time in newly released varieties. In our case we were only interested in the long term average rate of increase in yield gains, and the specification of the vintage function was simplified to the following two alternative forms:

$$Y_{it} = a + \sum_t b_t D_t + cV_i + u_t \qquad (1)$$

$$\ln(Y_{it}) = a + \sum_t b_t D_t + cV_i + u_t \qquad (2)$$

where $\ln(Yit)$ is the natural log of Y_{it} and V_i is the year in which variety i was released. The linear specification (equation 1) provides an estimate of the yield increase due to new varieties in absolute terms (i.e., c measures kg/ha/year yield gains) while the logarithmic specification gives the relative yield increase (i.e., c measures %/yr yield gains). Both specifications were tried, but because the logarithmic specification generally gave as good or better fit and since we were more interested in the relative yield gains, we report here only the logarithmic specification.

Data sources—For this analysis, we employed two quite comprehensive data sets. The first is the results of the International Spring Wheat Yield Nursery (ISWYN) sent by CIMMYT to many countries for the past 22 years to measure yield performance and other varietal characteristics such as disease resistance over a wide range of environments. This nursery has been grown at Faisalabad since 1964/65 and data are published in the ISWYN reports for all years except 1976. Methods and practices used in the ISWYN have varied over the years, but the nursery trials have always used relatively high management levels on small plots, although no fungicide is applied. The date of planting varies from 10 to 24 November, generally considered the optimal planting period for this area. The variety Siete Cerros (or its sister lines Mexipak and Kalyonsona) was included as a check in all ISWYN trials. Over the years, all widely grown commercial varieties from Pakistan, both tall and semidwarf, have also been included in the ISWYN, either as advanced lines or as released varieties.

The second data set consists of the results of a variety by date of planting trial conducted annually at the Khanewal Seed Farm since 1979/80. This replicated trial uses relatively large plot sizes and has included all major commercial varieties released since 1970. Sonalika is a common check variety over all years. Furthermore, each variety is grown at four dates of planting, typically ranging from 1 November to 31 December or early January. The performance of varieties over planting dates enables yield gains to be estimated under conditions more representative of farmers' conditions, since late planting has become increasingly more common in the Punjab as cropping intensity has increased. Nonetheless, the trials are planted with higher levels of inputs, especially fertilizer, than farmers use, so yields are considerably above farmers' levels.

Results—Results of some of the vintage regression models are reported in **Tables 2.11** and **2.12.** The F-ratio for the group of dummy variables for year of experiment is generally highly significant and the coefficient for *V*, the year of varietal release, is also significant and positive in most cases.

Estimates of the rate of yield gain due to new varieties are summarized in Tables **2.13** and **2.14** for various subsets of years, varieties, and dates of planting. The ISWYN data allow the estimation of yield gains to include the effect of the release of the first semidwarf varieties in the 1960s. However, it is also interesting to know the yield gains achieved in successive generations of semidwarf varieties. The results of

Table 2.11. Regression results for vintage model for ISWYN data, Faisalabad, 1965-86[a]

	All varieties since 1957,[b] all years 1965-86[b]	Semidwarf varieties released since 1965	
		All years 1965-86	Excluding rust years 1973,76,78
Independent variables[a]			
Year variety released	0.0187 (6.07)***	0.0125 (3.72)***	0.0102 (2.73)***
Dummy variables for year *D66-D86*[c]	F=8.63***	F=8.54***	F=3.06***
Constant	7.068	7.564	7.715
n	78	61	50
R^2	0.81	0.83	0.68

a Dependent variable is the natural log of yield.
b Includes tall variety C273 released in 1957.
c The number given is the F-ratio to enter the set of dummy variables for year.

both the vintage model and the yield relative to the check (Siete Cerros) indicate that yield gains for all varieties, including the change to semidwarf from tall varieties, has been nearly 2% per year, but for the semidwarfs alone, the yield gains have averaged about 1% per year.

The ISWYN data set includes several varieties, especially Siete Cerros, which have become susceptible to rust over time. Hence, the estimated yield increase to new varieties includes both the effect of increasing yield potential of new varieties as well as the decline in yield of some older varieties caused by a breakdown in rust resistance. In fact the yield of Mexipak does show fairly high variability compared to other varieties, probably because of rust attack. An attempt was made to account for this effect by removing the years 1973, 1976, and 1978, when rust was severe and Mexipak (Siete Cerros) was given a leaf rust rating of 60S or higher.[5] The estimated rate of yield increase for "non-rust" years falls from 1.25% to 1.0% using the vintage model, suggesting an average rate of decay of 0.25% per year caused by a deterioration in rust resistance. This estimate is only a rough guide and is probably

Table 2.12. Regression results for vintage model for normal season wheat varieties, Khanewal Seed farm variety x planting date trial, 1980-86

	All dates 20 Nov, 10 Dec, 1 Jan	Optimum date 20 Nov	Late planting 10 Dec, 1 Jan
Independent variables[a]			
Year of release	.0094 (2.52)**	.0083 (1.89)*	.0099 (2.03)***
Days planted after 1 Nov	-.0128 (20.2)***		-.0144 (12.0)***
Dummy variables for year *D*81-*D*86 [b]	F=2.35**	F=4.08***	F=1.86*
Constant	8.03	7.80	8.10
n	123	41	82
R^2	0.79	0.56	0.70

Note: *, **, *** significant at the 10%, 5%, and 1% levels, respectively; t-values in parentheses.
a Dependent variable is the natural log of yield.
b Number given in the F-ratio to enter the set of dummy variables for year.

5 The ISWYN data include rust scores for each variety and often provide an overall disease rating for the nursery of slight, moderate, or severe rust response.

an underestimate since natural rust infestations in small yield plots, surrounded by resistant varieties, might be expected to be lower than in large fields of the same variety.

The Khanewal Seed Farm data include 284 observations of variety by planting date by year. Only popular commercial varieties were included in the experiment but they can be divided into varieties for normal planting, varieties for late planting, and varieties for rainfed areas. Table 2.14 summarizes estimated yield gains for various groups of varieties and dates of planting. In the irrigated Punjab most wheat is planted between 15 November and 15 December, so the best estimate of yield gains under farmers' conditions is the average of *D2* and *D3* or the average of *D2*, *D3*, and *D4* (*D2* = 20 November, *D3* = 10 December, *D4* = end of December or early January). To account for these effects, date of planting was also included as an independent variable in the vintage equation.

Table 2.13. Estimates of annual wheat yield gains (%/yr) due to varietal improvement, ISWYN, Faisalabad, 1965-86

	Vintage model	Relative to check[a]
Varieties released since 1965		
All years	1.25***	0.75
Excluding rust years[b]	1.02***	na
Varieties released since 1957 (all years)	1.87**	1.90**

a Mexipak or Siete Cerros.
b 1973, 1976, 1978.
*** Significant at 1%; ** significant at 5%.

Table 2.14. Estimates of annual wheat yield gains (%/yr) due to varietal improvement, Khanewal Seed Farm, Pakistan, 1980-86

	Normal varieties	Early maturing varieties
Vintage model		
Over three planting dates[a]	.94**	-.57**
Optimum planting[b]	.83**	-.14
Late planting[c]	.99**	-.78**
Relative to check[d]		
Over three planting dates	.88**	na

a 20 Nov., 10 Dec., 3 Jan..
b 20 Nov.
c 10 Dec., 3 Jan.
d Blue Silver.
** Significant at 5%.

The estimates for normal season varieties again suggest yield gains from 0.75-1.25% per year. However, for early maturing varieties for late planting and varieties for rainfed areas, there is no evidence of any yield gains. The evaluation of rainfed varieties should be conducted in rainfed conditions so the latter result is not surprising. For late planting, significant yield gains have been made for "normal" season varieties. These gains largely reflect the relatively good performance of Pak-81 and WL-711 under late planting (Byerlee, Akhter, and Hobbs 1987). The overall yield gains estimated relative to the check, Sonalika, also give a similar estimate of 0.88% per year.

In synthesis, the results of the analysis of two comprehensive data sets by two methods give quite comparable results of yield gains to new varieties of about 1% per year or a little less since semidwarfs were first released, and nearly 2% per year if the introduction of semidwarfs is also included. These figures are quite comparable to estimates for Mexico by Evans (1981) and Waddington et al.(1986) and for the UK and Australia by Godden and Brennan (1987).

There remains the question of whether these results can be applied to yield gains in farmers' fields under farmers' management. For some varieties, especially Pak-81, farmer surveys and on-farm experiments show that yield gains under farmers' conditions are comparable (Byerlee et al. 1986), and we are willing to extrapolate these results to the farm level. However, to allow for the effect of a breakdown in rust resistance, a conservative overall estimate of yield gains of 0.75% per year due to new varieties may be more appropriate.

Implications for Varietal Replacement

This estimate of yield gains can be fed into the model of varietal replacement at the farmer level described above and by Heisey and Brennan (1989). Given the present seed-to-grain price ratio of about 1.5, and assuming yield gains of 0.75% per year and annual deterioration in the performance of varieties of 0.25%, farmers would be willing to change varieties every four years. If annual yield gains from breeding were 1% and annual deterioration were 0.5%, individual varietal replacement time would be three years. These desired replacement times, coupled with an aggregate mean age of varieties of about nine years, imply that seed of new varieties reaches farmers an average of about seven years after release. Even if the price of seed were raised to a 2:1 ratio with grain, under the other assumptions specified above, the desired replacement times would be eight and five years. To maintain an aggregate mean age of nine years would require that seed reach farmers in four-and-a-half to six years. Aggregate mean age of varieties would be reduced if the increase in seed price stimulated seed production and sales.

Conclusions

Several measures of varietal diversity applied to wheat in the Punjab indicate that varietal replacement has been slow and that exposure to disease risk has been high. Because of the large area sown to susceptible varieties, losses to rust have been considerable. However, wheat breeding has continued to provide potential benefits by increasing yield potential and changing the sources of disease resistance in available varieties. Although the rate of varietal release per million hectares of wheat has been somewhat low, the number and quality of the varieties released in the Punjab *have* been great enough to allow acceptable varietal diversification over space and time, had they been more rapidly adopted by farmers. Reasons for the slow rate of adoption will be among the major topics of following chapters.

Chapter 3

Identifying Wheat Varieties Grown in Pakistan

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This chapter discusses the difficulties of monitoring the varieties grown in farmers' fields, focusing on the major problems of identification and sampling. It compares several current estimates of varietal coverage, both to illustrate the problems involved in estimating the proportion of total wheat area planted to different varieties and also to expand the analysis of varietal diffusion.[1]

Current Varietal Monitoring

Wheat varieties planted by farmers in Pakistan are not regularly monitored or reported. Agricultural statistics published by the Ministry of Agriculture differentiate between high yielding and other wheat varieties, but those data do not permit inferences about the rate of varietal replacement or the degree of disease susceptibility.

The most thorough varietal monitoring is presently conducted for the Punjab by the Crop Reporting Service (CRS) in Lahore, who collect information on wheat varieties as part of their annual estimation of area and yield. Their estimates of varietal coverage are not published, however, and wheat scientists are either unaware of their existence or uncertain of the methodology used to produce them. Although the CRS hesitates to claim accuracy for its estimates below the provincial level (reasons for this will become apparent later), their data remain the single most useful source for any analysis of varietal change in Pakistan, especially since equivalent data for other provinces are not available.

Wheat varieties grown by farmers are also monitored occasionally by specialized institutions, such as agricultural extension or the Federal Seed Certification Department (FSCD). In addition to being occasional, these surveys tend to overrepresent large-scale farmers and thus to overestimate the area planted to new varieties.

In 1985/86 social scientists from the Pakistan Agricultural Research Council (PARC) conducted a major study of the constraints to rapid diffusion of new, disease-resistant wheats in three major cropping systems.[2] Ferozewala, Gujranwala, and

1 More detailed information on the research reported in this chapter can be found in Akhter et al. (1986b); Akhter et al. (1987); Sharif et al. (1988); Khushk et al. (1987); Heisey et al. (1986 and 1987); and Ahmad et al. (1988). Heisey et al. (1986 and 1987) also describe the methodology used in estimating the relative areas covered by different wheat varieties.

2 Much of the analysis in Chapters 5 and 6 is based on this study.

Daska *tehsils* (subdistricts) were selected to represent the rice-wheat system of the northeastern Punjab; Lodhran, Mailsi, and Bahawalpur *tehsils* to represent the cotton-wheat system of the southern Punjab; and the irrigated part of Mardan District to represent the irrigated Peshawar plain, North West Frontier Province (NWFP).[3] (Survey areas are shown in Figure 1.1, page 2.) Thirty villages were randomly selected in each of the rice-wheat and cotton-wheat survey areas, and 20 villages were randomly chosen in irrigated Mardan. Over 1,200 farmers in the 80 villages were interviewed about the wheat varieties they were growing. Social scientists returned to the same villages later with wheat breeders from provincial wheat research institutes to identify the varieties grown in over 3,000 village wheat fields. In subsequent years, the social scientists have returned to the same villages to conduct similar surveys of farmers, though there have been no more breeders' surveys. In addition, farmer and breeders' surveys were conducted in two cotton-wheat *talukas* (subdistricts) and two sugarcane-wheat *talukas* in Sind in 1986/87. These surveys provide the basis of some of the estimates reported below.

Problems in Varietal Monitoring

The first problem in monitoring varieties is to identify them correctly. Identification can be done through physical identification or farmer interviews. Large surveys relying on physical identification are too costly for widespread use because only a few individuals have the specialized skills to identify with accuracy all varieties grown by farmers, even when the crop has reached maturity.[4] On the other hand, relying on farmer interviews can also be problematic. Interviews with farmers in the Punjab and Sind revealed that 5-20% of the surveyed area was planted to wheat varieties that farmers could not name. In Mardan, the proportion was much higher: in three years of surveys, one-third to one-half of the wheat area was planted to varieties that farmers either could not name or referred to as "Mexipak," which in addition to being a true varietal name is also the local name for any semidwarf wheat. Another complicating factor is that farmers identify their wheat varieties by the name given by the person who initially supplied the seed or on the basis of their own knowledge of a variety's characteristics. The present system of assigning varieties similar names makes it easy to confuse varieties (Punjab-81 and Punjab-85, for example, or Pak-81 and Punjab-81).

3 The major rotation in Mardan is maize-wheat. However, sugarcane-wheat is also important. The number of crops grown makes it somewhat more difficult to describe the farming systems of Mardan than the systems in the two other survey areas (see Hussain et al. 1985).

4 Nonspecialists are likely to rely on gross attributes of plant character such as height, which results in problems like the overidentification of the particularly short variety Yecora in relation to its sister lines Pari-73 and Sandal (Chapter 2). Specialists working in seed certification might be best suited for physical identification of varieties (N.I. Hashmi, personal communication).

Despite some drawbacks, farmer interviews are likely to remain the major instrument in varietal monitoring. Even at present, interviews produce useful information; judicious questioning about the length of time a variety has been planted can lead to a decision about whether or not it is a recent release, even though the specific name of the variety is not obtained.

In the surveys reported here, "don't know" responses were divided into "new, don't know" and "old, don't know" categories. Varieties were labeled "new, don't know" if the farmer did not know the variety's name but said it was new. Supplementary questioning about the length of time the farmer had been growing the variety and the length of time other farmers in the same village had been growing it were used to confirm the farmer's opinion. This process required a certain amount of subjective judgment on the part of the enumerator and probably resulted in slight overestimation of the "new, don't know" category at the expense of the "old, don't know" category.

The other major constraint to estimating varietal coverage accurately is sampling. Most large-scale varietal surveys, such as that of the CRS in the Punjab, are byproducts of other research efforts and not designed primarily to record varietal information. Thus, sampling design is unlikely to maximize the efficiency of estimates of area planted to given varieties. This problem is complicated by the fact that, to the authors' knowledge, all the surveys described earlier used a cluster sampling design. Cluster sampling reduces survey costs through the selection of first-stage sampling units defined by location ("clusters"); second-stage sampling units are chosen from within the cluster. In the special studies in the rice-wheat, cotton-wheat, and Mardan areas, the first-stage unit was the village.

Cluster sampling can produce efficient estimators if individual clusters are relatively heterogeneous with respect to the parameters in question and if there is relatively high homogeneity between clusters. Unfortunately this is not likely to be the case with respect to wheat variety. Researchers' experience in conducting specialized varietal identification studies has shown that varieties tend to be concentrated in particular villages. A farmer is more likely to grow the same variety grown by another randomly selected farmer in the same village than a variety grown by a randomly selected farmer in a different village. Similarly, two wheat fields inspected by a breeder in the same village are more likely to be planted to the same variety than a random pair of wheat fields from two different villages. Estimates of varietal coverage from cluster sampling designs are therefore likely to have relatively high sampling error. In the short run, this method can be improved by choosing a relatively high number of clusters (villages) and a relatively low number of farmers (or fields) within each village.[5]

5 In the long run, as the CRS moves towards area frame sampling designs, better estimates of varietal coverage are likely to result as a by-product.

Finally, if a survey is to provide estimates of varieties that cover relatively little area, it is in effect sampling from a rare population. Unless a relatively expensive survey is designed, it is unlikely that the estimates will be very accurate.

Survey of Farmers and Breeders' Survey, 1985/86

The special surveys conducted in 1985/86 exemplify some of the difficulties in accurately estimating varietal coverage. Varieties were identified by farmers and by wheat breeders in the same villages. Because of the sampling problem and the identification problem discussed earlier, there were large discrepancies in some of the estimates (**Table 3.1**).

Table 3.1. Estimates of percentage area planted to major wheat varieties in three zones of Pakistan, survey of farmers and breeders' survey, 1985/86

Zone and variety	Farmer survey	Breeders' survey
Rice zone		
Pak-81	26	16
Punjab-81	17	13
Yecora	10	4[a]
Blue Silver	10	5
Sandal	6	16[a]
WL-711	2	13[a]
Cotton zone		
WL-711	37	46
Blue Silver	21	8[a]
Bahawalpur-79	12	10
Mardan		
"Mexipak"	26	<1[a]
Pak-81	20	24
SA-42	14	22
WL-711	10	34[a]

a Estimate from breeders' survey lies outside the 95% confidence interval of estimate from farmer survey.

These discrepancies can be evaluated by survey area as well as by variety. It is clear that a major reason for the differences in estimates in Mardan is farmers' more limited knowledge of varietal names. Although very little Mexipak is grown now in any area of Pakistan, farmers in Mardan said they were growing "Mexipak" on one-quarter of the surveyed area. Breeders also identified a good deal more WL-711 than farmers did; on the other hand, estimates for the new variety Pak-81, which is spreading rapidly in Mardan, and the old variety SA-42, which has a distinctive appearance at maturity and a distinctive local name, were relatively close in the two surveys. Nonetheless, it is likely that percentages from farmer surveys in areas like Mardan underestimate the coverage of major varieties.[6]

The discrepancies for Yecora and Sandal in the rice-wheat zone might be related to the fact that they are sister lines. Yecora was introduced in 1974 and large amounts of seed were imported; in 1981 it was banned. Yecora's sister lines Pari-73 and Sandal were released in Pakistan in 1973 and are still approved but recommended for replacement. Although it is clear that Yecora was the dominant variety in the

6 For example, in the next two years (1986/87 and 1987/88), area under "new, don't know" varieties, as well as Pak-81, increased substantially in Mardan. Most of this "new, don't know" area can be presumed to be under Pak-81.

Punjab in the late 1970s and early 1980s, there has probably been some tendency for farmers and the CRS to overestimate Yecora and underestimate Pari-73 and Sandal.

In all three areas, estimates for WL-711 were higher in the breeders' survey and lower in the survey of farmers. For Blue Silver the situation was exactly the reverse. In the 1985/86 surveys, the discrepancy for Blue Silver was particularly apparent in the cotton-wheat zone. WL-711 is a variety of intermediate maturity and Blue Silver is early maturing. Though their physical characteristics are somewhat similar, they can be distinguished near maturity with only moderate difficulty.

The discrepancy between farmers' and breeders' identification of WL-711 in Mardan is partially accounted for by farmers' tendency to be unaware of varietal names.[7] The discrepancy for the cotton zone is more problematic. Subsequent surveys of farmers in the same area of the cotton zone, confirmed by unpublished CRS estimates, show a large, even increasing, proportion of wheat area under Blue Silver. Perhaps the cluster sampling problem is even more severe for the breeders' survey than the survey of farmers; and, as in Mardan, both WL-711 and Blue Silver may be referred to as "India" by farmers, although the name more commonly applies to WL-711.

Current Estimates of Varietal Coverage

Estimates from the Crop Reporting Services and special studies—Though some wheat varieties are more widely adapted than others, different varieties are often more popular within different cropping systems. An obvious example is the use of certain varieties in irrigated agriculture and others in rainfed agriculture. Different requirements for maturity and disease resistance also account for varietal diversity over widely dispersed areas. For those reasons, and also because of differences in recording methodology, the Punjab-wide varietal estimates from the CRS cannot be compared directly with those from the special studies, which covered a much smaller area. Nonetheless, examining the different estimates for some of the major varieties together helps identify regional differences in varietal use (**Tables 3.2** to **3.4**).

The estimates from the special studies for 1985/86 and 1986/87 are broadly consistent with the CRS estimates for the same years. In particular, both indicate that Pak-81 is undergoing rapid adoption and Yecora is nearly phased out. Two other results from the special studies might be predictors of province-wide trends: namely, that WL-711 and Punjab-81 probably reached their peak coverage in the years of the studies and are likely to have entered the disadoption phase.

7 In fact, in Mardan "India" might refer to either WL-711 or Blue Silver, as both WL-711 and Blue Silver's sister line, Sonalika, were imported from India. Here, "India" has been recorded under WL-711; otherwise the discrepancy for WL-711 in Mardan would be even greater.

Besides indicating general trends in varietal use and disuse, the special studies provide specific evidence of preference for particular varieties in the three crop production zones. Pak-81, Punjab-81, and Yecora are clearly important in the rice-wheat area, whereas WL-711 and Bahawalpur-79 are much more significant in the cotton-wheat area. Blue Silver is important in both zones, but particularly in the cotton-wheat area. WL-711 performs well when planted late, and Blue Silver has traditionally been recommended for late planting. Although WL-711 has been

Table 3.2. Percentage area planted to major wheat varieties in the Punjab, 1985/86 and 1986/87

Variety	1985/86	1986/87
Pak-81	9	17
Punjab-81	14	15
Blue Silver	14	12
Bahawalpur-79	2	2
WL-711	18	20
Yecora	12	8

Source: Crop Reporting Service, Lahore

Table 3.3. Percentage area planted to major wheat varieties in the rice-wheat survey area, 1985-89

Variety	1985/86	1986/87	1987/88	1988/89
Punjab-85	--	--	--	5
Pak-81	26	38	50	55
Punjab-81	17	7	7	6
Blue Silver	10	11	5	6
Bahawalpur-79	--	--	--	--
WL-711	2	--	1	--
Yecora	10	8	2	3

Source: Agricultural Economics Research Unit, Faisalabad

Table 3.4. Percentage area planted to major wheat varieties in the cotton-wheat survey area, 1985-89

Variety	1985/86	1986/87	1987/88	1988/89
Pak-81	6	11	11	17
Punjab-81	9	5	14	7
Blue Silver	21	22	27	35
Bahawalpur-79	12	9	12	9
WL-711	37	29	24	14
Yecora	1	1	--	2

Source: Agricultural Economics Research Unit, Faisalabad

banned since 1982, and although the Varietal Evaluation Committee has recommended that Blue Silver be phased out, the actual choice of varieties in the cotton zone has been determined by the constraints of the cropping system rather than by recommendations based largely on disease resistance.

Recent trends in varietal use in the special study areas—Data from three years of farmer surveys in the rice-wheat zone, cotton-wheat zone, and Mardan illustrate patterns in varietal use and identify trends among varieties in each zone. Some distinctions will be made in those data. First, "new varieties" in any year are defined as *those released no more than five years ago*. Second, in any year, varieties are classified as "recommended" or "banned" according to the list issued after the annual meeting of the wheat Varietal Evaluation Committee.[8] On the basis of those two definitions, varieties are classified as "new recommended," "old recommended," or "banned." A third category, "all varieties released in 1979 or more recently," is the basis of the study of the diffusion of new wheat seed and new wheat varieties, presented in Chapters 5 and 6.

In the rice zone the wide diffusion of post-1978 releases (**Table 3.5**) is the result of farmers' adoption of Pak-81. The "new, don't know" category has also increased in area, implying that one or more recent releases are being adopted fairly rapidly. The area under Punjab-81 appears to be declining and Yecora can be considered nearly phased out. Although the large variability in the estimates makes it difficult to speculate about varieties that cover smaller proportions of the area, figures for 1987/88 suggest that the area planted to Blue Silver may also be declining.

Table 3.5. Changes in the percentage area of recommended and other wheat varieties, rice zone, Pakistan, 1985-89

Varietal group	1985/86	1986/87	1987/88	1988/89
New recommended[a]	31	48	3	8
Old recommended[a]	26	23	79	78
Banned/mixed	43	29	18	14
Post-1978 releases	49	55	76	80

a New varieties are those released no more than five years before the survey. Recommended varieties are those recommended by the Varietal Evaluation Committee. "Don't know" responses divided into "new, don't know" and "old, don't know" on the basis of subsidiary questioning.

8 The Varietal Evaluation Committee is made up of wheat scientists from PARC as well as from provincial wheat research networks.

In the cotton zone, the adoption of post-1978 releases has been much slower. Pak-81, Punjab-81, and Bahawalpur-79 appear to make up nearly equal proportions of that category. On the other hand, there has been a significant shift out of banned varieties into recommended varieties in the most recent year (**Table 3.6**).

In Mardan, the relative area planted to old varieties is particularly high compared to the other two study areas. Mardan has relatively little area planted to varieties released in the 1970s and still recommended (**Table 3.7**). The increase of recommended varieties in Mardan has been overwhelmingly the result of the diffusion of Pak-81. The area under "new, don't know" varieties has been particularly high in the last two years, implying that, although the estimated area under Pak-81

Table 3.6. Changes in the percentage area of recommended and other wheat varieties, cotton zone, Pakistan, 1985-89

Varietal group	1985/86	1986/87	1987/88	1988/89
New recommended[a]	19	27	3	1
Old recommended[a]	35	32	71	81
Banned/mixed	46	41	26	18
Post-1978 releases	31	36	43	44

a New varieties are those released no more than five years before the survey. Recommended varieties are those recommended by the Varietal Evaluation Committee. "Don't know" responses divided into "new, don't know" and "old, don't know" on the basis of subsidiary questioning.

Table 3.7. Changes in the percentage area of recommended and other wheat varieties, Mardan, Pakistan, 1985-88

Varietal group	1985-86	1986-87	1987-88
New recommended[a]	24	40	3
Old recommended[a]	17	5	51
Banned/mixed	59	55	46
Post-1978 releases	24	40	47

a New varieties are those released no more than five years before the survey. Recommended varieties are those recommended by the Varietal Evaluation Committee. "Don't know" responses divided into "new, don't know" and "old, don't know" on the basis of subsidiary questioning.

in Mardan is about 30%, the true proportion may be closer to 45%. The latter percentage would make the diffusion of Pak-81 in Mardan comparable to its spread in the rice-wheat area.

Recommendations for Monitoring

Several measures could improve identification of varieties in farmer surveys in Pakistan and elsewhere. First, more distinctive varietal names could be chosen. Second, enumerators should be trained to record "don't know" responses and local names; farmers should not be prompted with the name of a variety that the enumerator knows. Sampling designs could also improve. If cluster sampling is used, more clusters with fewer farmers per cluster would improve sampling efficiency, as varietal use tends to be correlated over short distances.[9] However, large-scale varietal monitoring is likely to remain a byproduct of other surveys, notably those intended to estimate wheat production and yield. Agencies that monitor varieties, such as Pakistan's Crop Reporting Services, should be consulted to determine if their current sampling designs could, with minimal modifications, produce useful estimates for major cropping systems within large areas.

Estimates of wheat varietal coverage should be circulated rapidly and widely to policy makers, wheat breeders, and pathologists. In Pakistan, disseminating these data in February or March would allow more in-depth assessment of the current crop and assist the Varietal Evaluation Committee and the Federal Committee on Agriculture to recommend varieties and set seed production targets. Furthermore, CRSs in provinces other than the Punjab should be encouraged to collect and report varietal data; varieties should be identified following guidelines suggested above.

Finally, special studies may occasionally need to be done in areas of interest to pathologists or epidemiologists. The special studies reported here, if they are continued, will allow longitudinal analysis of varietal change within particular cropping systems. They will prove particularly useful if they are integrated with analyses of other changes, both in wheat technology and within the cropping system.[10]

9 For example, data from the studies reported in this chapter show that planting of new varieties tended to be concentrated in some villages rather than to be spread evenly over most of the villages.

10 For example, studies conducted by the Agricultural Economics Research Unit, Faisalabad, and the PARC/CIMMYT collaborative program, have looked at the rapid spread of an earlier maturing basmati rice variety, and the use of combine harvesters by larger farmers, in the rice-wheat zone (Sharif et al. 1989; and Smale 1987, respectively). These changes may affect the choice of wheat varieties as they imply somewhat earlier planting dates for wheat.

Chapter 4

Wheat Seed Production and Marketing in the Punjab and NWFP

M. Aslam Chaudhry, Paul W. Heisey, and Munir Ahmad

Recommendations on priorities for varietal development are not likely to succeed unless the goals of the research program are integrated with those of the seed production and marketing system. Without sufficient seed of recommended resistant varieties, farmers simply cannot reduce their losses from rust diseases. This chapter describes seed production in Pakistan, focusing again on the Punjab and also briefly on NWFP, to see how the system has improved in the past and determine how it can be made more effective in the future.[1]

The Wheat Seed Industry in Historical Context

Increased government involvement in procuring and distributing seed in Pakistan began with the establishment in 1961 of the Agricultural Development Corporation (ADC). The quantities of wheat seed sold during the ADC period are shown in **Table 4.1.** On average, that seed was enough to cover 2-4% of the total wheat area in Punjab Province, although substantial amounts of seed were sold in the late 1960s when seed of high-yielding varieties was first imported from Mexico.

Under the ADC, pre-basic seed produced at government research institutes was multiplied into basic seed at ADC farms. Basic seed was multiplied into certified seed at registered growers' farms and then offered for sale to farmers. However, coordination between the research institutes and the ADC was limited. The pre-basic seed provided to ADC was often insufficient and substandard; the contract multiplication system existed in name only.

Table 4.1. Wheat seed sold in the Punjab Province during the Agricultural Development Corporation period, 1965-73

Year	Wheat seed sold (000 t)	Certified seed as percent of total seed requirements
1965/66	12.2	3.3
1966/67	15.5	4.0
1967/68	38.9	9.1
1968/69	24.2	5.3
1969/70	8.8	2.0
1970/71	6.7	1.5
1971/72	9.7	2.3
1972/73	17.0	3.9

Because of alleged malpractices and seed mixing during its first few years, the ADC was not permitted to commission agents for marketing seed and had to set up its own network of 47 bulk centers and 212 retail points throughout

1 A fuller treatment of this subject can be found in Chaudhry and Heisey (1987). The cooperation of Chemonics International Consulting Division in supporting this research is gratefully acknowledged.

the country. Staffing problems led the ADC to recruit employees from the military, but they lacked agricultural experience. Seed targets were established arbitrarily with little reference to market demand.

These inadequacies combined to make the quantity and quality of seed offered for sale to farmers unacceptable. The ADC was dissolved in 1972 and its functions relating to seed production and marketing were assumed by the provincial governments. In Punjab Province, Punjab Agricultural Development and Supplies Corporation (PAD&SC) took over most of ADC's assets and staff and continued operations.

Unfortunately the new organizational structure did not rectify the problems that brought about ADC's failure. To replace the seed production system with a modern seed industry that would release new varieties and multiply, process, certify, store, and market seed, the government initiated a Seed Industry Project in 1976 with the financial and technical assistance of the World Bank. The main benefit anticipated from the project was the higher crop yields to be obtained by users of improved quality seed. To implement the project, provincial seed corporations were established in the Punjab and Sind. One of them, the Punjab Seed Corporation (PSC), now markets seed for 12 crops, although cotton and wheat seed are by far its dominant products.

The Present Seed Production System in the Punjab

The PSC produces pre-basic wheat seed at the research institutes or at the Foundation Seed Cell, Khanewal. Pre-basic seed is multiplied into basic seed at the PSC farms and supplied to registered growers contracted by the PSC to produce certified seed. At all stages of seed multiplication, standing crops are inspected by an independent agency, the Federal Seed Certification Department (FSCD). Seed is procured only from fields approved by the FSCD. That agency also tests the purity and quality of seed during processing and distribution. In addition to the routine seed certification tests of the FSCD, the PSC has established its own Internal Quality Control Cell at each plant site. This system also tests seed at the fields of registered growers, in their stores, and at PSC plant sites or stores.

Pre-basic seed production—Pre-basic seed of impeccable quality is essential to a successful seed program. In Pakistan, pre-basic seed is produced at the research institutes two years ahead of the certified seed crop, under the direct supervision of plant breeders. To handle pre-basic seed production adequately, the research institutes have been provided with sophisticated laboratory equipment under the Seed Industry Project.

Because pre-basic seed is produced two years before the certified seed crop, production in year *t* depends upon certified seed requirements in year *t+3*. Certified seed requirements depend upon anticipated seed demand and rate of seed

replacement.[2] In the early years of the Seed Industry Project, breeders lacked resources to produce the quantities of pre-basic seed that were required. To meet the anticipated demand for certified seed, it was decided to produce two generations of basic seed at the PSC farms (2,370 ha in three farms at Khanewal and 70 ha at Sahiwal). This increased the certified seed production cycle from three years to four. To shorten the cycle, a "Foundation Seed Cell" was established in 1980/81 at the PSC seed farm in Khanewal to produce pre-basic seed under breeders' supervision. In the first three years of the Foundation Seed Cell program, the PSC share in pre-basic seed production increased from 20-40% to over 90% from 1983/84 onward.

Basic seed production Basic seed is the progeny of pre-basic seed. To ensure the closest possible control over production and handling, basic seed is produced on PSC farms. The PSC, after taking over the farms, levelled the fields and provided such resources as tubewell irrigation, tractors, agricultural machinery, and management and technical guidance for the tenants.

Area sown to pre-basic seed and total basic seed production are shown in **Table 4.2**. Each variety's share in the total basic seed production plan has changed over the years as new varieties have been introduced.[3] Sandal, Lyallpur-73, LU-26, and Pari-

Table 4.2. Production of basic wheat seed at Punjab Seed Corporation farms

Year	Pre-basic seed (t)	Area sown for basic seed (ha)	Basic seed production (t)	Yield (t/ha)
1976/77	2.8	52	183	3.51
1977/78	5.9	79	291	3.68
1978/79	19.6	273	991	3.63
1979/80	6.8	128	456	3.58
1980/81	8.3	86	313	3.63
1981/82	15.2	155	610	3.93
1982/83	7.2	46	202	4.42
1983/84	31.5	132	436	3.31
1984/85	114.2	685	2,569	3.75
1985/86	153.6	617	1,834	2.96

2 See Chaudhry and Heisey (1987) or the project documents (World Bank 1976; PSC 1977) for assumptions used in planning the Seed Industry Project. They imply, very roughly, a certified seed requirement of 70,000 t/yr for the Punjab. Using fairly conservative assumptions about seed multiplication ratios, this implies production of 25-40 t of pre-basic seed each year.

3 Details of pre-basic and basic seed production for each year by variety can be found in Chaudhry and Heisey (1987).

73 dominated the PSC seed multiplication program during its early years when total output was lower than at present. More recently, Pak-81, Punjab-81, and Blue Silver have been the leading varieties featured in the seed production plan.

Certified seed production—To improve reliability of seed supplies and minimize managerial problems, farmers selected by the PSC to produce certified seed must meet certain standards. The criteria for selection are:

- The grower should be cooperative, reliable, financially sound, and prepared to adopt recommended farm development and crop production practices;
- The farm unit of the grower/family should be at least 40 ha and preferably directly cultivated; and
- Farms should be near the seed processing plants. (Progressive growers with large mechanized farms located farther from processing plants are chosen occasionally.)

There are currently 572 PSC-registered growers, 310 in category "A" and 262 in category "B." The PSC enters into contracts with category "B" growers only if the total production target is beyond the capacity of its category "A" growers. During recent years, certified wheat seed was produced on an average of 19,000 ha of category "A" farmers' land and 13,000 ha belonging to category "B" farmers.

The quantities of wheat seed procured from registered growers are shown in **Table 4.3**, along with annual targets fixed by the government and targets planned in the original PC-I (Seed Industry Project) scheme. Production of certified seed for four individual varieties widely grown by farmers is also shown.[4] The total amount of wheat seed procured by the PSC rose from 4,000 t in 1979/80 to 43,000 t in 1986/87. Most of this increase in certified seed procurement occurred in the PSC's first five years; it has levelled off since 1983/84. The total amount of "improved wheat seed" reported as distributed in the Punjab doubled from 1979/80 to 1986/97, from 22,000 t to the current figure (Government of Pakistan 1983). It appears that in the early years of PSC operation PAD&SC was distributing seed that was not produced by the PSC.[5]

The PSC fell short of procurement targets every year except for 1979/80 and 1982/83, when it sold all the seed it procured. In 1979/80 the procurement target was very low compared to following years. It was PSC's first year in the market and marketing

4 Further details of certified seed production by variety can be found in Chaudhry and Heisey (1987).

5 It is unlikely that much of the non-PSC seed distributed was certified by the FSCD, as this agency was established by the Seed Act of 1976 and was probably not fully operational until the 1980s.

efforts were substantial in relation to the amount of seed procured. The year 1982/83 was good because seed of WL-711 and Punjab-81 was in great demand, and PSC stocks consisted mainly of those varieties.

The procurement targets from 1979/80 to 1981/82 were very much in line with those planned in the Seed Industry Project appraisal report (PC-I). But in 1983/84 and thereafter, targets fixed by the government and quantities actually procured were significantly below the targets planned in the PC-I scheme.

The relationship between amounts of certified seed procured for the four varieties listed in Table 4.3 and the area covered by those varieties is shown in **Figure 4.1.** The same scales are used in each part of the figure. The figure indicates that seed of those four varieties continues to spread although certified seed production has diminished or stopped. For the older varieties Blue Silver and WL-711, it is difficult to establish the amount of time between seed production and significant area coverage, especially since some seed of those varieties was probably first distributed outside of the PSC network. For the more recent releases Pak-81 and Punjab-81, area seems to have increased rapidly about two years after the first large increases in seed production.

Multiplication Capacity and Initial Multiplication Decisions

In many seed multiplication schemes, particularly in the earlier stages of production of basic and pre-basic seed, seed rates are lower than those usually chosen by farmers (Hanson et al. 1982). The aim is not to maximize biological yield (or economic profit) but rather the ratio of seed output to seed input. Though greater-than-normal quantities of other inputs may maintain yields (Brennan and Appleyard 1982), some yield reduction is also a possibility.

Table 4.3. Certified wheat seed production (tons), Punjab, Pakistan

	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87
Total	4,100	11,500	19,800	33,300	44,200	48,500	44,500	43,300
Annual target	4,100	14,900	22,400	29,900	44,800	52,300	52,300	48,500
Planned target	4,100	14,900	22,400	26,100	62,200	62,200	62,200	62,200
Major varieties								
Pak-81	--	--	--	356	8,790	25,200	24,100	20,100
Punjab-81	80	562	964	8,530	18,700	10,600	8,290	8,940
Blue Silver	87	1,520	3,910	7,440	10,400	8,920	8,940	11,900
WL-711	394	1,750	7,070	8,200	--	--	--	--

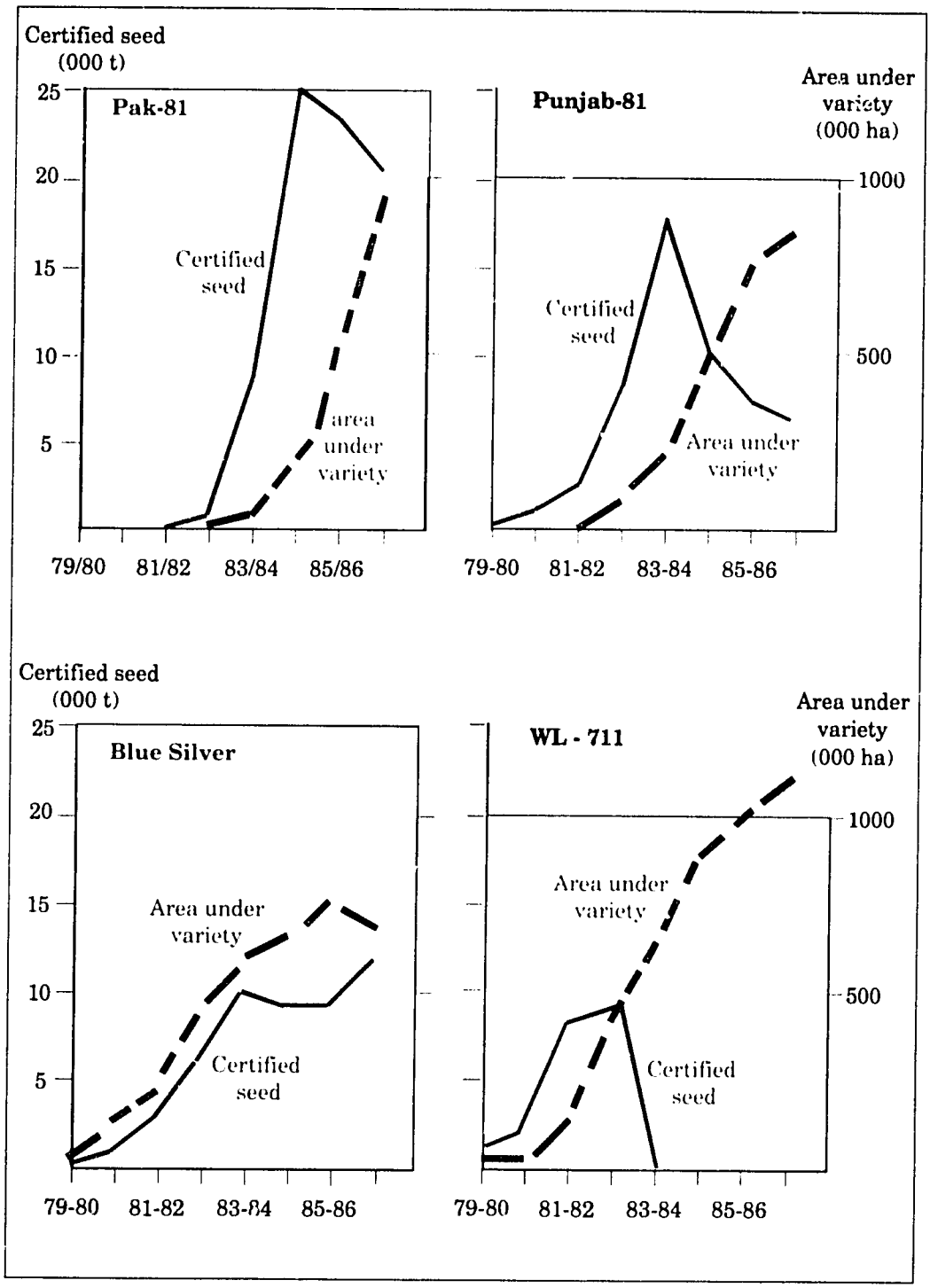

Figure 4.1. Certified seed production and varietal diffusion for four varieties, 1979-87.

The data in Tables 4.2 and 4.3, as well as data for individual varieties, indicate that implied multiplication ratios from pre-basic to basic seed and from basic to certified seed vary greatly from year to year. Furthermore, multiplication ratios from pre-basic to basic seed are often rather low. The fairly good yields in Table 4.2 indicate that some aspects of production were carefully managed on the PSC seed farms. On the other hand, seed rates implied by the second and third columns of the table are often high, even higher than "normal" seed rates for irrigated wheat in Pakistan. One explanation is that some of the pre-basic seed does not meet standards for basic seed production. Another possibility is that some pre-basic seed is diverted from basic seed production, either because production plans for varietal mix change or for other reasons. Data for some popular varieties, notably Pak-81 and Punjab-81, also show rather low multiplication ratios, implying that diversions are not the result of changes in production plans.

It seems that the main cause of fluctuating multiplication ratios from basic to certified seed is that the amount of certified seed procured is mainly determined by the government's procurement target and PSC's perception of how much seed it can sell, rather than by the amount of basic seed available from the previous production cycle. In years when the ratio of certified to basic seed is low, either some basic seed does not go into certified seed production, some seed produced by registered growers does not meet certification standards, or seed produced by registered growers is simply not procured by the PSC. On the other hand, in years when the apparent ratio of certified to basic seed is high, the PSC may have procured certified seed indirectly from farmers who were not issued basic seed for multiplication under contract, if the seed they produced met certification standards.

Given the area PSC now has available for basic seed production and the number of its contract growers, the corporation clearly has the capacity to meet total wheat seed production targets. But the PSC generally follows a conservative approach and procures only as much seed as its managers feel can be sold, with some reference to the annual seed production targets fixed by the Federal Committee on Agriculture. The targets are generally based on the amount of seed sold and on targets assigned in the previous year. The PSC is not a member of the Federal Committee on Agriculture, and constraints faced by the PSC in procuring and selling seed are not taken into account when targets are set. Too high a procurement target can lead to procurement of seed that does not meet seed certification standards or is of unapproved varieties.

The PSC can now make 8,000-9,000 t of seed of individual varieties available to farmers three years after release (as it did with Pak-81) or even two years after release when release seems to have been anticipated (Punjab-81). There may be several ways to increase seed production capacity, but doing so requires early decisions about *which* varieties to multiply. Past coordination of varietal choice between the government and the PSC has not been encouraging; procedures for

selecting, retaining, and withdrawing varieties for seed multiplication and distribution have not been understood clearly by all parties. Although the seed production cycle takes three to four years, decisions to retain or reject a variety are made yearly.

For example, in 1981/82 the Ministry of Food and Agriculture (MINFA) and PARC recommended that Blue Silver, Bahawalpur-79, Sandal, Pari-73, and Indus-79 be grown for only one year, and only in specified limited zones.[6] But the next year PSC was asked to multiply those varieties again, because replacements for them were not forthcoming. In another instance, during 1981/82 the variety WL-711 was not allowed to be distributed because it had been banned, but PSC had to procure it because it was already planted with contract growers.

One reason for the PSC's conservatism in multiplying recently released varieties is that breeders and the seed corporation have limited knowledge of a variety's acceptability to farmers. Breeders attempt to evaluate promising materials by planting them in microplots in farmers' fields. After that, lines proposed for release are tested for two years in the National Uniform Wheat Yield Trials (NUWYTs). Plot sizes in the microplot trials and the NUWYTs are too small for farmer evaluation. Also, for breeders to evaluate the materials properly, the level of management must be somewhat more intensive than the management farmers usually provide. Since farmers' reactions are not recorded, breeders and the PSC have little information about a variety's commercial possibilities over a wide area.

Seed Processing and Quality Control

Seed processing includes drying, cleaning, grading, and packing. Under the Seed Industry Project, three seed processing plants are to be installed, one each at Khanewal, Sahiwal, and R.Y. Khan. Each plant will have the capacity to process about 27,600 t of wheat seed. The plant at Khanewal has been in operation since 1985, but the other two are not yet functional. In the meantime, the PSC uses other processing methods, such as cleaning wheat seed with locally made sieves.

Total planned storage capacity in open storage and silos will be about 43,000 t. Currently the PSC stores about 22,000 t of wheat seed annually in its own facilities and hires warehouses, some of which cannot be fumigated properly, for storing the remaining seed.

The Industry Council for Development (ICD) report on Pakistan's seed industry (1987) notes that the assumption that a seed certification law addresses all consumer protection issues is not justified. The apparent lack of consumer protection laws at the retail level provides merchants with the opportunity to mix noncertified seed with high-quality certified seed. However, despite current problems with seed

6 Indus-79 never achieved commercial success.

processing and quality control, two recent studies conducted by the Punjab Economic Research Institute (PERI) and the PSC (Sharif et al. 1986; PSC 1986) indicate that 80% or more of farmers sampled throughout the Punjab were satisfied with the quality of seed supplied by the PSC. The PERI study referred specifically to wheat seed. The PSC results might be biased positively both because the quality of cotton seed produced by the PSC is exceptionally good and because the survey was done by PSC field staff, who were also responsible for procuring and distributing seed. Even though few consumers appear to complain about the quality of PSC wheat seed, consumer protection measures should be strengthened.

Seed Marketing

The distribution network—The PSC sells its seed through public and private organizations. At first the PSC used the retail outlets of PAD&SC, but as it expanded it began selling seed through private dealers, its own outlets, and branches of the Provincial Cooperative Bank. The PAD&SC also markets seed through private dealers who are primarily agents for PAD&SC fertilizers.

Between 1981 and 1986 the number of PSC outlets increased from under 400 to over 900. These may be viewed as potential outlets, as the amount of seed handled per outlet varies widely. The largest market share in 1985/86 was held by PAD&SC, which handled 59% of PSC wheat seed sold in the Punjab. These sales were made through 186 PAD&SC sale depots as well as some of the 581 private dealers carrying PSC seed. The rest of the private dealers, who receive seed directly from the PSC, accounted for 27% of the Punjab market. Most of the remaining seed, approximately 14%, was sold by 11 PSC sale depots located either at seed processing plant sites or divisional headquarters. Although 140 Cooperative Bank branches supposedly handle PSC seed, less than 1% of the seed sold was marketed through the bank.

A geographic breakdown of sale points shows that private dealers and PSC depots are concentrated in the cotton zone, suggesting that PSC depots are more likely to be located in areas where a more profitable product, cotton seed, can be marketed. The concentration of PSC depots (8 out of 11) in the cotton zone is also influenced by the fact that PSC farms and seed processing plants are located there.

The PAD&SC has had difficulty establishing itself as an effective institution for marketing agricultural inputs. Its market shares for its two major products, fertilizer and seed, have declined with time because of the private sector's increased involvement in marketing inputs. That trend has led the PAD&SC to reduce its sale points by about half in recent years and has diminished the PSC's enthusiasm for selling its seed through the PAD&SC network. But it is awkward for PSC to decline to use PAD&SC as its distributing agent: the two organizations share the same Chairman and Board of Directors and the PSC has not developed an alternative marketing arrangement although it has been in business for almost eight years.

Some of these problems are reflected in the dealings of the two public sector organizations with the network of private dealers. A majority of the private dealers selling seed are PAD&SC agents. When they come to PAD&SC stores to get fertilizer, they are sometimes required to take seed as well. Private dealers who deal directly with the PSC received a commission of Rs 12 per 90-kg bag in 1985/86, but those selling seed for the PAD&SC received Rs 8 per 90-kg bag. The PAD&SC retains the balance of the PSC commission to support its own operations. Furthermore, these commissions, even after a 100% increase between 1985/86 and 1986/87, are still less than 5% of final product price. Commissions on fertilizer are nearly 20%. The PAD&SC dealers are particularly unhappy with the situation.

Management of seed distribution--Before the selling season begins, the PSC asks its dealers, private and public, about their anticipated demand and later transports the seed to dealers' stores at its own expense in accordance with a mutually agreed upon supply schedule. As the season proceeds, supplies are adjusted depending on the market.

Seed is supplied to public sector agencies and private dealers on a "cash and carry" basis as a matter of policy, but in practice the requirement is usually relaxed for public sector agencies. Some private dealers who have established their creditworthiness with the PSC also receive seed on credit against guarantees.

The PSC pays the same rate of commission to all distributing agents with whom it deals directly. If some of the stocks supplied to distributors are not sold, PSC takes them back at its own expense and refunds the dealers. The PSC is considering ending this policy to avoid transportation costs, but such a change would discourage PSC agents from requesting more seed. Already some dealers state that the PSC is reluctant to take back unsold stocks.

Most dealers handling PSC seed are dissatisfied with the corporation's seed distribution. Poor planning and coordination between the marketing staff and stores staff mean that seed supplies are often delayed, quantities dispatched sometimes exceed quantities requested, or seed is sent to a geographic zone for which it is inappropriate. The quality of packing material is reportedly very poor. All of these factors negatively affect the total sales volume at the retail level, compounding the problem of unsold stocks.

All marketing activities of the PSC are supervised by the staff of the Marketing Division, where one assistant manager is presently responsible for monitoring seed sales in three districts. If sales are to be supervised effectively, the number of marketing field staff must be increased, as this area is too large for one person to cover.

Total sales—Presently, the PSC produces approximately 44,000 t of wheat seed—about 70% of the demand for certified seed planned in the original project and about 9% of the total annual provincial demand (**Table 4.4**).[7,8] Ten percent of annual demand might not be too different from wheat seed production in other parts of the world (J. Longmire, personal communication).

In the early years of the PSC, almost all of the corporation's wheat seed was sold in the cotton-wheat zone, particularly in Multan Division. The proportion of seed sold in that zone has fallen steadily but, even in 1985/86, Multan and Bahawalpur Divisions, with 30% of the total Punjab wheat area, accounted for 43% of PSC wheat seed sales. The concentration of both seed production and retail outlets in this area is certainly responsible for the zone's large share of sales.

Even though it obtains quantities of seed smaller than the targets assigned by the government, the PSC in some years does not sell all the seed it procures and offers the remainder for sale as grain in the open market. The PSC has been unsuccessful in selling all its seed stocks for several reasons. First, procurement targets are set arbitrarily. Second, the seed marketing system is inefficient. Improved marketing requires greater coordination between units within the PSC and better planning of which varieties to produce and where to market them. Finally, neither the seed project planners nor PSC management have resolved the aims and principles of seed pricing in the marketing process. The implications of this last problem are discussed next.

Table 4.4. Procurement and sale of Punjab Seed Corporation wheat seed (tons), 1979-86

Year	Target	Procured	Sold	Balance
1979/80	4,100	4,100	4,100	0
1980/81	14,900	11,500	10,000	1,500
1981/82	22,400	19,800	19,600	200
1982/83	29,900	33,300	33,300	0
1983/84	44,800	44,200	41,100	3,100
1984/85	52,300	48,500	48,500	0
1985/86	52,300	44,500	41,000	3,500

7 Total sales figures include seed sold to other provinces and exported to other countries. However, the quantities sold to other provinces and countries have been small relative to total sales.

8 A breakdown of sales by districts within the Punjab can be found in Chaudhry and Heisey (1987).

Current pricing and subsidies—The PSC, like many other quasi-public organizations dealing in seed, tends to base pricing decisions on costs. Before the selling season, the PSC Marketing Division proposes the sale rate of seed, which is usually approved by the Board of Directors. The sale rate is fixed to recover the actual expenditure incurred in procuring, storing, and handling seed. To ensure the PSC's financial viability, a corporation margin is added to the end price of seed.

Various cost items that enter into the calculation of the retail price of seed are shown in **Table 4.5**. Although the procurement price of wheat has increased by 60% since 1980/81 and the premium paid to contract growers has stayed constant during the last five years, it is difficult to interpret changes over time in other costs. The PSC distributes most of seed handling and other operating costs over wheat and cotton seed, so one reason for irregular changes in the cost structure may be the variation in total volume of wheat and cotton seed that is procured and sold.

Nonetheless, it is hard to understand why the corporation margin is charged in one year and not in another; how it differs from corporation overheads; or how distribution costs can stay constant over time when total quantities handled, transportation costs, and wage rates are all increasing. Also, it is important to note that the commission paid to dealers was Rs 12 per 90-kg bag instead of Rs 8, the figure used in calculating the 1986/87 sale rate. This discrepancy may result from inconsistencies noted earlier in the actual commission that is paid to the final dealer.

The price of wheat seed was subsidized for the first six years of the Seed Industry Project. The government subsidy was gradually reduced after 1983/84 and ended completely in 1986/87. There may still be a small element of cross-subsidization within the PSC, which assigns a smaller share of corporation overheads to wheat seed than to cotton seed because farmers are relatively more willing to pay for cotton seed. Furthermore, the initial fixed costs of establishing seed farms and processing plants are not reflected in the price of seed.

When farmers change wheat varieties, their willingness to pay for seed is fairly high. However, for a given variety, incremental benefits associated with the use of certified wheat seed may not always be enough to support a high seed-to-grain price ratio if a farmer has only been planting a variety for a few years or can purchase fairly good seed from a neighboring farmer. The PSC should recognize that, although it enjoys a monopoly in the certified wheat seed market, it cannot increase the price of wheat seed without adopting a more aggressive marketing strategy that emphasizes varietal replacement.

The PSC does not have a marketing research unit and bases its seed production and distribution plans on historical trends. Furthermore, no regular information is collected about why one variety is preferred over another in a particular cropping

Table 4.5. Prices and costs of wheat seed (Rs/90-kg bag), Punjab, Pakistan, 1980-87

Description	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87
Procurement price	112.50	130.50	130.50	144.00	144.00	157.50	180.00
Premium to growers	9.67	11.25	11.25	11.25	11.25	11.25	11.25
Procurement cost[a]	16.57	15.36	14.11	15.12	15.75	15.14	13.86
Cost of jute bag	14.00	11.75	12.40	13.25	14.27	15.40	15.73
Sieving losses[b]	0.00	0.00	4.68	3.40	3.42	3.66	4.10
Distribution cost[c]	7.10	7.10	7.10	7.10	9.48	10.99	8.30
Commission to dealer	5.00	5.00	5.00	5.00	6.00	6.00	8.00
Interest on capital[d]	9.02	8.16	10.13	11.92	11.97	12.87	14.36
Corporation overheads	6.94	5.49	7.79	7.48	15.04	14.58	13.20
Corporation margin[e]	4.83	0.00	0.00	5.36	5.40	5.82	0.00
Total cost	185.63	195.03	202.96	223.88	236.58	253.21	268.80
Subsidy	15.63	18.03	18.03	18.03	11.56	6.21	0.00
Sale rate	170.00	175.00	185.00	205.00	225.00	247.00	269.00

a Includes filling, weighing, stitching, stacking, loading, unloading, transportation from grower's field to plant site, storage, sieving, fumigation, transportation from plant to stores, workcharge staff, taxes, and market fee.

b About 2% of "total procurement price" (procurement price + premium + procurement cost).

c Transportation from PSC stores to dealers' store, loading, unloading, stacking, and taxes.

d Charged on "total procurement price" for six months. Interest rate used was 13% in 1980/81 and 1982/83; 10.5% in 1982/83; and 14% from 1983-84 onwards.

e About 3-5% of "total procurement price."

zone.[9] Sales promotion is weak. The PSC has been in the business for nine years, yet the brand name of its product has not been established. All of these factors suggest the need to establish a strong marketing research unit capable of regularly generating information and analyzing marketing problems. If such a unit is established, a reorganization of existing procurement and marketing field staff would be appropriate.

The Wheat Seed System in NWFP: Production and Distribution

The Agricultural Development Authority (ADA) of North West Frontier Province (NWFP), which is also responsible for the supply of other agricultural inputs in NWFP, organizes the production of certified wheat seed in the province.[10] In theory, the system works as follows. Pre-basic seed is provided by wheat breeders from the research institutes, notably the Cereal Crops Research Institute (CCRI), Pirsabak. Basic seed is grown on government farms run by agricultural extension. Certified seed is produced by registered growers, who are private farmers. Both the Federal Seed Certification Department and representatives of the ADA inspect the seed at all stages of the process.

If growers clean seed, they receive a higher price premium. Both the growers and the ADA primarily use hand sieves to clean seed. The ADA owns no storage facilities and hires privately owned storage. Seed is fumigated, and though there are some losses in storage, they have been minimal.

The ADA maintains some 25 to 30 sale points throughout NWFP. The amount of wheat seed moving through these sale points varies widely. In recent years one-third to one-half of the total wheat seed distributed by the ADA has passed through the two distribution centers in Mardan District, the district covered in the surveys reported in Chapters 3, 5, and 6.

The smooth flow of seed from pre-basic through certified production to the farmer is often interrupted. Though the ADA sometimes cannot market a substantial portion of the wheat seed it procures, in the recent past there has been a strong demand for seed from various development projects in the province. This demand has led to seed diversions before the certified stage, at times forcing the provincial research institutes into the role of seed supplier.[11]

9 During 1986 PSC did carry out a large-scale, farm-level survey to find out farmers' preferences about seed varieties, packing sizes, and publicity media. Survey farmers, who may have held somewhat more land than the average, were located throughout the Punjab. Data were tabulated but no further analysis was made.

10 A fuller treatment of the NWFP wheat seed system can be found in Heisey et al. (n.d.).

11 This phenomenon has been more pronounced for maize seed than for wheat seed.

Total wheat seed procured by the ADA between 1982 and 1986 has been about 3,000 to 4,000 t (**Table 4.6**). Varietal procurement has concentrated on Pak-81; Blue Silver and Lyallpur-73 are the other major varieties. Up until 1985/86, a substantial proportion of this seed was bought from the Punjab Seed Corporation (PAC), but in 1986/87 the ADA was successful in obtaining its entire requirement from registered growers in NWFP. The amount of seed procured has ranged between 4 and 5% of the total annual wheat seed requirement of the province, comparable to the situation in the Punjab in the late 1960s and early 1970s (Chapter 4).

Wheat seed targets for NWFP and the problems of unsold seed—Many assumptions must be made in setting seed targets. Wheat seed is not replaced every year because farmers maintain their own seed; a desirable target for seed turnover might be every five years (Chapter 2). Farmers in rainfed areas are more likely to grow older tall varieties for which seed is not supplied by the formal seed system. Furthermore, the particular problems of marketing seed to small farmers make it difficult to maintain much effective demand from the very smallest farmers. In NWFP, a greater proportion of the wheat area is unirrigated than in any other province; furthermore, farm size is much smaller than in the Punjab. These factors suggest that a reasonable target for certified wheat seed procurement as a proportion of total seed use might be lower in NWFP than in the Punjab.

There is no substitute for a thorough seed planning exercise. Nonetheless, applying the same assumptions used in the PSC planning document (see Chaudhry and Heisey, 1987)[12] would imply an annual certified seed requirement for NWFP of 8,000 t. Reducing this amount by a further 25% to reflect the lower demand caused by very small farm size and remote farm locations in NWFP suggests a target of around 6,000 t per annum for wheat seed procurement by the ADA.

Table 4.6. Wheat seed (tons) procured and distributed in NWFP by the Agricultural Development Authority

Variety	1982/83	1983/84	1984/85	1985/86	1986/87
Pak-81	54	2,138	2,170	2,450	2,041
Blue Silver	1,253	688	731	763	523
Lyallpur-73	454	543	270	344	464
Pirsabak-85	--	--	--	--	116
Others	1,412	668	181	8	206
Total procured	**3,173**	**4,037**	**3,352**	**3,565**	**3,350**
Total distributed	**3,069**	**3,402**	**2,959**	**2,254**	**2,945**

Source: ADA, Peshawar

12 In particular, taking into account the high proportion of unirrigated land or the lower percentage area planted to high yielding varieties in NWFP.

Seed production is, as noted, a somewhat greater constraint to the adequate supply of wheat seed in NWFP than in the Punjab. Yet in NWFP, as in the Punjab, the inability of the seed authority to market larger quantities of seed has also been a major constraint to greater seed production. In 1985/86 one-third of the wheat seed procured by the ADA remained unsold, leading to considerable concern among provincial authorities, as unsold stocks are put on the open grain market. The losses incurred are reflected in increases in the next year's seed price. In 1986/87, the gap between procurement and distribution narrowed again, largely because of substantial purchases by development projects. A single project alone took 30% of the total provincial procurement. The provincial government also reinstituted the practice of distributing some certified wheat seed through agricultural extension.

Seed Pricing in NWFP—Seed pricing is determined by adding storage and distribution costs to the wheat grain price and the premium paid to the registered growers. Despite this stated pricing policy, seed prices in recent years have been nearly identical to the seed prices of the PSC (**Tables 4.7** and 4.5). This in effect must mean some hidden subsidies, as the grain price is generally higher in NWFP than it is in the Punjab. Furthermore, if the alternative to ADA seed is seed from the PSC, seed prices in NWFP should tend to be higher because of transportation costs. The higher grain price in NWFP also means the seed-to-grain price ratio is *lower* in NWFP than in the Punjab.

Table 4.7. Price of certified wheat seed, NWFP

Year	Rs/90-kg bag	Seed-to-grain price ratio[a]
1984-85	243	1.44
1985-86	247	1.16
1986-87	266	1.24

Sources: ADA, Peshawar; Agricultural Economics Research Unit (PARC) at Tarnab, Peshawar

a This figure is based on the price of grain in Mardan District.

Conclusions

The system of multiplying and distributing improved wheat seed has changed for the better in the Punjab under the PSC and in NWFP, but there is room for improvement. Pakistan and other countries could benefit from long-term planning in determining absent from seed production policy. Furthermore, coordination among institutions that formulate policy and those that implement seed production programs is essential. For example, since the seed production cycle in Pakistan presently takes three to four years, seed production policy should be planned and implemented accordingly. Possible changes in seed production planning include streamlined varietal testing, multiplication of promising lines before they are released as varieties, and greater coordination between the PSC, the Varietal Evaluation Committee, and the Federal Committee on Agriculture.

Actual physical capacity to multiply seed is the least binding constraint faced by the PSC, although production and processing might be improved. For example, multiplication ratios could be improved either through changing agronomic practices or reviewing quality standards to ensure they are not overly stringent. The location of seed production farms could be diversified and seed could be increased out of season. Unfinished seed processing plants should be completed. Because improved marketing will increase seed demand, these physical production changes may become more urgent in the future.

In Pakistan some possibilities for developing a well-coordinated, integrated, and expanded seed marketing system include:

- Offering higher, uniform commissions to final sales agents;
- Relying more on private sector seed marketing;
- Relaxing the "cash and carry" condition to some extent;
- Closer PSC monitoring of its production and marketing costs;
- Experimenting with smaller packages, more distinctive packaging, and greater sales promotion;
- Taking more realistic approaches to seed certification and consume protection;
- Improving coordination between various sections of the PSC, especially stores and marketing: and
- Conducting more regular market research.

Expanding the seed distribution network and offering greater incentives to retailers will necessitate increasing the final seed price. Marketing margins will have to become consistent with those presently offered for fertilizer in Pakistan and for seed in other countries. Seed prices in Pakistan are currently low relative to grain prices. The ratio of seed price to grain price is 1.5, compared to around 1.7 for developing countries worldwide. In many Asian countries, including India, the ratio is 2 or more (Gregg 1983; Singh 1985; Katyal 1987; Tunwar 1987), yet wheat varietal replacement is faster in the Punjab of India than in the Punjab of Pakistan.[13] Experiences in other countries suggest that private dealers generally require a margin of 20% to encourage them to participate in seed marketing. This is at least double what dealers currently receive from PAD&SC.

13 Contract growers in India also receive higher premiums than in Pakistan.

Even if the price ratio were raised to 2 (for example, by paying 15% commissions to retail dealers *and* registered growers), for farmers the desired time period for replacing the varieties they grow would not rise to more than six or eight years under reasonable parameter assumptions (Chapter 2). If higher seed prices make seed more widely available and allow greater promotion of seed, it is highly likely that the aggregate weighted mean age of varieties will decrease. Even if the varietal life span favored by farmers were as high as eight years, mean age of varieties would decrease if time between a variety's release and availability to farmers were reduced to four years or less, an entirely reasonable goal for the seed system.

Chapter 5

Farmers' Seed Sources and Seed Management

Khaleel A. Tetlay, Paul W. Heisey, Zulfiqar Ahmed, and Munir Ahmad

Efforts to improve the pace of varietal replacement will benefit from information gathered at the farm level to determine where farmers get the wheat seed they use, where they get seed when they decide to change varieties, and how they manage seed retained from their own fields.[1] Data for the study described in this chapter were collected in 1986 during the survey of constraints to the rapid diffusion of new, disease-resistant wheats. Social scientists from the Pakistan Agricultural Research Council (PARC) administered detailed interviews to 146 farmers in the 30 villages selected in the rice-wheat zone; 149 farmers in the 30 villages in the cotton-wheat zone; and 99 farmers in the 26 villages in irrigated Mardan. (Survey locations are depicted in Figure 1.1.) Further details about the surveys can be found in Tetlay et al. (1987c).

Data from the three survey areas are broadly similar but nevertheless reveal certain contrasts. Some differences relate to the fact that the seed system in North West Frontier Province (NWFP) is more rudimentary than in the Punjab. Others relate to contrasts between the two cropping areas in the Punjab (recall that seed production and distribution in the Punjab is particularly concentrated in the cotton zone). Seed depot density cannot be calculated exactly for the three survey areas because data on depots are only available at the district level. However, if we calculate density of seed outlets for the districts where the survey areas were located, the results confirm high density in the cotton zone and low density in Mardan (**Table 5.1**). Another difference among the areas is that newer wheat releases were more widely diffused in the rice zone than in the cotton zone at the time of the surveys, largely because WL-711, a high yielding, well-adapted but rust susceptible variety, was dominant in the cotton zone.

Table 5.1. Seed depot density (retail seed outlets per 100,000 ha of wheat)

Punjab Province	**15.1**
Rice zone (Shekhupura, Gujranwala, and Sialkot Districts)	8.8
Cotton zone (Multan, Vehari, and Bahawalpur Districts)	22.6
NWFP	**3.3**
Mardan District	2.1

Note: Cooperative Bank Outlets are not included in the Punjab, since they handle very little wheat seed.

1 A more comprehensive account of this research can be found in Tetlay et al. (1987a) and Heisey et al. (n.d.).

In this chapter and the next, "new varieties" at the time of the 1986 surveys are those released in 1979 or thereafter, since those varieties were in most cases in the initial stages of adoption. When the survey was taken, Punjab-81 had already been banned north of Faisalabad because of stripe rust susceptibility (i.e. in the rice zone, where it is grown, and in Mardan, where it is not), but it is included as a new variety because the factors influencing its adoption resemble those influencing the adoption of other new varieties.[2]

Farmers' Sources of Wheat Seed

In all three areas, the most common source of wheat seed planted in 1985/86 was seed retained from the previous year's crop (**Figure 5.1**). Roughly one-fifth to one-quarter of the farmers got their seed from other farmers. Some 10% or fewer purchased seed at a depot.[3]

An examination of some of the more popular varieties in each zone clarifies patterns of seed acquisition. Obviously, farmers planting older varieties were more likely to have been planting them longer and to be using retained seed. On the other hand, farmers planting new varieties were more likely to have obtained their seed from a seed depot. Some evidence indicates that the source of seed of new varieties, notably Pak-81, was more often other farmers, whereas seed of old varieties was less likely to be obtained from other farmers (**Tables 5.2** to **5.4**).

Initial Seed Sources for New Wheat Varieties

Patterns of seed acquisition become more evident if we look at farmers' sources of seed for new varieties *the first time* they plant them. As expected, seed depots were the major initial seed source for farmers in the two zones in the Punjab but were much less important in Mardan, where the seed system is less developed. Looking at all three zones together, it is apparent that other farmers were the source of seed for about half the farmers who started growing a new variety (**Figure 5.2**).

Some farmers in Mardan first got seed of new varieties from research or extension. The "other" category in Mardan usually refers to cases in which farmers said they got seed at a depot, but did not know the depot's correct location; it is likely that some of that seed came from research or extension.

2 In recent years, Punjab-81 has been declining in area in the rice-wheat zone both because the PSC no longer makes its seed available there and because it has proven to be particularly susceptible to shattering (see Chapter 3 and Chaudhry et al. 1985).

3 The "other" category for the two Punjab zones refers to farmers who got seed from a variety of sources. In Mardan, the analysis was done by fields, so sources did not overlap.

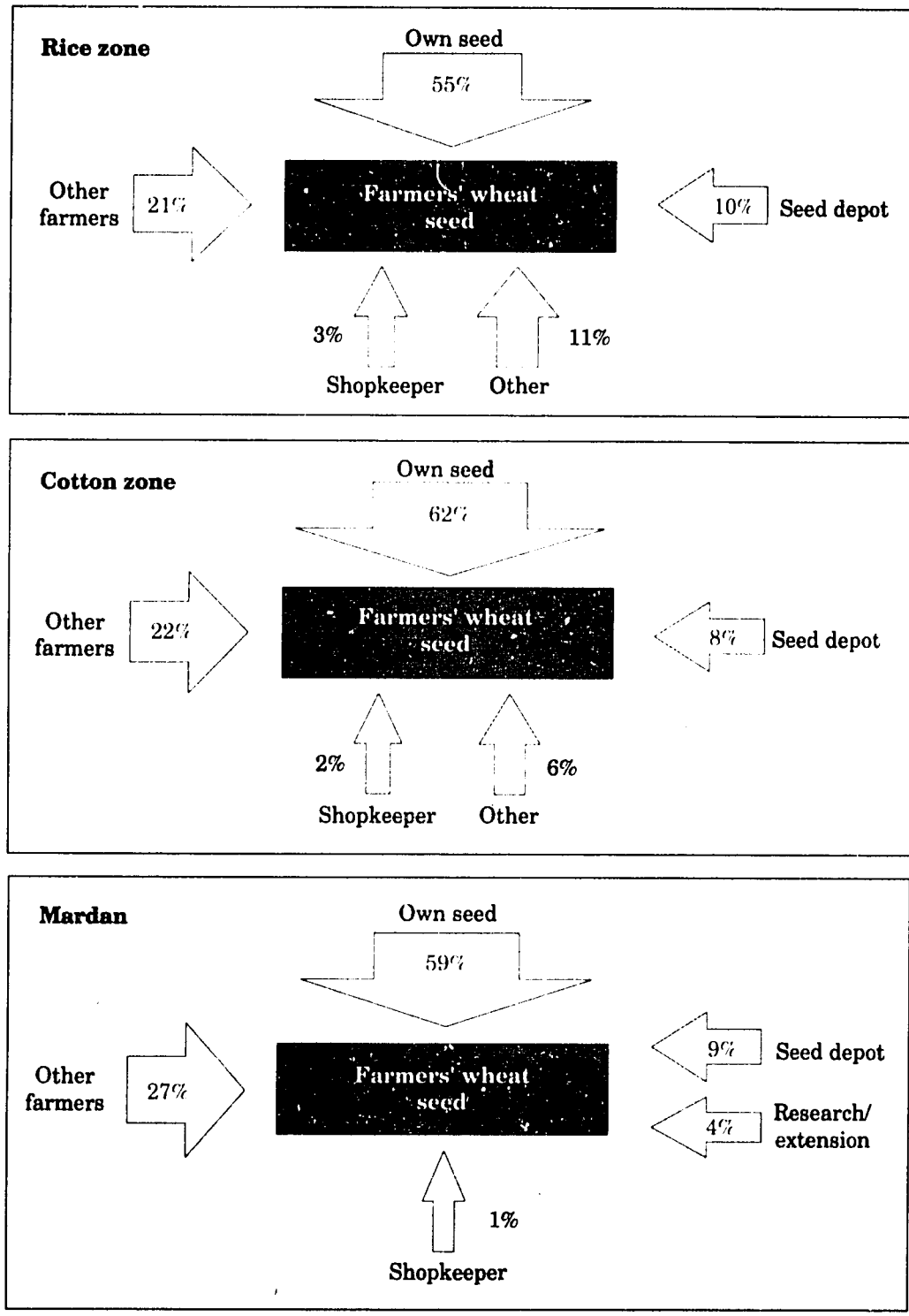

Figure 5.1. Seed sources for varieties currently planted.

Table 5.2. Sources of wheat seed of new varieties and other popular varieties currently planted, rice zone

Source	Percentage of farmers				
	Pak-81	Punjab-81	Blue Silver	Yecora	Sandal
Own	17	39	76	85	56
Other farmers	39	21	5	--	12
Seed depot	20	15	5	--	4
Shopkeeper/ grain merchant	7	6	5	--	--
Other	17	18	9	15	28
Total	**100**	**100**	**100**	**100**	**100**

Table 5.3. Sources of wheat seed of new varieties and other popular varieties currently planted, cotton zone

Source	Percentage of farmers				
	Pak-81	Punjab-81	Bahawalpur-79	Blue Silver	WL-711
Own	37	52	48	67	70
Other farmers	26	19	39	12	20
Seed depot	32	24	4	8	--
Shopkeeper/ grain merchant	--	--	4	2	--
Other	5	5	4	10	10
Total	**100**	**100**	**100**	**100**	**100**

Table 5.4. Sources of wheat seed of new varieties and other popular varieties currently planted, Mardan

Source	Percentage of fields			
	Pak-81	Blue Silver	SA-42	"Mexipak"[a]
Own	35	53	56	81
Other farmers	35	35	37	19
Seed depot	15	12	--	--
Research/extension	15	--	--	--
Shopkeeper/ grain merchant	--	--	7	--
Total	**100**	**100**	**100**	**100**

a "Mexipak" is often used as a generic name for semidwarf wheat in Mardan; it usually refers to an older high yielding variety that the farmer has been growing for a considerable time (Chapter 3).

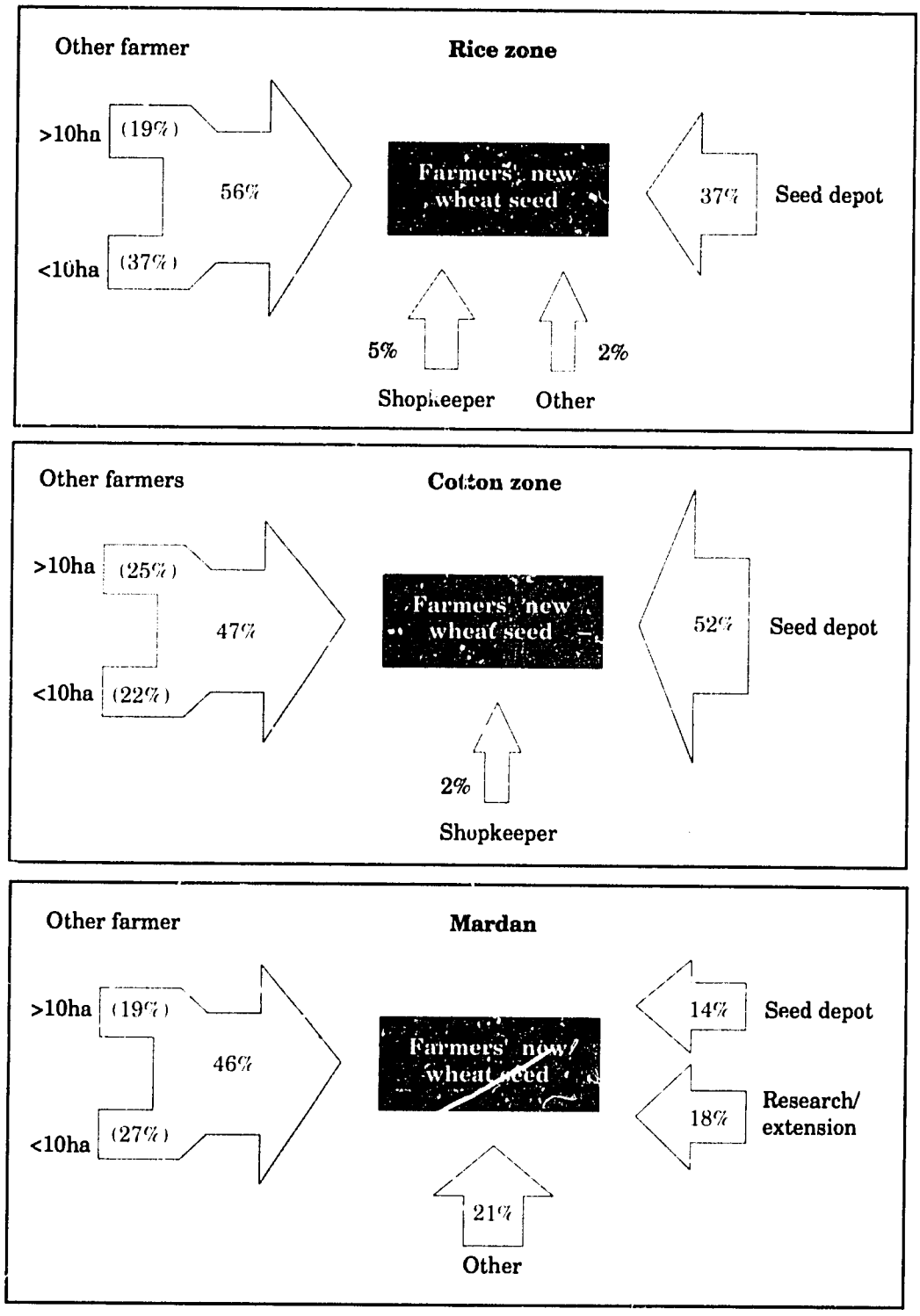

Figure 5.2. Initial seed sources for new varieties.

Farmers who first acquired seed of new varieties from the depot tended to be larger farmers (**Table 5.5**), whereas smaller farmers more often got seed of new releases from other farmers. In Mardan, because of the smaller numbers involved, research and extension are grouped with the seed depot as an initial source of seed because they represent a formal institution rather than the informal but powerful mechanism of farmer-to-farmer seed transfer.[4]

Table 5.5. Farm size and percentage farmers using new varieties who initially got wheat seed from seed depot/research/extension

Zone	Farm size (ha)	Farmers (%)
Rice zone	< 10 ha	22
	≥ 10 ha	6
Cotton zone	< 10 ha	43
	≥ 10 ha	6
Mardan	< 10 ha	19
	≥ 10 ha	71

Note: Research/extension applies only to Mardan.

Farmers who supplied seed of new varieties to other farmers tended to have larger than average farms. Still, half or more of the farmers who initially obtained new varieties from other farmers said their source was a farmer with less than 10 ha (**Table 5.6**). Source farmers were also close to the farmers they served; over half the farmers who got seed from other farmers contacted someone in their own village and over 80% received seed from a farmer within a 5-km radius (**Table 5.7**).

Table 5.6. Type of farmer from whom seed of new wheat variety was obtained

Farmer type	Percentage of farmers		
	Rice zone	Cotton zone	Mardan
Landlord	2	7	--
< 10 ha	66	47	58
≥ 10 ha	32	46	42

Table 5.7. Distance to farmers providing seed of new wheat varieties

Distance	Percentage of farmers		
	Rice zone	Cotton zone	Mardan
Same village	52	54	69
< 5 km	32	29	15
5-10 km	3	13	8
> 10 km	13	4	8

4 In Mardan, farms are quite small so the 10-ha division between "small farms" and "large farms" is less appropriate than in the Punjab. Forty-six percent of all farmers with over 4 ha initially got seed of new varieties from a seed depot, research, or extension, whereas 24% of the farmers with under 4 ha got new wheat seed from these sources. It seems likely that in Mardan it is primarily the very largest farmers who have contact with formal seed sources.

In all three survey areas, over 90% of farmers planting new varieties said they had no problems obtaining seed. Three-quarters or more financed the seed with their own money; the other significant way of obtaining seed was to exchange grain for seed with another farmer (one-sixth to one-fifth of the farmers got their new seed that way). Yet in both the rice and cotton zones, around half of the farmers who knew about new varieties but had not planted them said seed was unavailable. This was the most common reason given for not planting new varieties. In Mardan, the same explanation was given by 9 of the 24 farmers who knew about new varieties but were not planting them.

Farmers' Contact with the Seed Industry

About half the farmers in all three zones knew the correct location of the nearest seed depot. Some farmers in each zone said they knew the location but did not identify it correctly, an occurrence much more common in Mardan than in the Punjab (**Table 5.8**). Mardan District has only two Agricultural Development Authority (ADA) depots, one in Mardan and one in Swabi, although there are other ways in which seed can be distributed. Significantly more farmers in the Punjab who were aware of new varieties (they were already planting them or had heard of them) knew the correct location of the depot nearest them. In Mardan, there was no relationship between varietal awareness and accurate knowledge of the seed depot.

Over one-third of the farmers surveyed in the rice and cotton zones had actually visited a seed depot whereas only one-fifth of the farmers in Mardan had done so (Table 5.8). As farmers who had visited a depot are a subset of those who knew the depot location, factors related to visits are likely to resemble factors related to knowledge of the depot. In the Punjab, farmers planting new varieties were more likely to have visited a seed depot. In Mardan, there was no relationship between the two variables.

Many variables can influence whether or not a farmer knows the location of the nearest seed depot or visits it: human capital variables such as literacy; farm size and tenure variables; information sources, such as agricultural extension; or

Table 5.8. Percentage of farmers who knew seed depot location and had visited a depot

	Rice zone	Cotton zone	Mardan
Knew correct location	51	46	52
Stated other location	14	11	38
Did not know location	35	44	10
Visited depot[a]	38	36	21

a Includes only farmers with correct knowledge of depot location.

distance from the depot. Variables used in the analysis reported below are defined in **Table 5.9.** Since these variables are unlikely to operate independently, a variable-by-variable analysis of relationships with knowledge of seed depots or visits to them is likely to be misleading (Feder, Just, and Zilberman 1985). Instead, probit analysis, which uses a number of independent variables, has been used to predict the probability of whether or not a given farmer knew the location of the seed depot, and also to predict whether or not the farmer had visited a depot.

Several equations were estimated for each of the three zones. Results of one of the better equations for each zone (better in terms of goodness of fit as determined by the regression chi-squared statistic) are presented in **Tables 5.10** and **5.11.**[5] This approach is not entirely satisfactory because there are likely to be causal relationships between some of the explanatory variables. However, the results help determine which variables are more likely than others to predict farmers' contact with the seed depot.

Table 5.9. Variables used in probit analysis of knowledge of seed depot location and visits to seed depot

AGE	Farmer's age in years
ASQ	AGE^2
LIT	Dummy variable = 1 if farmer was literate
LNSIZE	Natural logarithm of farm size in hectares
OWN	Dummy variable = 1 if farmer owned some or all of the land he farmed
STATUS	Dummy variable = 1 if farmer was a village or union council official, government employee, member of a religious committee, member of a cooperative society, or shopkeeper
EXT	Dummy variable = 1 if farmer met with agricultural extension personnel in year previous to the survey
RADIO	Dummy variable = 1 if farmer listened to agricultural programming on the radio in year previous to survey
DEMO	Dummy variable = 1 if farmer hosted or visited a wheat demonstration
DIS	Distance (km) from a farmer's village to seed depot

5 Results of the equations presented in Table 5.10 and 5.11 were also checked for consistency with the other estimated equations.

The results are consistent with our expectations, except for several anomalous relationships in the smaller Mardan sample. Literacy is the key human capital variable, positively related to knowledge of and visits to the seed depot in the rice zone and in Mardan. In the cotton zone, literacy is not significant at standard levels but the coefficient does have asymptotic t-values significant at the .20 level. In Mardan, a quadratic age specification is also significant, implying that as a farmer's age increases up to the mid-forties, the farmer is more likely to know where the seed depot is or to have actually visited it; after that increasing age reduces the probability.

Table 5.10. Factors related to correct knowledge of seed depot location, probit analysis

Independent variables[a]	Rice zone	Cotton zone	Mardan
AGE	0.0498 (1.10)	0.0347 (0.653)	0.220 (2.96)***
ASQ	-0.000590 (-1.27)	-0.000328 (-0.558)	-0.00224 (2.97)***
LIT	0.582 (2.13)**	0.393 (1.45)	1.12 (2.38)**
LNSIZE	0.225 (1.69)*	-0.153 (-1.20)	-0.330 (-1.84)*
OWN		0.279 (0.979)	0.564 (1.60)
STATUS	0.214 (0.730)	0.409 (1.30)	-1.51 (-2.82)***
EXT	0.529 (1.85)*	0.570 (2.05)**	0.621 (1.50)
DIS	-0.0350 (-1.15)	-0.0397 (-1.80)*	
Constant	-1.51	-1.07	-4.71
	n = 142 $\chi^2(7) = 36.3$	n = 141 $\chi^2(8) = 20.3$	n = 92 $\chi^2(7) = 25.3$

Note: Asymptomatic t-values in parentheses; *** indicates significance at 1% level; ** at the 5% level; and * at the 10% level.

a Dependent variable is KNOW; dummy = 1 if farmer knew the correct location of the seed depot nearest his village.

Extension contact is the main information source related to contact with the seed depot. In the rice and cotton zones, farmers who had seen extension personnel within the last year were significantly more likely to know where the seed depot was. In the rice zone and Mardan, extension contact was significantly related to visits to the seed depot. There was an anomalous result regarding information sources in Mardan, where farmers who had listened to agricultural programming on the radio within the last month appeared less likely to have visited the seed depot.

Table 5.11. Factors related to visits to seed depot, probit analysis

Independent variables[a]	Rice zone	Cotton zone	Mardan
AGE		0.0625 (1.16)	0.381 (2.60)***
ASQ		-0.000602 (-1.01)	-0.00362 (-2.53)***
LIT	0.888 (3.43)***	0.418 (1.56)	1.74 (2.60)***
LNSIZE	0.192 (1.56)	-0.107 (-0.809)	-0.245 (-1.21)
OWN			0.606 (1.30)
STATUS		0.638 (2.08)**	-1.08 (-1.67)*
EXT	0.623 (2.32)**	0.337 (1.20)	1.12 (2.44)***
RADIO			-0.827 (-1.88)*
DEMO	0.343 (1.26)		
DIS	-0.0389 (-1.24)	-0.0508 (-2.16)**	
Constant	-1.18	-1.50	-10.7
	n = 146 $\chi^2(5) = 42.2$	n = 141 $\chi^2(7) = 21.3$	n = 87 $\chi^2(8) = 30.3$

Note: Asymptomatic t-values in parentheses; *** indicates significance at 1% level; ** at the 5% level; and * at the 10% level.

a Dependent variable is VISIT; dummy = 1 if farmer had visited a seed depot.

Variables related to general status or resource base, such as farm size, tenure, or social status, are mostly insignificant or anomalous. Increasing farm size did appear to increase the likelihood of seed depot knowledge in the rice zone, but the effect in Mardan was negative. All in all, farm size bore little relationship to seed depot knowledge or contact. This finding does not necessarily contradict earlier indications that larger farmers planting a new variety for the first time were more likely to acquire seed of the variety at a seed depot. What the present results seem to indicate is that larger farmers have significantly higher levels of literacy and extension contacts and, once these other variables are taken into account, farm size does not have much of an effect one way or the other on their contact with the seed depot.

The most anomalous result is the highly significant negative effect of social status in Mardan.[6] Social status also appeared to be negatively related to depot visits in Mardan, but positively related in the cotton zone.[7]

In the cotton zone, where retail seed outlets are most concentrated, farmers located farther from the depot were less likely to know where it was or to visit it. The relationships were also negative in the rice zone, but not significant at standard levels. There were no relationships in Mardan, where the formal seed system is a much less active agent of varietal diffusion.

Management of Retained Seed

From year to year, the most significant source of wheat seed is seed that farmers retain themselves. Farmers in the three surveyed areas were asked if they managed seed crops any differently from the rest of their grain: did they select a special field for seed, or thresh and store seed separately from other grain?

Farmers in the rice zone and Mardan were somewhat more likely than cotton zone farmers to choose a separate field for seed, either before or at harvest. Over all three zones, 40-50% of surveyed farmers threshed and stored seed apart from the rest of their grain (**Table 5.12**). Threshing seed separately was the criterion for determining if the farmer made special efforts to preserve seed quality. The few farmers who stored seed separately without threshing it separately were not included in the "special seed management" group for further analysis.

6 In Mardan, only 17 farmers had positive social status, a rather crudely defined variable referring to farmers who were village officials, ran shops, and so on. Nearly all of these farmers were literate. However, literate farmers without "social status" were significantly more likely to identify seed depot location correctly than literate farmers with status. Perhaps farmers with status were more familiar with non-ADA seed sources such as research farms or extension offices.

7 When the social status dummy is left out of the estimating equation in the cotton zone, the coefficient for literacy becomes significant at the .05 level, suggesting that the "social status" variable may be picking up some of the same influence as the literacy variable did in the other zones.

Very few other characteristics of farmers could be related to whether or not they used special seed management practices. In both the rice zone and Mardan, seed management practices of farmers planting new varieties did not differ from practices of farmers who did not plant them. Farmers in the cotton zone who planted new varieties were significantly more likely to manage their seed to maintain quality.

Since few farmer characteristics were related to seed management on a variable-by-variable basis, no probit analysis was done to predict whether or not a farmer would thresh seed separately from grain. A few variables did appear to affect seed management when analyzed individually. With increasing farm size, the likelihood increased that farmers in the rice and cotton zones threshed seed separately; in the rice zone and Mardan, farmers who had contact with extension in the last year appeared more likely to thresh seed separately.

Conclusions

The evidence presented in this chapter confirms that the major source of wheat seed is seed retained from the previous year's crop. The next most frequent source of seed is other farmers. Less than 10% of farmers surveyed obtained seed at a depot. Fewer than half of the farmers who retained their own seed sought to ensure its purity by selecting or threshing it separately.

When farmers change varieties, other farmers are the most important source of seed. In the Punjab, where the seed system is better developed, seed depots are almost equally important as a source of seed when farmers want to change varieties. In Mardan seed depots are much less significant as an initial source of new seed. In the Punjab farmers planting new varieties are significantly more likely to know where the seed depot is and to have visited it; in Mardan there is no relationship between planting new varieties and contact with the seed depot. Farmers with larger

Table 5.12. Farmers' seed management practices for retained wheat seed

	Percentage farmers using retained seed		
Practice	**Rice zone**	**Cotton zone**	**Mardan**
Kept separate field, threshed and stored separately	17	7	15
Selected field at harvest, threshed and stored separately	20	4	36
Threshed and stored separately only	7	26	--
Subtotal:			
Attempted to maintain seed purity	**44**	**37**	**51**
Stored separately only	4	3	3
Did not store separately	51	60	47

holdings are more likely to use a seed depot as the initial source of seed for new varieties. Dispersing seed distribution points more widely would probably hasten the spread of new varieties.

A number of associated farmer characteristics appear to influence whether farmers know about or have visited the seed depot and whether they manage seed and grain crops differently. The most consistent explanatory variables are literacy and contact with extension. Farm size does seem to make a difference in one case—initial source of new seed. Larger farmers may also be more likely to manage seed differently than grain. With regard to seed policy it should be noted that more often than not new seed enters a village when a larger farmer obtains it from the formal seed system. Seed then spreads from farmer to farmer within the village or spreads to an adjoining village. Farmer-to-farmer seed diffusion is highly localized, as fewer than 10% of farmers obtain seed from a village more than 10 km away. Despite the strengthening of the formal seed production and distribution system, informal, farmer-to-farmer seed transfer clearly remains a major means of diffusing seed, as in the early days of the Green Revolution (Lowdermilk 1972).

Chapter 6

Farmer Characteristics, Varietal Choice, and the Spread of New Wheat Releases

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This chapter seeks to explain factors related to farmers' awareness and adoption of newer wheat releases. Certain traits of farmers and varieties explain a two-step process in which a farmer first becomes aware of new varieties and later adopts them.[1,2]

Griliches' (1957) classic study of the spread of hybrid maize in the USA has been succeeded by a vast literature on the adoption of agricultural innovations.[3] Much of the literature concerns itself with the adoption curve, an S-shaped cumulative frequency curve, which can refer either to the aggregate level or to individual farmers.[4] In Pakistan, adoption of high yielding varieties (HYVs) followed the classic S-shaped pattern. But the replacement of individual wheat varieties is more completely represented as a process of adoption and disadoption (Brennan and Cullis 1987), a pattern visible in Figure 2.2 (page 14) where the area covered by major wheat varieties in Punjab is shown. During the adoption phase, the curve is similar to the monotonically increasing curve usually studied.

In 1985/86, at the time of the adoption survey discussed in this chapter, cross-sectional differences in farmers' awareness and adoption of new varieties were distributed as in **Table 6.1.** The data in Table 6.1 are consistent with the area estimates of Chapter 3, where it was noted that the spread of new varieties in the

Table 6.1. Farmers' awareness and adoption of new wheat varieties

	Percentage of farmers		
	Rice zone	**Cotton zone**	**Mardan**
Planting total area to new varieties	27	22	14
Planting partial area to new varieties	27	20	14
Aware of but not planting new varieties	13	16	29
Unaware of new varieties	33	42	42

1 This chapter is partially based on material in Tetlay et al. (1987b and 1987c).

2 For a technical description of the type of model used here, see Maddala (1983).

3 This literature is summarized in Feder, Just, and Zilberman (1985).

4 At the aggregate level for a given innovation, the height of this cumulative frequency curve at a given time can be measured in different ways. For individual farmers, adoption curves show the degree to which the farmer uses the input(s) of interest.

rice-wheat zone was greater than in the two other areas at the time of the survey. Farmers in the rice zone who grew new varieties tended to have grown them for less than the average length of time; farmers in Mardan, for more. In other words, new varieties appear to have diffused faster in the rice zone than in the other two areas, a conclusion further supported by the aggregate data of Chapter 3. Diffusion of new wheat varieties has been somewhat slower in Mardan because the seed system is less developed. Although seed outlets are more heavily concentrated in the cotton zone than in the rice zone, diffusion in the rice zone has proceeded faster because the older varieties in the cotton zone are particularly well adapted to the zone's environment and crop rotations

Farmers' Perceptions of Wheat Technology

Perceptions of technological components for increasing wheat productivity—In the 1985/86 adoption survey, farmers were asked to identify which technological components were most important, second most important, and third most important for increasing wheat yields. They did not identify variety as a major component. Any attempt to determine which factors were most important to farmers is subject to ambiguity because individual choices can be weighted differently, but it is clear that in all three zones better land preparation ranked highest and more fertilizer second. In the three zones, variety ranked between third and fifth.

In diagnostic surveys conducted in the same zones (Byerlee et al. 1986), variety was found to be one factor strongly affecting farmers' yields. For direct technology transfer, variety was among the highest priorities in each area. The difference between the relative importance attached to variety by researchers and farmers may be related to several factors. First, differences in yield due to variety might not be immediately evident prior to harvest. Second, seed is a relatively small amount of farmers' production cost and farmers might tend to weight the importance of an input in proportion to its cost. Finally, the fact that the new varieties were, in general, diffusing slowly at the time of the study meant that farmers had relatively few opportunities to compare yields of old and new varieties.

Farmers' perceptions of the disease threat--During the survey, farmers were asked about major diseases affecting wheat; 70-90% of them were aware of rust. (In the rice and cotton zones, about 90% mentioned smut, noted by only 55% of the farmers in Mardan.) Of the farmers who knew about rust, half to three-quarters called it "a problem" (**Table 6.2**). But even though many farmers knew about rust and some thought it a problem, relatively few farmers in Punjab thought it could recur. The different results for Punjab and Mardan were probably caused by the way

5 Farmers in Punjab were asked whether or not they agreed with the statement, "Rust used to be a problem but it is no longer a problem;" in Mardan, they were asked whether or not they agreed with the statement, "Rust could be a problem again in the future."

the question was phrased in the survey areas.[5] This question probably influenced the answers to subsequent questions about differences in varietal rust resistance and loss of resistance over time.

One-quarter of the respondents in Punjab thought some varieties were more resistant than others; in Mardan the proportion was a little less than half. In all zones, half or less of the farmers who thought some varieties were more resistant than others thought that resistant varieties could lose their resistance. Since more farmers in Mardan agreed with the statement on differential rust resistance, a similarly larger proportion there thought resistant varieties could break down (Table 6.2).

Regardless of problems with some of the questions about rust, it is clear that in all surveyed areas farmers' knowledge of disease was rather limited. Relationships linking farmers' characteristics to disease knowledge variables were generally not significant.[6] Farmers' awareness of rust as a major problem would probably be much greater in a year immediately following an epidemic. Similarly, awareness would be greater among farmers growing a particularly susceptible variety in a year immediately after that variety suffered noticeable yield losses from rust. But in a relatively normal year some years after farmers have experienced serious losses from rust, the threat of disease by itself is unlikely to motivate farmers to change varieties, given the current state of their knowledge about varietal rust resistance and rust epidemics.

Table 6.2. Farmers' awareness of the rust problem

	Percentage of farmers		
	Rice zone	**Cotton zone**	**Mardan**
Mentioned/knew about rust	71	89	82
Thought rust was a problem some years or every year	54	65	73
Thought some varieties were more resistant than others	25	26	47
Thought resistant varieties could lose their resistance	6	12	25

6 Nonetheless, in the rice zone and Mardan, farmers who planted or knew about new varieties did seem more likely to believe that some varieties are more resistant than others. In Mardan, literacy and extension contact seemed to be positively related to a belief in differential varietal resistance; extension contact, radio contact, and social status seemed positively related in the rice zone; and in the cotton zone, younger farmers and farm owners appeared more likely to believe some varieties had greater resistance. Given the very limited numbers of farmers who thought resistant varieties could break down, in only one case did a farmer characteristic appear to affect this belief: extension contact in the cotton zone. It is likely that in a multivariate analysis the apparent significance of some of these variables might disappear.

Reasons for varietal choice—Variety was not the first factor farmers thought of when they were asked what was most important for increasing yield. But when farmers growing new varieties were asked why they had changed from old to new cultivars, they cited yield more than any other reason (**Table 6.3**). The other frequent responses for changing variety were yield decline or disease susceptibility of the old variety; they are also related to a difference in yields. Some farmers who noted that new varieties yielded better also mentioned the yield decline of old varieties; unfortunately, data from two of the survey areas do not permit all factors to be separated out. Even though farmers' awareness of disease is rather low, it is worth noting that losses from disease are sometimes part of the yield comparison that motivates varietal change.

When farmers planting old and new varieties were asked why they planted both types, the most common response across all three zones was that they wanted to compare the performance of each type. In addition, 30-40% of the farmers in each zone planted both types for reasons related to diversification: they wanted one variety for late planting or one for home consumption, or simply wanted to avoid risk (**Table 6.4**). Farm size was a highly significant determinant of the number of varieties planted. In all three zones, mean farm size for farmers planting more than one wheat variety was much larger than for farmers planting only one variety.[7]

"Objective" varietal characteristics and farmer behavior—Several characteristics besides superior grain yield are often thought to influence farmers to plant new varieties: straw yields (Husain 1987), taste and baking quality, and resistance to moisture stress (Byerlee et al. 1986). To see if particular varietal

Table 6.3. Farmers' reasons for adopting new wheat varieties

	Percentage of farmers[a]		
	Rice zone	**Cotton zone**	**Mardan**
Higher yields	72	83	78
Declining yield of old variety	9	5	--
Disease susceptibility of old variety	9	7	4
Other	10	5	18

a Farmers sometimes mentioned declining yield or disease losses of the old variety as well as higher yields of the new variety. However, in some of the survey areas it is not possible to recover how many farmers mentioned these factors in conjunction with higher yields.

7 Diversification over old and new varieties was one of the few ways in which farm size did appear to affect varietal diffusion, if other variables were taken into account. See footnote 14.

characteristics had induced farmers to adopt new varieties, some "objective" measures of varietal characteristics were examined along with evidence of farmers' behavior regarding each characteristic.

Yield—Data from the ISWYN and Khanewal seed farm trials, analyzed in Chapter 2, can be used to compare grain yields of several popular wheat varieties. At "normal" planting dates, the new variety Pak-81 yields better than all other varieties considered here. The old variety WL-711 also yields more than other important varieties, and the old variety Sandal may also yield somewhat better. Four other varieties (Punjab-81, Blue Silver, Bahawalpur-79, and Yecora) yield about the same under identical management conditions, although one trial ranks them in the order in which they have just been listed (for our purposes, Punjab-81 and Bahawalpur-79 are considered new varieties).

Yield and planting date—In all three survey areas, farmers plant wheat at dates which are later than optimal, a practice strongly related to the previous crop in the rotation and seen most frequently in the cotton-wheat cropping system (Byerlee et al. 1986). Thus, not only yield performance *per se* but also yield performance at late planting dates may affect farmers' choice of varieties.

Plant breeders usually try to develop early maturing varieties for circumstances in which the growing season is curtailed. Among the varieties listed earlier, Blue Silver and Bahawalpur-79 are short season releases recommended for late planting. The new variety Faisalabad-83, not widely grown, and the old rust susceptible variety SA-42, common in Mardan, are also short season varieties.[8]

Table 6.4. Farmers' reasons for planting both old and new wheat varieties

	Percentage of farmers[a]		
	Rice zone	**Cotton zone**	**Mardan[b]**
Compare performance	35	57	43
Different variety for late planting	14	17	43
Seed multiplication	19	7	--
Different variety for home consumption	14	3	--
Risk aversion	3	13	--
Other	16	3	14

a Some farmers offered more than one reason; the most prominent is recorded here.
b Only 14 farmers in Mardan planted both old and new varieties.

8 WL-711 is an intermediate maturity variety, one of the reasons it has fit so well into the cropping system in the cotton-wheat zone, but for simplicity it will be analyzed with the full season varieties.

A second approach taken by researchers to the constraint of late planting, particularly in areas where heat stress is a problem, is to plant a variety late and evaluate its performance regardless of whether it is supposed to be an early, intermediate, or late maturing variety. Under this criterion, at late planting dates Pak-81, a relatively long season variety, continues to perform very well with respect to the short season varieties Blue Silver and Bahawalpur-79; WL-711 also may perform somewhat better. Punjab-81 does well at late planting, but the yields of old varieties Sandal and Yecora decline greatly when they are planted late (Hobbs 1985; Chapter 2).

Crop rotation and variety—Crop rotation and varietal characteristics combine to influence farmers' varietal choices in different ways in the three survey areas. In the cotton zone, where late planting is common, both normal season and short season varieties were planted late (**Figure 6.1**). Larger farmers in all three zones were more likely to plant more than one variety. In the cotton zone, however, farm size did not vary between farmers planting a short season variety and those who did not. All varieties chosen, whether by the larger farmers who tended to plant more than one variety or the smaller farmers who planted only one, had to perform relatively well at late planting.

In the rice zone somewhat less wheat is planted late, although planting dates vary more from year to year than they do in the cotton zone. Figure 6.1 shows that, in contrast to the cotton zone, in the rice zone short season varieties were usually planted later than full season varieties. Furthermore, farmers planting short season varieties tended to have more land than farmers who did not. These factors suggest that farmers in the rice zone often choose full season varieties for earlier planting and early maturing varieties for later planting. (Their choice probably relates to the fact that Yecora, once the dominant variety in the rice zone, suffers heavy yield losses at late planting.) Also, larger farmers in the rice zone may have a wider range of wheat planting dates than do smaller farmers, and thus be more likely to switch to an early variety at the later dates.

Mardan presents a different picture of farmers' choices of variety and planting date. In the sample analyzed here, late planting was less common than in either the cotton or the rice zone (Figure 6.1). As in the rice zone, early maturing varieties were usually planted after full season varieties. But compared with farmers in the rice zone, farmers in Mardan who planted early maturing varieties (notably the old variety SA-42) tended to have less land than farmers planting only full season varieties. As in the other two zones, larger farmers in Mardan were more likely to diversify across varieties, but they were more likely to diversify across two or more full season varieties.

Straw yield—Another factor that may influence varietal choice, particularly for small farmers, is straw yield. Straw yield (or perceived straw yield) was probably a greater consideration when long strawed varieties were first replaced by shorter strawed, HYVs at the start of the Green Revolution. In changing from one semidwarf

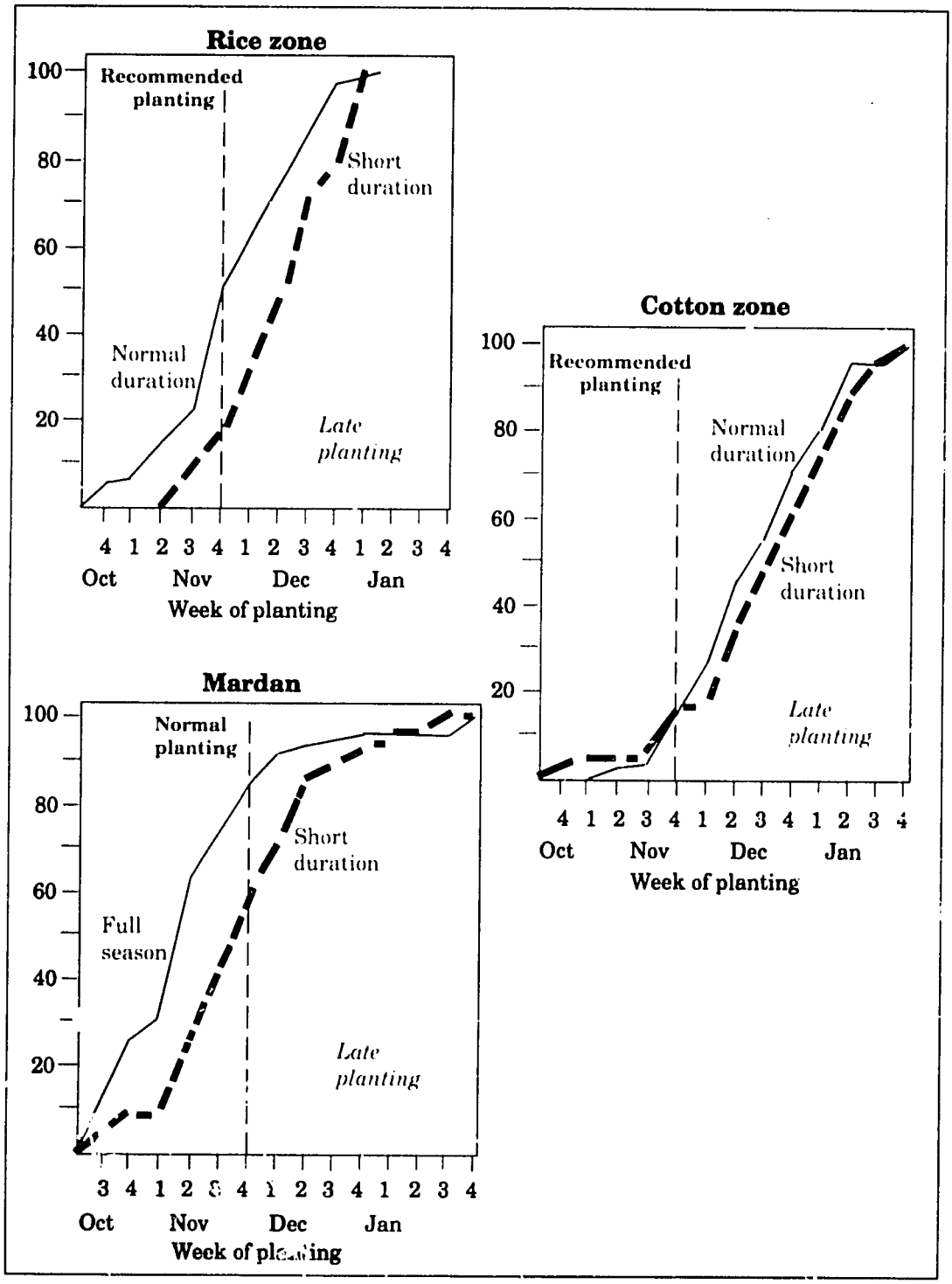

Figure 6.1. Cumulative dates of planting by wheat varietal group in rice zone, cotton zone, and Mardan, Pakistan.

variety to another, straw yield is probably less significant, although it may be more important in Mardan than in Punjab, as fodder prices tend to be higher in NWFP.[9] However, it is hypothesized that harvest indices between one HYV and another are similar enough to imply that a strong positive correlation usually exists between straw yield and grain yield.

Seed shrivelling—An independent assessment of shrivelling characteristics of wheat varieties is not readily available. A variety's shrivelling characteristics are probably related to its performance when it is planted late. There was not much evidence from the survey, however, that farmers' evaluation of shrivelling characteristics was significantly related to their judgement of how a variety performed when it was planted late.

Seed shattering—Data on important commercial varieties' susceptibility to shattering are not readily available. However, Punjab-81 has been found to be relatively susceptible, both in trials designed to evaluate this trait (Chaudhry et al. 1985) and in farmers' experience.

Baking quality—Although baking quality can be evaluated by such objective measures as gluten strength, in this study it was treated essentially as a subjective judgement and is discussed in the next section.

Subjective varietal characteristics—Farmers in the survey who were either planting new varieties or knew about them were asked to compare characteristics of a specific old variety that they had planted or were planting with those of a specific new variety they were planting or knew about. For each characteristic, farmers were asked whether they thought the new variety was better, the old variety was better, or both varieties were the same. "Don't know" responses were also recorded.

In the rice zone, responses of farmers already planting new varieties differed significantly from the responses of farmers who had only heard of new varieties, for all characteristics. As expected, farmers with no direct experience of new varieties were more likely not to have an opinion. Also as expected, a larger proportion of farmers planting new varieties evaluated them favorably. Their positive opinions were strongest for grain and straw yield, intermediate for late planting performance and shrivelling, and weakest for shattering resistance and *chapati* (baking) quality.

9 In fact, though grain-to-straw ratios are higher for HYVs than for the varieties they replaced, greater biomass production may still lead to higher straw production from fields sown to semidwarfs. Nonetheless, perceptions are important: Husain (1987) demonstrates that even today, in mountainous areas of northern Pakistan, farmers believe the traditional varieties produce more straw than the HYVs although objective yield cuts show per hectare straw production to be about equal. Straw quality may also be an issue.

In fact, farmers planting new varieties, as well as farmers who were not, were more likely to say that the old variety had more shattering resistance and made better *chapatis*. This response was particularly striking for *chapati* quality (**Table 6.5**). These evaluations are probably related to the relatively greater use of Punjab-81 (which is particularly subject to shattering) in the rice-wheat zone, and a preference for Yecora for quality.

In the cotton zone, differences between nonadopters and adopters were also significant for all characteristics. Even more than in the rice zone, farmers who had only heard of new varieties were less likely than farmers who had adopted them to voice an opinion about their characteristics. For all characteristics, adopters were more likely to rate the new variety more favorably and nonadopters to rate the old one more favorably. Adopters were most likely to give favorable ratings for late planting performance and general yield performance; they gave the lowest ratings for shattering and shrivelling characteristics (**Table 6.6**).

In Mardan, differences between adopters and nonadopters were significant only for opinions on yield. Adopters overwhelmingly favored their new variety and nonadopters were more likely to support the old one. Although the differences among

Table 6.5. Farmers' perceptions of wheat varietal characteristics, rice zone

		Percentage of farmers			
		New	**Old**	**Same**	**Don't know**
Which variety . . .					
Yields more?	P[a]	74	12	12	2
	K[a]	33	17	28	22
Provides more straw?	P	77	18	4	2
	K	39	22	17	22
Makes better *chapatis*?	P	21	72	7	0
	K	11	50	11	28
Is better for late planting?	P	51	23	18	9
	K	11	39	17	33
Shatters less?	P	35	40	21	4
	K	6	33	11	50
Shrivels less?	P	48	16	16	20
	K	11	17	17	56

a Row "P" refers to farmers who plant new varieties. Row "K" refers to farmers who know about new varieties but do not plant them.

adopters' and nonadopters' opinions of *chapati* quality, shattering resistance, and shrivelling resistance were not significant, adopters were more likely to favor the new variety and nonadopters the old. Adopters were more likely than nonadopters to say the old variety gave the same or more straw. Finally, both adopters and nonadopters were more likely to favor the old variety for late planting (**Table 6.7**).

Farmers' Awareness and Adoption of New Wheat Varieties

Variables affecting awareness and adoption—Even a relatively simple change, such as starting to plant a new semidwarf wheat variety, is influenced by complex, interrelated factors, just as when seed-fertilizer technology was first adopted in irrigated Pakistan (Lowdermilk 1972). Adoption is analyzed here as a two-stage process in which the farmer first becomes aware of a new variety and then adopts it. That approach is particularly useful in a situation like this, when, four to five years after the release of several good new varieties, one-third or more of the surveyed farmers had not heard of them.

Table 6.6. Farmers' perceptions of wheat varietal characteristics, cotton zone

		Percentage of farmers			
		New	**Old**	**Same**	**Don't know**
Which variety . . .					
Yields more?	P[a]	57	24	19	0
	K[a]	7	33	0	60
Provides more straw?	P	51	33	16	0
	K	7	20	13	60
Makes better *chapatis*?	P	51	40	9	0
	K	0	33	0	67
Is better for late planting?	P	63	14	14	9
	K	13	27	0	60
Shatters less?	P	44	19	21	16
	K	7	20	7	67
Shrivels less?	P	33	12	29	26
	K	0	20	7	73

a Row "P" refers to farmers who plant new varieties. Row "K" refers to farmers who know about new varieties but do not plant them.

Probit analysis was used to study the effects of several factors operating simultaneously. Although probit analysis does not take into account the likely interaction of some of the explanatory variables, it is preferable to two-way variable-by-variable analysis. The variables, some of which are the same as those defined in Chapter 5, are defined in **Table 6.8.** Several human capital variables were used. Age may be thought of as a partial proxy for experience. A quadratic specification for age was employed in many of the equations estimated.[10] A literacy dummy, LIT, distinguishes literate from illiterate farmers. Education level dummy ED1 denoted farmers with one to eight years of education, and ED2 refers to farmers with more than eight years of education.

Table 6.7. Farmers' perceptions of wheat varietal characteristics, Mardan

		Percentage of farmers			
		New	**Old**	**Same**	**Don't know**
Which variety . . .					
Yields more?	P[a]	86	7	4	4
	K[a]	24	59	12	6
Provides more straw?	P	32	46	21	0
	K	41	41	18	6
Makes better *chapatis*	P	57	25	14	4
	K	35	41	18	6
Is better for late planting?	P	29	57	4	11
	K	24	53	6	18
Shatters less?	P	50	18	25	7
	K	29	41	18	12
Shrivels less?	P	39	18	32	11
	K	24	41	24	12

a Row 'P' refers to farmers who plant new varieties. Row 'K' refers to farmers who know about new varieties but do not plant them.

10 This implies that, if coefficients were significant and of the proper sign, experience increased the likelihood of awareness up to a point where it began to be outweighed, perhaps, by greater conservatism. In general, the quadratic specification was somewhat more likely to improve the fit or result in significant coefficients than either linear or logarithmic specifications.

We also used two other variables that often appear in the adoption literature: farm size (in our analysis we used LNSIZE, the natural logarithm of farm size in hectares) and a dummy, OWN, distinguishing farm owners and part owners from tenants. Farm size may have an independent effect because a relatively fixed cost of acquiring information is spread over a larger area (Feder and Slade 1984), or because larger farmers may have greater access to information or credit.

Table 6.8. Variables used in probit analysis of awareness and adoption of new wheat varieties

AGE	Farmer's age in years
ASQ	AGE^2
LIT	Dummy variable = 1 if farmer was literate
ED1	Dummy variable = 1 if farmer had 1-8 years of education
ED2	Dummy variable = 1 if farmer had more than 8 years of education
LNSIZE	Natural logarithm of farm size in hectares
OWN	Dummy variable = 1 if farmer owned some or all of the land he farmed
EXT	Dummy variable = 1 if farmer met with agricultural extension personnel in year previous to the survey
RADIO	Dummy variable = 1 if farmer listened to agricultural programming on the radio in year previous to survey
VIL	Transformed from percentage of village wheat area covered by new varieties as identified by breeders; transformation by subtracting the mean and dividing by the standard deviation of the original variable
ROAD	Dummy variable = 1 if farmer's village was on a metalled road
YIELD	Dummy variable = 1 if farmer thought new variety clearly superior to old variety in grain yield
CHAP	Dummy variable = 1 if farmer thought new variety clearly superior to old variety for making *chapatis*
LATEPL	Dummy variable = 1 if farmer thought new variety clearly superior to old variety for late planting
SHRES	Dummy variable = 1 if farmer thought new variety clearly superior to old variety for shattering resistance

Variables for two "modern" sources of information were employed. The first is a dummy variable, EXT, distinguishing whether or not the farmer had any direct contact with extension in the year immediately preceding the survey. The second, RADIO, is another dummy variable dividing farmers into those who had listened to agricultural programming on the radio over the previous year and those who had not.

In this context it is interesting to note which initial sources of information about new varieties were most frequently identified by the farmers themselves. The most important source, cited by half or more of the farmers in all three zones, was other farmers (**Table 6.9**). This finding, in conjunction with the finding that other farmers were often the first source of seed for new varieties, reinforces the conclusion that local sources of information about new wheat technology remain nearly as important as they were when the Green Revolution began (Lowdermilk 1972).

Farmers interviewed for this study mentioned extension as a major source of information slightly more often than farmers in Lowdermilk's study. Extension was mentioned more frequently in the cotton zone and Mardan, where adoption was slower, than in the rice zone. This response corresponds to Lowdermilk's findings. In earlier stages of adoption, farmers in contact with formal sources of information are more likely to be adopting the new technology.

Two alternative variables were used to reflect village effects. The first, VIL, was the percentage area planted to new varieties in the surveyed village as identified by the breeders (Chapter 3).[11] The second was a dummy, ROAD, indicating whether or not the farmer's village was on a metalled road.

Table 6.9. Source of information about new wheat varieties, from farmers planting them

	Percentage of farmers		
	Rice zone	**Cotton zone**	**Mardan**
Other farmers	69	48	57
Extension	14	30	28
Seed depot	9	8	7
Radio	8	12	4
Other	--	2	4

11 This variable was transformed by subtracting the mean and dividing by the standard deviation to make it more nearly the same magnitude as the other variables.

The variables described above were used to predict whether or not a farmer would be aware of new varieties. In addition, four opinion variables were added to the analysis of adoption for those farmers aware of new varieties. Since the opinion variables were highly interrelated, variables for straw yield and shrivelling were dropped. For the others (yield, *chapati* quality, late planting performance, and shattering resistance), dummies were included with a value of one if the farmer thought the new variety was clearly superior with respect to the characteristic and zero if the farmer favored the old variety, thought them both the same, or did not know. The *chapati*/baking quality variable was dropped from the cotton zone equation as its inclusion led to instability in the coefficients of the other variables.

Awareness of new varieties—The multivariate analysis uses some of the variables described above to predict the probability that a farmer was aware of new varieties. This analysis had most predictive power, and more coefficients were significant with the expected signs, for the rice zone, where diffusion of new varieties had proceeded farthest at the time of the survey.

Across all zones, the human capital variables most strongly related to awareness of new varieties were education and literacy. In the cotton zone, farmers with some education were significantly more likely to be aware of new varieties than farmers with no education. In the rice zone, farmers with more than eight years of education were much more likely to know about new varieties. Age coefficients were significant in the rice zone, implying that, as a farmer's aged increased (up to the late forties), so did the likelihood that the farmer would know about new varieties; after the late forties, the likelihood decreased (**Table 6.10**).

Only in Mardan did increasing farm size significantly increase the probability that the farmer would be aware of new varieties. In the rice zone, owners were somewhat more likely than tenants to know about new varieties.

Contact with information sources was significant only in the rice zone. Farmers who listened to agricultural radio programs were much more likely to be aware of new varieties; extension contact also had a significant effect. However, given that most farmers said they first learned about new varieties from other farmers, it is likely that radio and extension contact did not *cause* varietal awareness. Rather, farmers who actively sought agricultural information through these and other channels were also more likely to know about new varieties.[12]

In contrast to the results for formal information sources, which are limited and difficult to interpret, characteristics of the village in which the farmer lived did seem to have an effect on whether a farmer had heard about new varieties. In both the rice

12 This is an example of probable specification error. The "true" model might have a variable called "active information seeking" that would affect both varietal awareness and use of information media.

Table 6.10. Factors affecting awareness of new wheat varieties, probit analysis

Independent variables[a]	Rice zone	Cotton zone	Mardan
AGE	0.0860 (1.78)*	0.00369 (0.0729)	-0.104 (-1.42)
ASQ	-0.000809 (-1.66)*	-0.0000563 (-0.0989)	0.00118 (1.44)
LIT			0.559 (1.30)
ED1	-0.202 (-0.624)	0.822 (2.86)***	
ED2	1.00 (2.36)**	1.09 (2.96)***	
LNSIZE	0.198 (1.32)	0.0412 (0.335)	0.404 (2.05)**
OWN	0.594 (1.72)*	-0.172 (-0.642)	-0.477 (-1.30)
EXT	0.614 (1.84)*	-0.202 (-0.729)	0.472 (1.17)
RADIO	0.808 (2.79)***	-0.133 (-0.561)	-0.132 (-0.426)
VIL	0.616 (3.76)***		0.379 (2.19)**
ROAD		0.535 (1.88)*	
Constant	-2.79	-0.378	1.93
	n = 143 $\chi^2(9) = 47.1$	n = 144 $\chi^2(9) = 18.3$	n = 88 $\chi^2(8) = 16.9$

Note: Asymptomatic t-values in paretheses; *** indicates significance at the 1% level; ** at the 5% level; and * at the 10% level.

a Dependent variable is AWA: dummy variable = 1 if farmer was aware of new wheat varieties.

zone and Mardan, the larger the proportion of total village wheat area covered by new varieties, as estimated by the breeders' survey (Chapter 3), the greater the likelihood a farmer living in that village would know about new varieties.[13] In the cotton zone, the results were less striking. Nonetheless, farmers in villages on paved roads were more likely to know about new varieties.

These results show that across zones two factors were more likely than others to significantly influence awareness of new varieties. One was education or literacy, which was positively related to varietal awareness in both Punjab zones. Literacy was also a significant determinant of seed depot knowledge in Mardan (Chapter 5), suggesting that literate farmers are generally more likely to have information about new agricultural technology. The other factor significantly influencing awareness of new varieties was the village in which the farmer was located. This result strengthens the conclusion that farmer-to-farmer transfer of information as well as seed is a basic channel of communication for wheat technology. Farm size was an important factor only in Mardan, where the seed system is least developed, diffusion of new varieties was not as advanced at the time of the survey, and fewer farmers in the survey were literate.

Adoption of new wheat varieties—Once farmers are aware of new varieties, the major factor influencing adoption appears to be farmers' perceptions of a new variety's characteristics compared to those of the variety they are growing. Responses of farmers who knew about new varieties were analyzed to determine whether or not they would be planting one or more of the new wheat releases. Few of the other variables used in the analysis of varietal awareness were significant in distinguishing farmers who planted new varieties from those who only knew about them (**Table 6.11**). The quadratic specification for age was significant only in the cotton zone. Literacy was significant in Mardan, but the sign was in the wrong direction. Increasing farm size raised the probability that a farmer had adopted a new variety in the cotton zone and Mardan. This suggests the hypothesis that large farmers may be somewhat more likely to be early adopters of new varieties. In the rice zone, on the other hand, where diffusion of post-1978 releases had proceeded the farthest at the time of the survey, farm size had no significant effect on adoption.[14]

13 Though it is clear that village location was an important determinant of varietal awareness, attempts to explain why one village would have a greater proportion of wheat area under new varieties than another, in terms of other village characteristics, were unsuccessful.

14 Another effect of farm size is not visible in the probit analysis separating adopters from nonadopters. Larger farmers were more likely to plant both a new variety and an old variety. Smaller farmers were more likely to specialize in either a single old variety or a single new variety. This relates to the relationship already noted between farm size and number of varieties planted. It is also visible in a *logit analysis* that predicts the probabilities that farmers fall into one of three categories: planting only old varieties, only new varieties, or planting both (Tetlay et al. 1987b).

Table 6.11. Factors affecting adoption of new wheat varieties by farmers aware of them, probit analysis

Independent variables[a]	Rice zone	Cotton zone	Mardan
AGE	-0.0393 (-0.458)	0.381 (2.06)**	-0.235 (-1.40)
ASQ	0.000563 (0.604)	-0.00384 (-1.95)*	0.00269 (1.38)
LIT	0.177 (0.281)	-1.15 (-1.23)	-2.37 (-2.04)**
LNSIZE	0.164 (0.710)	0.809 (1.82)*	0.968 (2.14)**
OWN	-0.0112 (-0.0114)	-0.0751 (-0.0663)	0.866 (0.784)
EXT	-0.506 (-1.11)	-0.663 (-0.709)	-0.233 (-0.334)
VIL	0.266 (1.30)		0.131 (0.350)
ROAD		0.581 (0.714)	
YIFLD	0.932 (2.27)**	2.52 (2.15)**	2.28 (3.00)***
CHAP	0.296 (0.527)		-0.588 (-0.842
LATEPL	0.852 (1.70)*	3.10 (2.76)***	0.665 (0.820)
SHRES	1.45 (2.24)**	1.01 (1.10)	0.0568 (0.072)
Constant	-0.0426	-10.2	3.19
	n = 75 $\chi^2(11) = 28.4$	n = 55 $\chi^2(10) = 40.0$	n = 41 $\chi^2(11) = 27.7$

Note: Only farmers aware of new varieties are included in the analysis. Asymptomatic t-values in parentheses; *** indicates significance at the 1% level; ** at the 5% level; and * at the 10% level.

a Dependent variable is PLANT: dummy variable = 1 if farmer planted one or more new varieties.

Tenure, extension contact, and village effects appeared to play no role in the actual adoption of new varieties. These results differ from those for awareness (Tables 6.10 and 6.11). The most significant variables overall recorded farmers' perceptions of the new variety's performance compared with that of the old variety.[15] In all three zones, farmers who believed that new varieties clearly yielded better were significantly more likely to be planting them. In the cotton zone and the rice zone, opinions concerning late planting performance were also important. This variable was particularly significant in the cotton zone, as one might expect given the large proportion of wheat planted late in that area.

Beliefs concerning shattering resistance were important only in the rice zone. Again, this result makes sense because Punjab-81 was planted extensively in the rice zone in 1985-86 and its susceptibility to shattering is well known. In contrast, opinions on *chapati* quality did not significantly affect planting behavior. This means, for example, that in the rice-wheat area farmers' preference for *chapatis* made from Yecora did not stop them from changing to varieties perceived to be higher yielding or better for late planting.

These probit regressions, while emphasizing the importance of farmers' perceptions in determining adoption behavior, do not explain how farmers' opinions are formed. A partial explanation may be found in the estimated equations with the perceived characteristics variables left out. These equations, not reported here, had little explanatory power. The single variable that did become significant in the rice and cotton zones was the percentage of village wheat area covered by new varieties. In Mardan, this variable became significant at the .20 level. This suggests the hypothesis that informal village demonstration effects, in addition to increasing awareness of new varieties, might also encourage adoption by giving farmers a greater opportunity to observe favorable characteristics of the new varieties.

The proportion of village wheat area planted to new varieties was obviously important in explaining varietal awareness, and possibly adoption as well. Nonetheless, obvious village characteristics such as distance to the nearest seed depot did not explain varietal proportions in simple Ordinary Least Squares regressions, nor did they explain awareness and adoption when entered directly into the probit regressions reported in Tables 6.10 and 6.11.

Conclusions

The analysis of varietal diffusion presented here focused on two stages: information and adoption. This chapter's findings tend to reinforce the conclusions of the previous one. Farmer-to-farmer transfer of both information and seed plays a major role in seed diffusion. This has been seen in several ways: other farmers are an

15 A more sophisticated model might treat farmers' perceptions of the new variety and their adoption behavior as determined simultaneously.

important general source of seed; other farmers are the most important source of information about new varieties; other farmers are a major source of seed of new varieties; and the proportion of wheat under new varieties in a village influences farmers' awareness of new varieties.

Education or literacy appears to be the most important characteristic related to information about new varieties, seed depot location, and so on. Extension contact is more ambiguous. Findings reported in the previous chapter indicated that extension contact often appeared to be related to farmer information, but in this chapter, there were few links between extension contact and simple awareness of new varieties. At the same time, farmers in the cotton zone and Mardan, where new varieties had spread less widely at the time of the survey, were more likely to cite extension as their initial source of information about new varieties. One tentative explanation for that phenomenon is that extension is a more important source of information for early adopters (Lowdermilk 1972). Since the majority of farmers had only been growing new varieties for one or two years at the time of the survey, this hypothesis was not directly confirmed by the data. If the hypothesis were correct, it would imply that the influence of extension spreads beyond the farmers with whom extension personnel are directly in contact.

Farm size appears important in several ways. Larger farmers are initially more likely to get seed of new varieties from the formal seed system; larger farmers are more likely to adopt new varieties when the overall rate of diffusion is relatively slow; and larger farmers are more likely to be partial adopters, growing old varieties along with new ones. Furthermore, large farmers are apt to be literate and have better extension contacts. These variables have been shown to affect seed depot contact, and literacy in particular influences awareness of new varieties. When diffusion begins to proceed more rapidly, the adoption behavior of larger and smaller farmers differs little except for larger farmers' greater tendency to diversify. Smaller farmers lag behind, not because they are reluctant to change, but because they are less likely to have full information about the new varieties in the initial stages of adoption because of lower literacy and fewer extension contacts.

When farmers do become aware of new varieties, the most important factors determining adoption appear to be seed availability and farmers' perceptions that the new variety will yield more than their old one. Other factors, such as late planting performance or resistance to shattering, are important depending on the cropping system of a particular area or its current varietal mix.

Chapter 7

Conclusions

Paul W. Heisey

Varietal replacement in cereals and legumes is important to farmers because new varieties may be superior to their old ones in yield or other desirable characteristics. Furthermore, a farmer's old variety may have deteriorated in yield because of seed intermixture, loss of germination potential, loss of resistance to diseases or pests, or other genetic deterioration resulting from cross-pollination. The relative importance of these factors is related to species: cross-pollination is very important in maize and of limited interest in self-pollinating crops such as wheat or rice, whereas diseases and pests may be of greater consequence in wheat or rice than in maize. Some, but not all, of these reasons for changing variety could also influence a farmer to obtain new seed of a variety he or she already grows. In this report, however, we have presented a case study for one crop, wheat, in one country, Pakistan, and our primary interest has been varietal replacement rather than seed replacement.

Policy makers may also be interested in the rate of varietal replacement. A faster rate of replacement might mean higher rates of return to research. Furthermore, compared to individual farmers, society as a whole might place a greater value on preventing epidemics of diseases and pests, and so even without institutional constraints to more rapid replacement, policy makers might want to influence the speed of varietal replacement.

The Process of Varietal Replacement

A large amount of literature from many disciplines has been concerned with "Green Revolutions"—the adoption of semidwarf wheat and rice varieties, or of hybrid maize. Green Revolutions might be viewed as instances of aggregate varietal replacement, although varietal replacement can take place at both the aggregate and the individual farmer level without being characterized as a "revolution." The distinguishing feature of a Green Revolution might be a relatively dramatic increase in yield, intimately related to particular genetic characteristics (e.g., dwarfing, photoperiod insensitivity), and, at least historically, to much higher economic optima for complementary inputs such as fertilizer. The differences between the most dramatic of revolutions and the most ordinary cases of varietal replacement are, however, differences of degree rather than kind, and this study has shown that many of the factors influencing varietal change at one end of the continuum can also operate during periods of less overt technological change.

This report has focused on wheat in Pakistan in the post-Green Revolution period. The following conclusions are therefore specific to crop, place, and time. However, they can also be viewed as hypotheses that might apply in different situations, perhaps after modification.[1] Four general areas are considered: the role of the

1 In some cases similar hypotheses have been tested in different circumstances—wheat in Australia (Brennan and Cullis 1987); soybeans in the southern USA (Houston et al. 1989).

research system in supplying new varieties; the role of the seed system in disseminating new varieties; sources of information concerning the existence, availability, and characteristics of new varieties; and the influence of yield and other varietal characteristics on farmer demand for varietal replacement.

The shift to reliance on a formal research system for improved crop technology, including varieties, might be an additional feature of "Green Revolutions" described above. Though "science-based" research played a part in crop improvement before periods of marked shifts in technology, it clearly became a much more identifiable source of improved germplasm during and after periods of rapid technological change. In Pakistan's Punjab, for example, contrast the total reliance on local wheat land races before 1911; the 11 varieties released between 1911 and 1965; and the 27 new varieties released between 1965 and 1985. Though maintenance research might be expected to play a larger part in the breeding effort in the post-Green Revolution period (Plucknett and Smith 1986), it is clear from the record that wheat breeding has also contributed substantially to yield gains in Pakistan since 1965.

"Green Revolutions" in addition mark a shift from the use of seed that is selected entirely by the farmer, or obtained from other farmers, to an increasing role for a formal seed production and dissemination system. Obviously for self-pollinating crops like wheat farmers will continue to maintain their own seed supplies, as they do in the world's large cereal exporters. Nonetheless, an active seed network, closely linked with both agricultural research and extension, is a prerequisite for more rapid varietal replacement in the post-Green Revolution period. Comparing the weighted average age since release of wheat varieties (9-11 years in Pakistan's Punjab, probably longer in other parts of the country) with the weighted length of time farmers had been growing their current varieties in our survey (two-and-a-half to three years in the Punjab, somewhat over five years in Mardan) suggests that there have been significant lags between varietal release and widespread seed availability. Furthermore, many farmers who eventually get seed of more recent wheat releases from other farmers would probably buy seed from seed depots if they were aware sooner of new varieties' existence and convinced of their improved characteristics.

Instead, however, seed systems are often viewed primarily as guarantors of seed quality rather than as agents of varietal replacement. Even with a shift in emphasis toward the latter role (without forsaking quality as an objective), the problems of planning seed supply and distribution remain formidable. In general, basic planning decisions, such as deciding the total amount of seed to produce, determining the mix of varieties to produce, and setting the marketing strategy, are more difficult than the more technical problems of seed production itself.

The agricultural information system, particularly agricultural extension, has a rather complex influence on the process of varietal replacement both during and after periods of rapid technological change. In this study, for example, we found that

contact with extension was significantly related to knowledge of the formal seed system, but in general not significantly related to varietal awareness and adoption. Some evidence, however, indicates that for early adopters extension might be an important first source of information about new varieties.

Similarly, the effects of factors expected to influence farmers' ability to process information (literacy or formal education) are also complex. We have reported that these farmer characteristics do appear to influence farmers' knowledge of the formal seed system and of new varieties but do not seem to affect actual adoption behavior given varietal awareness.

Much evidence suggests that the transfer of knowledge from farmer to farmer (both general information concerning new wheat technology and "specific" information embodied in new seed) is the single most important factor in varietal replacement. This appeared to be true both at the time of Pakistan's Green Revolution and at the time covered by this report. We hypothesize, however, that higher educational levels and more sophisticated extension messages potentially have a much greater role to play in post-Green Revolution varietal replacement.

Given the effects of all these other institutional variables, farmer demand still substantially affects the rate of varietal replacement. Theoretically, many factors, including seed price and learning costs, can affect this rate (Heisey and Brennan 1989). Nonetheless we conclude that the single most important factor affecting farmers' demand for new varieties is perceived yield advantage. This factor appears both in farmers' statements and in statistical relationships attempting to explain farmers' actual behavior. Note too the slower spread of more recent wheat releases in the cotton zone of the Punjab, despite the fact that seed production and distribution in the Punjab is most concentrated in that zone. More recent releases had less yield advantage over the variety dominant at the time of our study in the cotton zone compared to other surveyed areas.[2]

Other varietal characteristics also affect demand, but they tend to be much more location and time specific than yield. Disease resistance *per se* was not found to be an important farmer consideration in this study, as farmers' knowledge of wheat diseases was rather limited. Replacement varieties must have acceptable grain quality, but in general quality has become a much less influential factor in post-Green Revolution wheat production in Pakistan.[3] On the other hand, with increased emphasis on double cropping, performance at late planting has become a more

2 See Brennan and Cullis (1987) and Houston et al. (1989) for other empirical evidence from different countries on the influence of varietal characteristics, including yield, on varietal replacement and seed sales.

3 Wheat grain and straw quality may still be of relatively greater importance in some parts of Pakistan, such as rainfed or mountainous areas.

important criterion for wheat varieties in some areas. This, too, has probably affected varietal replacement in the cotton zone. Most of the relatively successful, more recent releases have been full-season varieties. Although they yield at least as well as earlier maturing varieties when planted late, this fact has not been widely recognized. In the cotton zone, as WL-711 continues to be phased out, it has been replaced as much by Blue Silver (an old, early, and also rust-susceptible variety) as by Pak-81, a more recent full-season release that performs well at late planting (Azeem et al. 1989).

Investigating Varietal Replacement

This study has used a number of different methods—institutional analysis, analysis of research data, farmer surveys—to investigate wheat varietal replacement in Pakistan. To examine varietal replacement at all, one element is crucial: a reasonably reliable method of determining which varieties are grown by farmers, and over what proportion of the total crop area. Specific data sources concerning variety are unlikely to exist, but varietal information may be collected as a part of other exercises designed to estimate areas, yields, and production, or to monitor basic technological practices. Among the cereals, varietal information should be easiest to obtain for crops like hybrid maize; somewhat more difficult to elicit for self-pollinating crops such as wheat or rice; and most difficult for cross-pollinating crops such as open-pollinated maize (where it is difficult to identify a variety which has become mixed over time).

To analyze the productivity of wheat breeding research, we have used experimental or observational data on yield gains and on other characteristics such as disease resistance. A description of the seed production and marketing system, data concerning seed production by variety and seed pricing, and data about farmers' seed sources were employed to examine the present and potential role of the seed system in varietal replacement. Farm survey data provided us with information concerning farmers' seed sources and allowed us to analyze their knowledge of new varieties, their stated reasons for certain choices, and the statistical relationships between their characteristics and their actual behavior. All of these other methods used here may be more or less useful depending on the varietal replacement question to be considered and the costs of obtaining data.

Recommendations for Pakistan

Some specific recommendations for Pakistan follow from the studies presented in this report. In some cases they may be useful in addressing problems in other countries where varietal replacement is not as rapid as might be desired. The need for appropriate policies related to varietal replacement and seed production is still as urgent in Pakistan at the start of the 1990s as it was when the research described in this report was initiated. Pak-81, released at the beginning of the 1980s, is approaching its maximum area coverage in some regions just as its resistance to rust

is beginning to break down. Blue Silver has been placed on the banned list even though the area planted to Blue Silver continues to increase in parts of the Punjab. Unless policy makers, extension workers, and scientists develop a common program of action to address this problem, the farmers of Pakistan will remain vulnerable to the considerable--and growing--risk of a rust epidemic.

Varietal replacement and release—The number of wheat varieties released must be maintained at least at current levels in Pakistan. Furthermore, breeders should aim to increase genetic diversity in their elite materials, as genetic diversity is a better defense against rust than varietal diversity *per se*.[4] Breeders should consider multiplying more seed of the most promising varieties before release. To enable earlier evaluation of a variety's commercial potential, more farmer evaluations of varieties should be sought before release. The varietal naming system should produce distinctive names that are easily recognized by farmers, rather than similar names that lead to confusion in farmers' minds. This kind of naming system would help educate farmers concerning potential differences in varieties and make varietal monitoring less difficult.

Monitoring wheat varieties grown by farmers—To formulate appropriate actions aimed at promoting varietal diversity and more rapid varietal replacement, wheat scientists and policy makers (for example, in Pakistan, the members of the Federal Committee on Agriculture) must be aware which wheat varieties farmers are growing. In the Punjab, the Crop Reporting Service (CRS), Lahore, should continue varietal monitoring through farmer interviews. In other provinces, particularly Sind and NWFP, the CRSs should be encouraged to add simple varietal identification questions to their yield estimation schedules. Enumerators should be trained to avoid prompting farmers and to record "don't know" answers. The CRSs should work with wheat breeders and the Agricultural Economics Research Unit (AERUs) of the Pakistan Agricultural Research Council to design the questions and train enumerators.

The CRS estimates of wheat varietal coverage for a given wheat season should be circulated rapidly and widely, to policy makers, wheat breeders, and pathologists, in February or March of each season. The Planning Unit, Food and Agriculture Division, Ministry of Food and Agriculture should discuss with CRSs the legitimacy of using current sampling designs to produce estimates of varietal coverage for major cropping systems. Interested institutional representatives, for example wheat researchers, should be party to these discussions.

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4 Several measures to speed varietal change or promote genetic diversity do not follow directly form this report but deserve mention: streamlining varietal testing by planting National Uniform Wheat Yield Trials (NUWYTs) and microplots at the same time rather than successively; maintaining backup materials for quick multiplication in case of a rust epidemic; and developing mutlilines or varietal mixtures.

Finally, the special studies discussed in Chapter 3 should be continued in the same villages sampled by the AERUs. This will permit more longitudinal analysis of the process of varietal change within given cropping systems.

Seed production and marketing—Seed production capability is less of a constraint to faster dissemination of new wheat varieties than the difficulty in deciding which varieties to multiply and the lack of seed promotion. Nonetheless, potential production changes would make new varieties available more rapidly. The possibility of increasing seed out of season should be considered. Breeders currently use the Kaghan summer nursery to advance their lines; a somewhat larger facility could be used for seed production. Seed certification standards should be reviewed to see if they emphasize seed quality at the expense of rapid multiplication.

Private marketing of wheat seed should be encouraged through better commissions paid to dealers. Financial incentives might be given to dealers contingent on their own active seed promotion. Eventually, marketing by registered growers, who are the last stage in the production process, should be considered.

Seed of new varieties should be available in smaller packets so farmers can test and multiply their own seed. Packaging should be distinctive to maintain consumer confidence.

Improved promotion and marketing of seed necessitate increases in seed price. This increase would not be incompatible with more rapid varietal replacement. Increases in the seed price should be timed to coincide with periods in which strong demand for seed is expected.

Extension and demonstration of new wheat varieties—Extension, seed corporations, and research should cooperate more closely in varietal demonstrations. Demonstrations should be planted much more widely in major wheat growing areas: each village over a given size should have at least one demonstration. Seed for demonstrations should be provided to extension. Demonstrations should be grown under farmer management, and some should be planted at later than optimal planting dates. These demonstrations should be simple; they should include two or three new varieties at most, along with the farmer's variety. This contrasts with the current system in the Punjab of planting up to 10 varieties in one demonstration trial. A field day for local farmers should accompany the harvest of the demonstration plot. Seed from new varieties in demonstrations should be distributed to farmers, although extension should not be seen as the primary agent for the delivery of inputs such as seed. Extension should also increase the amount of information it makes available about wheat diseases. Radio campaigns should be stepped up to increase farmers' knowledge of new varieties and rust problems.

Further Research on Varietal Replacement

The case of Pakistan clearly illustrates the importance of regular varietal replacement for farmers and for the nation as a whole. The studies described in this report offer a means to evaluate the complex relationships between wheat breeding, varietal testing, and release; seed production and distribution; extension; government policy; and varietal change at the farmer level. Nonetheless there are areas in which our knowledge of factors relating to varietal replacement is limited or nonexistent.

Future studies might, for example, develop methods of determining rough objectives for the number and genetic diversity of varieties to be released by mature plant breeding programs in countries with large areas planted to the crop in question. That kind of analysis, expanding on the methods presented in Chapter 2, should consider appropriate measures of genetic diversity (Priestly and Bayles 1980), the size and diversity of the production zones targeted, and the cost of achieving different degrees of diversity. The analysis should also consider the level of sophistication in marketing and information delivery by the seed and extension system responsible for transferring new varieties to farmers.

We have highlighted the difficulties of planning seed production and supply, especially when formal seed production is seen as an instrument of varietal replacement. Further research might begin with case studies of seed systems with different degrees of success in marketing seed of different crops. Such studies do exist; what is needed is to add the perspective of varietal replacement to the legal and institutional description they often contain.

Additional research is also required to verify empirically the relative strengths of the factors influencing farmers' demand for replacement seed. From the disciplinary point of view of economics, one of the more difficult conceptual issues is how to separate out availability constraints from actual demand components. In the few studies done to date relating to seed demand, including this one, availability constraints have simply been introduced as proxy variables in what is essentially an analysis of the demand side of the market. Another conceptual problem, particularly for crops for which farmers can maintain their own seed, is how to move from an abstract understanding of the factors influencing farmers to obtain seed of new varieties to a concrete set of planning tools for seed producers.

Finally, studies of other countries and particularly of other crops would help to sharpen our understanding of the features of varietal replacement that are universal and of the changes in assumptions and methods necessary to analyze factors more specific to time, place, and particular crops.

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